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SCIENCE AND ENGINEERING INDICATORS 2008

Volume 1

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National Science Board

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Cover Image

The cover for *Science and Engineering Indicators 2008* celebrates the 2007–09 International Polar Year with a montage of photographic images from the Arctic and Antarctic regions. At the center is an ice cave at Loudwater Cove, on Anvers Island. Arcing above it are smaller images showing (right to left) the Beacon Valley field camp in the Dry Valleys of southern Victoria Land, a deepwater cnidarian, a female polar bear and her cub on sea ice, a skua chick, an aurora borealis, a sunset at Cape Hallett, and an LC-130 Hercules cargo aircraft. *(Credit, ice cave: Zenobia Evans, National Science Foundation (NSF). Credits, images right to left: Josh Landis, NSF; Katrin Iken and Bodil Bluhm, University of Alaska, Fairbanks; The Hidden Ocean, Arctic 2005 Exploration; Ariana Owens, NSF; Patrick Smith; Ken Ryan, NSF; Jerry Marty, NSF).*

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National Science Board

January 15, 2008

MEMORANDUM FROM THE CHAIRMAN OF THE NATIONAL SCIENCE BOARD

TO: The President and Congress of the United States

SUBJECT: *Science and Engineering Indicators 2008*

It is our honor to transmit the eighteenth in the series of biennial science indicators reports, *Science and Engineering Indicators 2008*. The National Science Board submits this report as required by 42 U.S.C. § 1863 (j) (1).

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 2008* 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. An Overview chapter of this report distills selected key themes emerging from the eight chapters of Volume I of the two-volume publication.

The Board hopes that both the Administration and Congress 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.

Steven C. Beering

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Chairman
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Acronyms and Abbreviations

AAAS	American Association for the Advancement of Science
AACU	Association of American Colleges and Universities
AASCU	American Association of State Colleges and Universities
ACI	American Competitive Initiative
ACS	American Community Survey
ACT	American College Test
ADAMHA	Alcohol, Drug Abuse, and Mental Health Administration
ADP	American Diploma Project
AFT	American Federation of Teachers
AIA	Aerospace Industries Association
AID	Agency for International Development
AP	Advanced Placement
AP/IB	Advanced Placement/International Baccalaureate
APL	Applied Physics Laboratory
ATP	Advanced Technology Program
AUTM	Association of University Technology Managers
BEA	Bureau of Economic Analysis
BHEF	Business-Higher Education Forum
BLS	Bureau of Labor Statistics
CAMR	Coalition for the Advancement of Medical Research
CATI-MERIT	Cooperative Agreements and Technology Indicators database-Maastricht Economic Research Institute on Innovation and Technology
CENIC	Corporation for Education Network Initiatives in California
CGS	Council of Graduate Schools
CIA	Central Intelligence Agency
CPI	Consumer Price Index
CPS	Current Population Survey
CRADA	cooperative research and development agreement
CREATE	Cooperative Research and Technology Enhancement Act of 2004
DARPA	Defense Advanced Research Project Agency
DHS	Department of Homeland Security
DNA	deoxyribonucleic acid
DOC	Department of Commerce
DOD	Department of Defense
DOE	Department of Energy
DOI	Department of the Interior
DOJ	Department of Justice
DOL	Department of Labor
DOT	Department of Transportation
EC	European Community
ECLS	Early Childhood Longitudinal Study
ED	Department of Education
EDP	electronic data processing
EICC	EPSCoR Interagency Coordinating Committee
ELS	Education Longitudinal Study
EPA	Environmental Protection Agency
EPO	European Patent Office
EPSCoR	Experimental Program to Stimulate Competitive Research
Esnet	DOE's Energy Sciences Network
ETS	Educational Testing Service
EU	European Union
FAA	Federal Aviation Administration
FASB	Financial Accounting Standards Board
FDA	Food and Drug Administraton
FDI	foreign direct investment
FDIUS	Survey of Foreign Direct Investment in the United States
FFRDC	federally funded research and development center
FY	fiscal year
G-7	Group of Seven
G-8	Group of Eight
GAO	Government Accountability Office
GDP	gross domestic product
GE	General Electric Company
GED	General Equivalency Diploma
GGDC	Groningen Growth and Development Centre
GM	genetically modified
GSS	General Social Survey
GUF	general university fund
HHS	Department of Health and Human Services
HSARPA	Homeland Security Advanced Research Project Agency
ICT	information and communications technologies
IIE	Institute of International Education
IMLS	Institute for Museum and Library Services
IOF	involuntarily out of the field
IP	intellectual property
IRI	Industrial Research Institute
IRS	Internal Revenue Service
ISCED	International Standard Classification of Education
ISIC	International Standard Industrial Classification
IT	information technology

JPO	Japan Patent Office
JV	joint ventures
MER	market exchange rate
MNC	multinational corporation
MOFA	majority-owned foreign affiliate
MOU	memorandum of understanding
MREN	Metropolitan Research and Education Network
NACE	National Association of Colleges and Employers
NAE	National Academy of Engineering
NAEP	National Assessment of Educational Progress
NAFTA	North American Free Trade Agreement
NAGB	National Assessment Governing Board
NAICS	North American Industry Classification System
NAPA	National Academy of Public Administration
NAS	National Academy of Sciences
NASA	National Aeronautics and Space Administration
NASF	net assignable square feet
NCES	National Center for Education Statistics
NCLB	The No Child Left Behind Act of 2001
NCTAF	National Commission on Teaching and America’s Future
NCTM	National Council of Teachers of Mathematics
NGA	National Governors Association
NIH	National Institutes of Health
NIOEM	National Industry-Occupation Employment Matrix
NIST	National Institute for Standards and Technology
NITRD	Networking and Information Technology Research and Development
NNI	National Nanotechnology Initiative
NORC	National Opinion Research Center
NRC	National Research Council
NREN	NASA’s Research and Engineering Network
NS&E	natural sciences and engineering
NSB	National Science Board
NSCG	National Survey of College Graduates
NSDL	National Science Digital Library
NSF	National Science Foundation
NSRCG	National Survey of Recent College Graduates
NYSERNet	New York State Education and Research Network
OECD	Organisation for Economic Co-operation and Development
OES	Occupational Employment Statistics
OMB	Office of Management and Budget
OPEC	Organization of the Petroleum Exporting Countries
OSTP	Office of Science and Technology Policy
OWH	other Western Hemisphere
PC	productive capacity
PhRMA	Pharmaceutical Research and Manufacturers of America
PI	principal investigator
PISA	Program for International Student Assessment
PLTW	Project Lead The Way
PPP	purchasing power parity
PUMS	Public Use Microdata Sample
R&D	research and development
R&E	research and experimentation
RA	research assistantship
RDD	random direct dialing
RDT	research, development, and testing
S&E	science and engineering
S&T	science and technology
SA	single applicant
SAS	Service Annual Survey
SASS	Schools and Staffing Survey
SBIR	Small Business Innovation Research
SCANS	Secretary’s Commission on Achieving Necessary Skills
SCI	Science Citation Index
SciSIP	Science of Science and Innovation Policy
SDR	Survey of Doctorate Recipients
SE	socioeconomic infrastructure
SESTAT	Scientists and Engineers Statistical Data System
SIC	Standard Industrial Classification
SNA	System of National Accounts
SSCI	Social Sciences Citation Index
STEM	science, technology, engineering, and mathematics
STTR	Small Business Technology Transfer
TA	teaching assistant
TCB	The Conference Board
TI	technological infrastructure
TIMSS	Trends in International Mathematics and Sciences Study
U&C	universities and colleges
UK	United Kingdom
UNESCO	United Nations Educational, Scientific, and Cultural Organization
USCCB	United States Conference of Catholic Bishops
USDA	Department of Agriculture
USDIA	Survey of U.S. Direct Investment Abroad
USPTO	U.S. Patent and Trademark Office
USSR	Union of Soviet Socialist Republics
VA	Department of Veterans Affairs
VCU	Virginia Commonwealth University
WebCASPAR	Integrated Science and Engineering Resources Data System
WIPO	World Intellectual Property Organization

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 to inform the development of future policies. SEI does not model the dynamics of the science and engineering 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) under the guidance of the National Science Board (Board). It is subject to extensive review by outside experts, interested federal agencies, Board members, and NSF 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 a college-bound high school graduate. 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. A separate Statistical Appendix was added to SEI this year to aid readers' interpretation of the material presented.

SEI's Different Parts

SEI includes 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 titles are

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

An appendix volume, available online at http://www.nsf.gov/statistics/indicators/ and on the CD enclosed with this volume, contains detailed data tables keyed to each of the eight chapters listed.

A National Science Board policy statement "companion piece," authored by the Board, draws upon the data in SEI and offers recommendations on issues of concern for national science and engineering research or education policy, in keeping with the Board's statutory responsibility to bring attention to such issues. In addition, the Board for the first time has also produced a "digest" or condensed version of SEI comprising a small selection of important indicators. This *Digest of Key Science and Engineering Indicators* serves two purposes: (1) to draw attention to important trends and data points from across the chapters and volumes of SEI and (2) to introduce readers to the data resources available in the main volumes of SEI 2008 and associated products.

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 (1) to enable the reader to comfortably assimilate a large amount of information by putting it in an order that facilitates comprehension and retention and (2) to 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 nonexpert 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 to 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 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.

The State Indicators Chapter

This chapter consists of data that can be used by people involved in state-level policymaking, 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. In 2008, appendix tables are also included in volume 2 for the first time.

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 to foster consideration of state-level activities in this area.

The Overview Chapter

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 to 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.

Presentation

SEI is released in printed and electronic formats, and is published in 2 volumes: volume 1 provides the main text content and volume 2 provides the detailed tabular data. The complete content of both volumes is posted online at http://www.nsf.gov/statistics/indicators/ in html format and PDF, with text tables, appendix tables, and source data for each figure available in spreadsheet (MS Excel) format. In addition, selected figures are also available in presentation-style format as MS PowerPoint and JPEG files.

The printed version of SEI includes a CD-ROM in PDF and a packaged set of information cards. The CD-ROM contains volumes 1 and 2, and as with the online version, appendix tables in spreadsheet format. The full set of presentation slides is also included. The pocket-sized information cards highlight key patterns and trends. Each card presents a selection of figures with captions stating the major point that the figure is meant to illustrate.

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

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Introduction

This overview of the National Science Board's *Science and Engineering Indicators 2008* describes some major developments in international and U.S. science and technology (S&T). It synthesizes selected major findings in a meaningful way and is not intended to be comprehensive. The reader will find important findings in the report that are not covered in the overview, for example, 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 participation of underrepresented groups in U.S. S&T is growing, but slowly. More extensive data are presented in the body of each chapter, and major findings on particular topics appear in the Highlights sections that precede chapters 1–7.

The reader should note that the indicators included in *Science and Engineering Indicators 2008* derive from a variety of national, international, and private sources and may not be strictly comparable in a 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 often not well developed. Thus, even though many data series conform generally to international standards, the focus is on broad trends that should be interpreted with care; where data are weak, this is noted in the specific chapter. (For more on the limitations of existing data and analytic models, see "Afterword: Data Gaps and Needs.")

The overview highlights a trend in many parts of the world toward the development of more knowledge-intensive economies, in which research, its commercial exploitation, and other intellectual work play a growing role. Implicit in the discussion are the key roles played by industry and government in these changes.

A healthy economy provides the foundation for investments in scientific research and technological innovation. Therefore, the overview begins by describing broad trends in U.S. competitiveness in the rapidly changing global macroeconomic system. It then traces the growth and structural shifts in international high-technology markets and comments briefly on related developments in medium- and low-technology market segments. There follows an examination of the changing conduct and location of international R&D, which are both fundamental to, and recasting, international high-technology markets.

The overview then turns to the personnel needed to build and maintain knowledge-intensive economic activity. After reviewing evidence of the widespread upgrading of higher education levels in international workforces, the discussion turns to a review of the U.S. S&T labor force, including trends in the production of new workers with S&T skills. It presents data on the U.S. reliance on foreign-born and foreign-educated S&T workers and discusses the growing international mobility of highly trained persons. The overview concludes with a review of the performance of U.S. K–12 students on national and international tests.

Throughout, the overview examines relevant S&T patterns and trends in the United States that bear on, and are affected by, these external changes. Where possible, the overview presents comparative data for the United States, the European Union after its first major enlargement (EU-25), and Japan, China, and eight other selected Asian economies (the Asia-10).

Macroeconomic Indicators

Since the early 1990s, the globalization of S&T has proceeded at a quick pace. More open borders coincided with the development of the Internet as a tool for unfettered worldwide information dissemination and communication. Rising demand for business and leisure travel fostered the growth of dense and relatively inexpensive airline links. Systems of global and more limited trade rules gained in scope and stimulated a vast expansion in the production of, and international trade in, goods and services. Growing creation of wealth, though uneven, touched most countries and regions. Corporations responded by including international markets in their strategic planning and soon moved toward a global-market model for their business activities, suppliers, and customers.

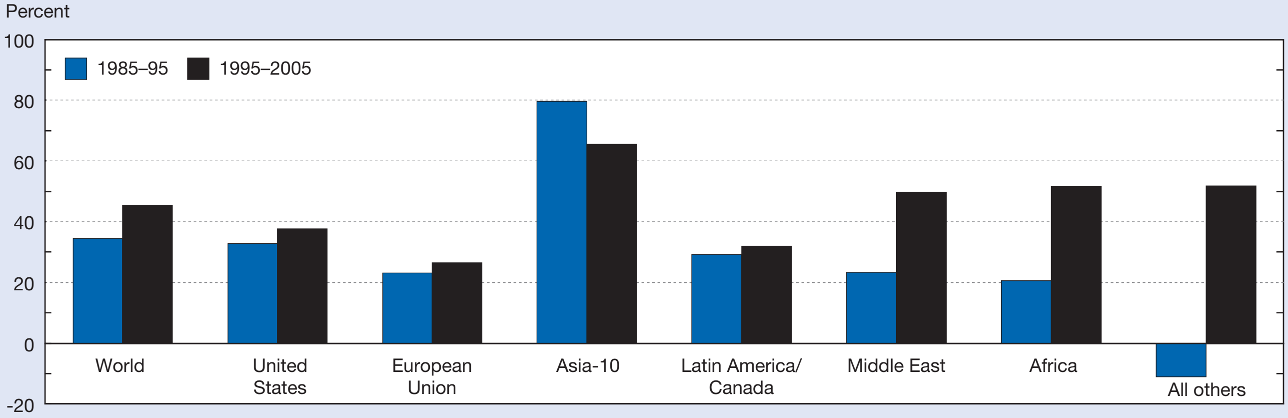
By the late 1990s, many governments had taken note of these developments. They increasingly looked to the development of knowledge-intensive economies for their countries' economic competitiveness and growth. Private companies seeking new markets set up operations in or near these locations, bringing with them technological know-how and management expertise. Governments anticipated and stimulated these moves with targeted and often generous incentives, decreased regulatory barriers, development of infrastructure, and expanded access to higher education. The overarching aim of these policies was the development of a knowledge-intensive economy that promised sustainable growth and economic well-being for decades to come.

In this changed and changing world, the United States continues to occupy a prominent position as the world's largest economy. On a number of broad macroeconomic measures, it has performed well over the past two decades. Its gross domestic product (GDP) growth has been robust, both overall and on a per capita basis, and its productivity growth has been strong.

U.S. GDP growth is robust but cannot match large, sustained increases in China and other Asian economies.

World Bank and other data show that the world's total economic output nearly doubled over the past two decades.[1] Although most world regions participated in this rapid expansion of total economic output, increases did not occur evenly. A group of East and Southeast Asian economies (the Asia-10) gained more rapidly than did most of the rest of the world, initiating a slow shift of the epicenter of world economic growth toward the region (figure O-1). Its GDP nearly tripled as China, India, and South Korea posted strong

Figure O-1
Real GDP growth, by region/country: 1985–95 and 1995–2005



GDP = gross domestic product

NOTES: Asia-10 includes China, India, Indonesia, Japan, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. China includes Hong Kong.

SOURCE: Conference Board and Groningen Growth and Development Centre, Total Economy Database (January 2007), http://www.ggdc.net.

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advances, even as Japan's economy struggled with slow growth. The rapid rise in Asian economic output over two decades, combined with slower growth elsewhere, pushed the region's share of world GDP from less than one-quarter in 1985 to 36% in 2005 (figure O-2).

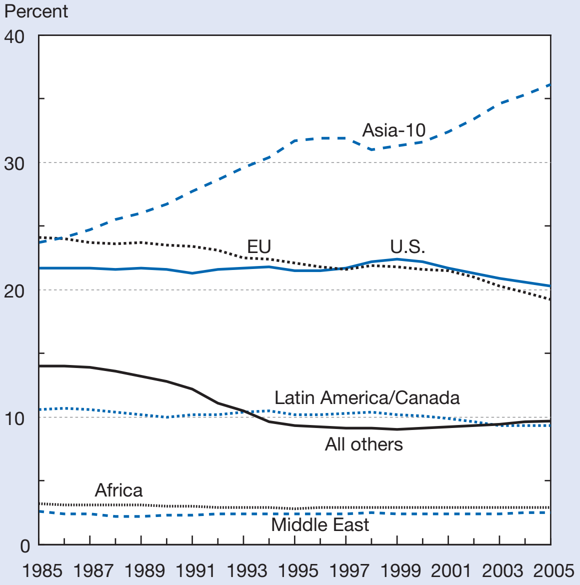
U.S. real GDP growth was slower than Asia's but faster than that of most other mature economies. It resulted in a near-doubling of real output over the two decades, leading to a small decline in the U.S. share of world GDP, from about 22% to just above 20% in 2005 (figure O-2). The EU-25 faced slower growth and a larger share decline from 24% to 19%. Japan's economy continued to grow in real terms but at a declining rate, leading to a fall of the country's world GDP share starting in the early 1990s, from about 8% of the total to 6% by 2005. The "all others" category in figure O-2 largely reflects the breakdown in growth of Eastern European and Asiatic countries of the former Union of Soviet Socialist Republics (USSR).

Even as others gain in per capita GDP, the absolute U.S. advantage widens because of its advantageous starting position.

GDP growth in part reflects increases in population, and GDP per person provides a convenient means of adjusting for this factor, albeit a measure that does not take in-country distribution into account.[2] A comparison of GDP and population growth rates shows a highly variable relationship for different regions and countries: very strong GDP growth for Asia, even after accounting for rising populations; average growth for the United States and the EU-25; and below-average growth for some other regions with fairly large population growth (figure O-3).

Over the past two decades (1985–2005), real annual growth of U.S. per capita GDP averaged 2.0%, almost identical to the world average and the growth rate of the EU-25. Many smaller EU countries, Ireland, the United Kingdom, and a smattering of countries in Latin America, the Middle

Figure O-2
World GDP shares, by region/country: 1985–2005



EU = European Union; GDP = gross domestic product

NOTES: Asia-10 includes China, India, Indonesia, Japan, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. China includes Hong Kong.

SOURCE: Conference Board and Groningen Growth and Development Centre, Total Economy Database (January 2007), http://www.ggdc.net.

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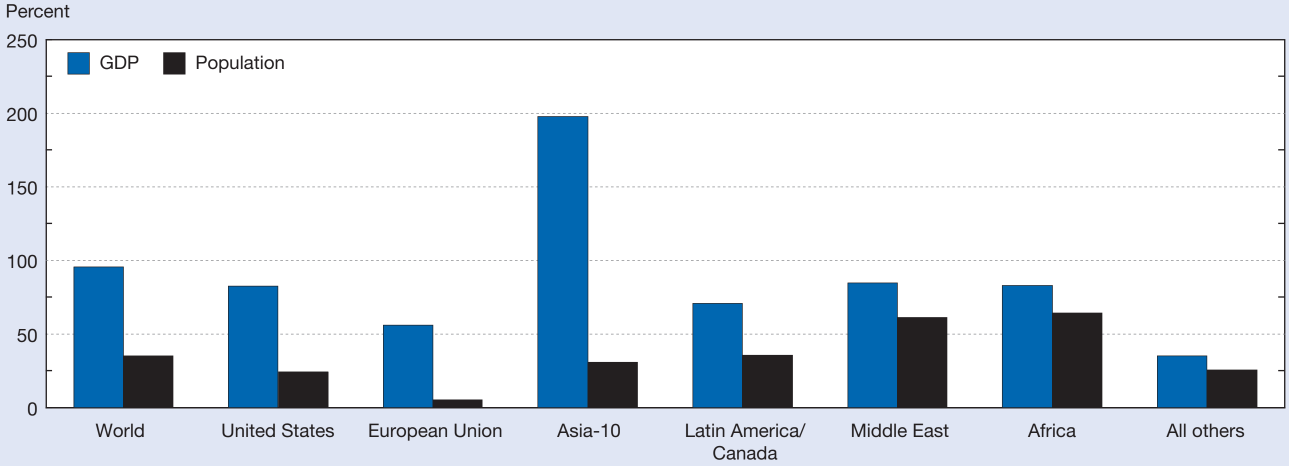
Figure O-3

Real GDP growth and population increase, by region/country: 1985–2005



GDP = gross domestic product

NOTES: Asia-10 includes China, India, Indonesia, Japan, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. China includes Hong Kong.

SOURCE: Conference Board and Groningen Growth and Development Centre, Total Economy Database (January 2007), http://www.ggdc.net.

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East, and Africa had higher growth rates. So did virtually all East and Southeast Asian economies, regardless of size. The highest growth rate of real per capita GDP[3] was achieved by China, averaging 6.6% over the period, followed by South Korea, Vietnam, Thailand, and others; India's GDP per capita rose by 4.2%. Of 11 economies with at least twice the U.S. average per capita growth, nine were in Asia (table O-1).

In terms of absolute per capita purchasing power, the United States has for decades led other regions by wide margins, the closest being the EU-25.[4] All regions but Africa and the former USSR-dominated category have shown two-decade increases, and the Asia-10 grouping has doubled its per capita GDP in real terms (figure O-4).

Table O-1

Real per capita GDP growth rates, by selected region/country/economy: 1985–2005

(Percent)

Economy	1985–95	1995–2005	1985–2005
World	1.4	2.3	1.9
United States	1.7	2.2	2.0
China	6.4	6.8	6.6
South Korea	7.8	3.7	5.7
Ireland	4.5	6.6	5.5
Vietnam	4.1	5.9	5.0
Thailand	8.0	1.8	4.9
Myanmar	0.4	9.4	4.8
Taiwan	5.1	3.7	4.4
Chile	5.5	3.0	4.3
Singapore	5.7	2.8	4.2
India	3.6	4.7	4.2
Malaysia	5.6	2.6	4.1

GDP = gross domestic product

SOURCE: Conference Board and Groningen Growth and Development Centre, Total Economy Database, January 2007, http://www.ggdc.net.

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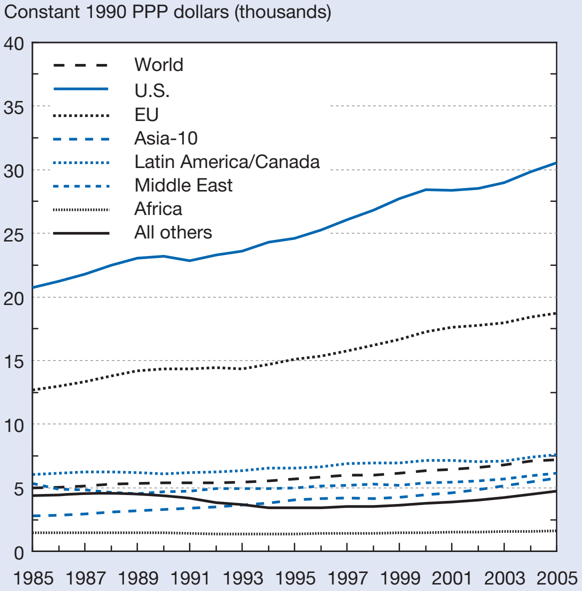
Figure O-4

Per capita GDP, by region/country: 1985–2005



EU = European Union; GDP = gross domestic product;
PPP = purchasing power parity

NOTES: Asia-10 includes China, India, Indonesia, Japan, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. China includes Hong Kong.

SOURCE: Conference Board and Groningen Growth and Development Centre, Total Economy Database (January 2007), http://www.ggdc.net.

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Despite faster rates of growth elsewhere, the United States widened its per capita GDP lead in absolute inflation-adjusted terms because of its large initial advantage. The absolute gap in 2005 was smallest for the EU-25 (about $12,000) and largest for Africa (about $29,000). The Asia-10 gap increased from about $18,000 to $26,000, despite the region's rapid GDP growth. Since 1985, this gap has increased for each region (figure O-5).

For some regions, the per capita GDP gap also increased as a fraction of their own growing per capita GDP. The only region to consistently reduce the relative per capita GDP gap with the United States was the Asia-10 (figure O-6). The Asia-10 group managed to reduce the size of the gap from 8 times its per capita GDP to under 5 times, reflecting impressive underlying GDP growth numbers coupled with moderate (1.4%) population growth (figure O-3).

Large relative productivity gains elsewhere fail to close absolute per-worker output gaps with the United States.

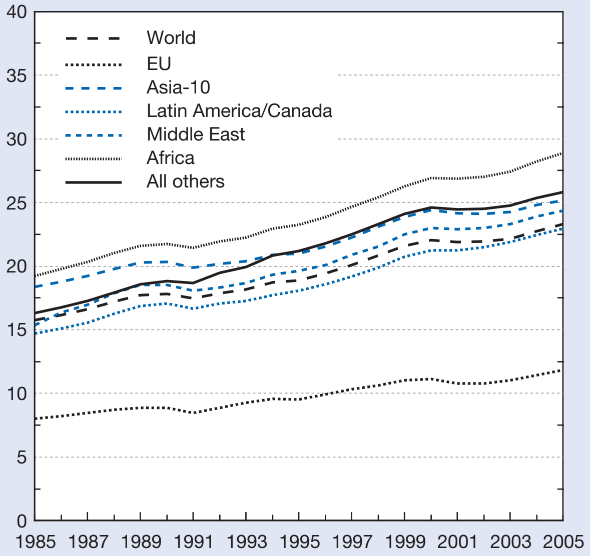
Rising productivity spurs economic growth and higher per capita resources. The preferred measure, volume of economic output per hour worked, is available for only a few countries. It shows that after enduring anemic productivity growth into the mid-1990s, the United States recovered to an annual, inflation-adjusted rate of about 2.5% from 1995 to 2004, significantly above the rates of major European economies and Japan.

A related measure, GDP per person employed, is more widely available and thus allows broad, but approximate, international comparisons. That measure shows generally higher real productivity gains for the regional aggregates in the 1995–2005 decade than in the preceding one, except for the EU-25 (figure O-7). Neither the United States, nor major European countries or Japan achieved the kind of productivity growth rates of some Asian economies. These averaged above 3% during the first decade and approached 4% during the second. China and India had real second-decade productivity growth rates of 6.6% and 4.4%, respectively, albeit from low bases.

In inflation-adjusted dollars, U.S. output per worker increased more steeply over the 20-year period than that of any other economy. Again, this reflects the much higher U.S. output per worker at the beginning of the period: a 2% increase on a high base is much larger, in absolute terms, than the same percentage rise on a small base. As a result, even countries with fast-expanding economies faced a growing gap with the United States (figure O-8). Even the EU-25, with a 20-year average productivity growth rate that matched that of the United States, saw its productivity gap widening after 1995.

Figure O-5
Per capita GDP gap with United States, by region: 1985–2005

Constant 1990 PPP dollars (thousands)



EU = European Union; GDP = gross domestic product;
PPP = purchasing power parity

NOTES: Asia-10 includes China, India, Indonesia, Japan, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. China includes Hong Kong.

SOURCE: Conference Board and Groningen Growth and Development Centre, Total Economy Database (January 2007), http://www.ggdc.net.

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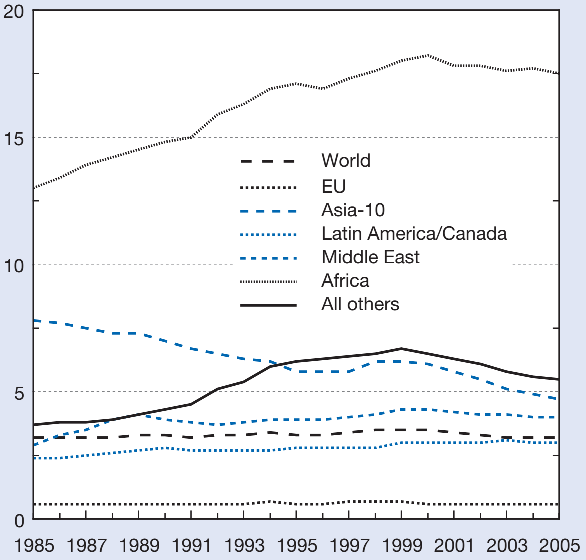
Figure O-6
Per capita GDP gap with United States relative to region's GDP: 1985–2005

Ratio



EU = European Union; GDP = gross domestic product

NOTES: Asia-10 includes China, India, Indonesia, Japan, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. China includes Hong Kong.

SOURCE: Conference Board and Groningen Growth and Development Centre, Total Economy Database (January 2007), http://www.ggdc.net.

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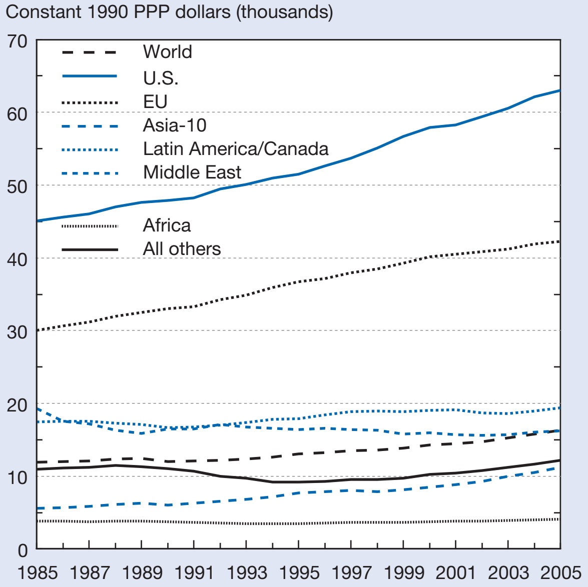
Figure O-7
Productivity output per employed individual: 1985–2005



EU = European Union; PPP = purchasing power parity

NOTES: Asia-10 includes China, India, Indonesia, Japan, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. China includes Hong Kong.

SOURCE: Conference Board and Groningen Growth and Development Centre, Total Economy Database (January 2007), http://www.ggdc.net.

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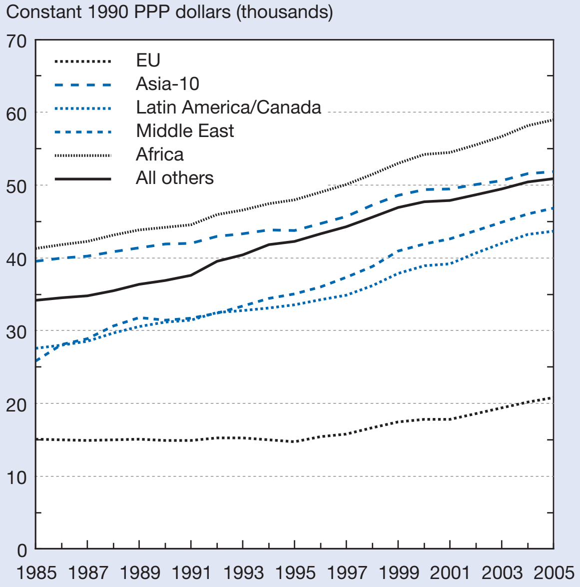
Figure O-8
Inflation-adjusted productivity gap with United States, by region: 1985–2005



EU = European Union; PPP = purchasing power parity

NOTES: Asia-10 includes China, India, Indonesia, Japan, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. China includes Hong Kong.

SOURCE: Conference Board and Groningen Growth and Development Centre, Total Economy Database (January 2007), http://www.ggdc.net.

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The United States remains robustly competitive on these macroeconomic measures.

In terms of these three indicators, the U.S. economy has managed to maintain a strong competitive position. Its absolute GDP growth was sufficiently robust to broadly maintain the U.S. world share in the face of expanding world GDP and a shift of rapid GDP growth toward Asian economies. Similarly, it has maintained its advantages in both purchasing power and productivity. While per capita GDP of economies in Asia and elsewhere was rising at very rapid rates, smaller rates of increase in U.S. per capita GDP kept widening the absolute dollar gap, reflecting and continuing the large initial U.S. advantage. U.S. productivity growth was sufficiently robust to keep the country well ahead, in absolute productivity measures, even as others raise their productivity growth rates from relatively low levels.

Knowledge-Intensive Economies

The notion of a knowledge-intensive economy is of relatively recent vintage but has taken a powerful hold on governments in many parts of the world. It is easy to see why. Industries that rely heavily on the application and exploitation of knowledge are driving growth in both manufacturing and services. They tend to create well-paying jobs, to contribute high-value output, and to stimulate economic activity generally. The global nature of these developments compels governments to take part in them or be left behind, to the detriment of a country's economic standing and well-being.

Industry anticipates and reacts to these same fundamentals. Growing markets, including rapidly expanding ones in Asia, beckon, especially for knowledge- and technology-intensive goods and services. They offer growing buying power, cheap labor, and often strategically structured government incentives intended to attract investment. Spurred by both market and government activities, these economies, and particularly their knowledge-intensive sectors, have grown very rapidly in a number of regions.

Indicators of the shift toward knowledge-intensive economic activity abound. Around the world, service sectors are expanding, driven by rapid growth of their most knowledge-intensive segments. Goods from high-technology manufacturing segments represent a growing share of manufacturing output. Countries are investing heavily in expansion and quality improvement of their higher education systems, easing access to them, and often directing sizable portions of this investment to training in science, engineering, and related S&T fields. The concept of innovation figures prominently in discussions of economic policy.

Taken together, these activities have spawned trends that are reshaping the world's S&T economy, now dominated not only by the United States and the EU, but also by selected Southeast and South Asian economies. The broad changes, generally starting in the mid-1990s and continuing unabated, have the United States holding its own in terms of (generally high) world shares, the EU-25 losing some ground, and the Asia-10 group increasing its world share. In Asia, Japan is losing world share on many indicators, while China is rapidly gaining ground, especially since the mid-1990s.

Knowledge-intensive industries are reshaping the world economy.

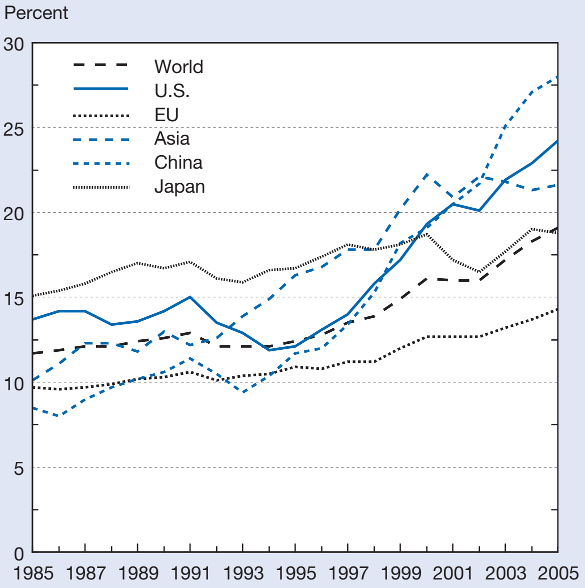
Knowledge-intensive industries, both in services and manufacturing, form a growing share of economic output worldwide and in many individual countries. While the estimated volume of worldwide services doubled between 1985 and 2005, knowledge-intensive services grew faster. After the mid-1990s, their growth accelerated to approximately 3.5% annually in real terms, compared with about 2.5% for other types of services. A similar shift occurred in high-technology manufacturing, where output rose from about 12% of total manufacturing output to about 19% over two decades (figure O-9).

These developments affected various countries and regions differently, leading to considerable shifts in world shares, particularly in high-technology manufacturing. The Asia-10's share increased from 29% to 41% over two decades. However, within the group, Japan's share declined from 25% in 1985 to 16% in 2005, while China's share rose, with sharp acceleration starting in the mid-1990s, from under 2% to 16% over the same period (figure O-10). The EU's share of high-technology manufacturing declined from about 25% through the mid-1990s to 18% in 2005. In contrast, U.S. high-technology manufacturing expanded sharply over the past decade to 24% of all U.S. manufacturing activity by 2005, up from 12% as late as 1995; this has kept the U.S. world share above 30% since the late 1990s.

Trade patterns in knowledge-intensive services and high-technology manufacturing have changed.

Trade volume in high-technology manufactures has risen about 10-fold over the two decades, with exports reaching approximately $2.3 trillion in 2005 (figure O-11). The arrival and rapid expansion of new, mostly Asian, manufacturing locations has shifted world export patterns, shrinking the shares of established manufacturing centers. The EU's world share fell from 39% to 28%, that of the United States from 23% to 12%, and Japan's from 21% to 9%. China's share increased dramatically after the late 1990s, reaching 20%, while the share of other Asian economies rose quite steadily from 7% to 25% in 2005 (figure O-12).

Figure O-9
High-technology manufacturing share of total manufacturing, by region/country: 1985–2005



EU = European Union

NOTES: Asia includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. China includes Hong Kong.

SOURCE: Global Insight, Inc., World Industry Service database, special tabulations.

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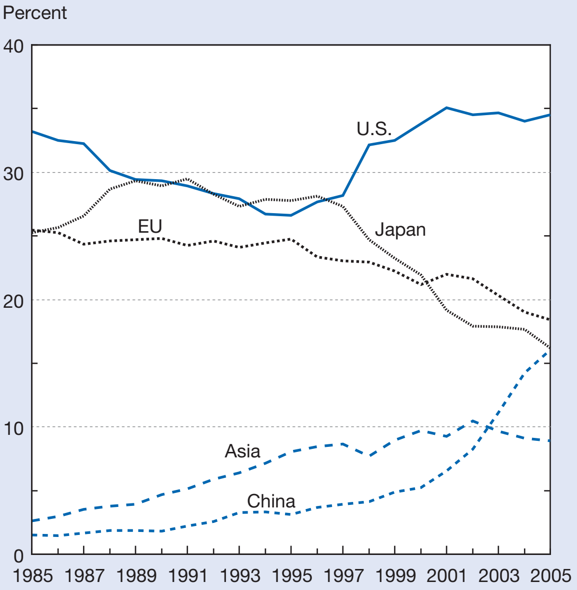
Figure O-10
World share of high-technology manufacturing, by region/country: 1985–2005



EU = European Union

NOTES: Asia includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. China includes Hong Kong.

SOURCE: Global Insight, Inc., World Industry Service database, special tabulations.

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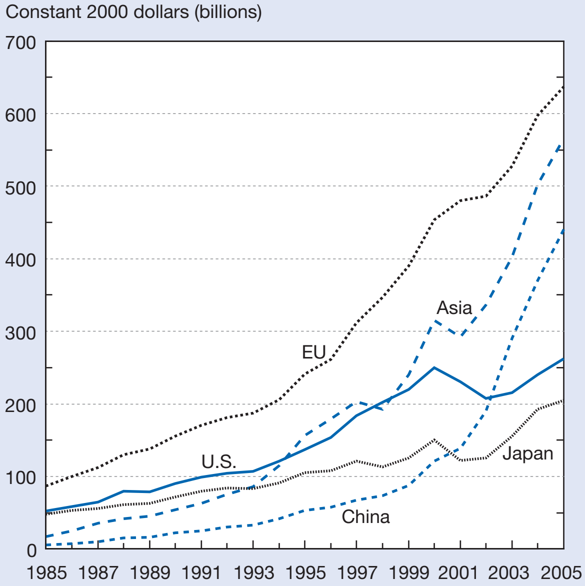
Figure O-11
Export volume of high-technology manufactures, by region/country: 1985–2005



EU = European Union

NOTES: Asia includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. China includes Hong Kong.

SOURCE: Global Insight, Inc., World Industry Service database, special tabulations.

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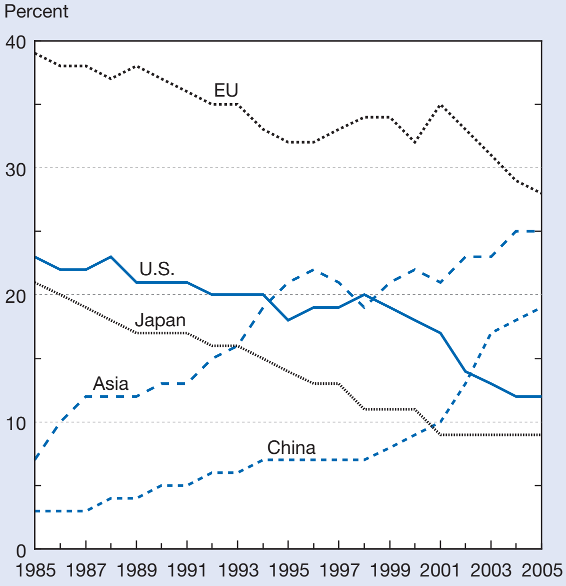
Figure O-12
World share of high-technology manufacturing exports, by region/country: 1985–2005



EU = European Union

NOTES: Asia includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. China includes Hong Kong.

SOURCE: Global Insight, Inc., World Industry Service database, special tabulations.

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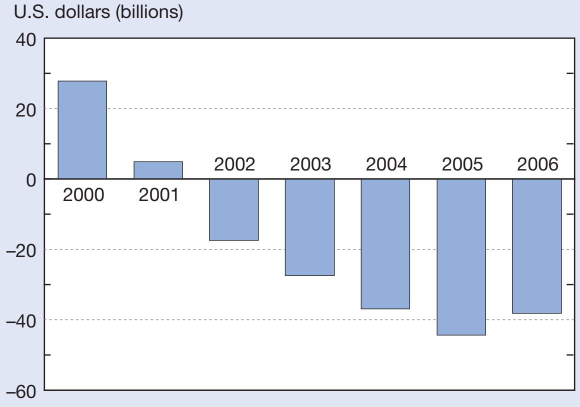
The comparative strength of the U.S. economy over the past several years was reflected in U.S. trade in high-technology goods, especially in information and communications technologies (ICT). The strong U.S. economy boosted imports of high-technology goods, which rose to $291 billion in 2006 from $196 billion in 2000. However, U.S. exports of these types of goods failed to keep pace, and imports have exceeded exports since 2002, producing the first U.S. trade deficit in this segment of the U.S. economy (figure O-13).

The growing technological sophistication of Asian trade partners is evident in the growing imports of high-technology goods from Asia that are not balanced by U.S. exports to these economies. The overall high-technology goods deficit is driven by trade with Asia, while trade with Europe, North American Free Trade Agreement (NAFTA) partners, and Latin America is broadly in balance (figure O-14).

However, the United States continues to maintain a healthy position in royalties and fees for intellectual property. This includes both cross-border intrafirm transactions and transactions between unaffiliated firms; the latter accounted for approximately 25% of all such transactions over the past two decades (figure O-15).

Figure O-13
U.S. trade balance in high-technology goods: 2000–06



SOURCE: Census Bureau, Foreign Trade Division, special tabulations.

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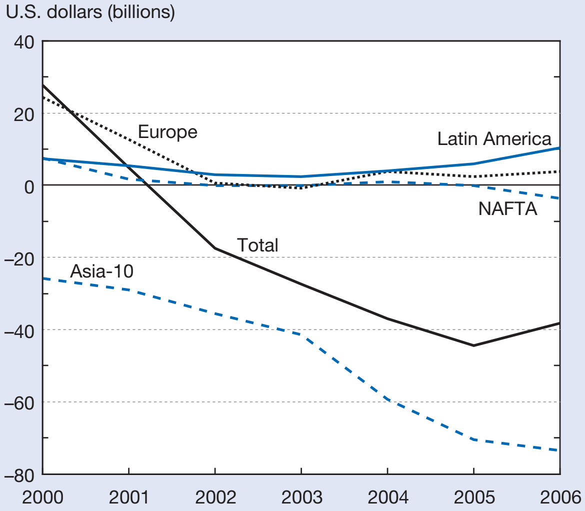
Figure O-14

U.S. advanced technology product trade balance, by region: 2000–06



NAFTA = North American Free Trade Agreement

NOTES: Asia-10 includes China, India, Indonesia, Japan, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. China includes Hong Kong. Europe includes EU-25 plus Norway; Latin America includes Argentina, Brazil, Chile, Costa Rica, Peru, and Venezuela.

SOURCE: Census Bureau, Foreign Trade Division, special tabulations.

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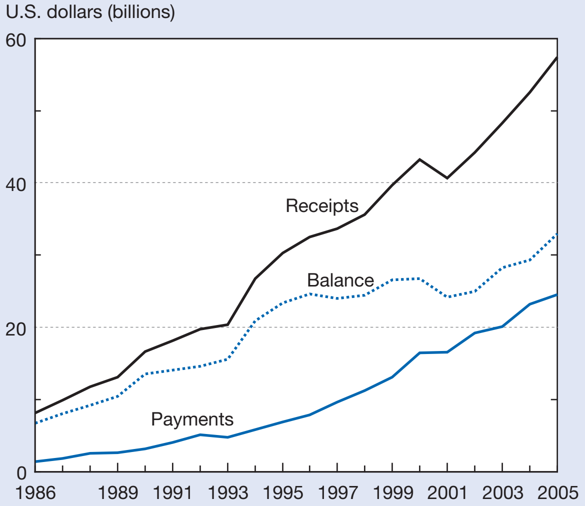
Figure O-15

U.S. receipts and payments of royalties and fees for intellectual property: 1986–2005



SOURCE: Bureau of Economic Analysis, U.S. International Services: Cross-Border Trade 1986–2005, and Sales Through Affiliates, 1986–2004, table 4, http://www.bea.gov/international/intlserv.htm, accessed 28 June 2007.

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Nascent S&T capabilities are reflected in gains in patenting and scientific publishing.

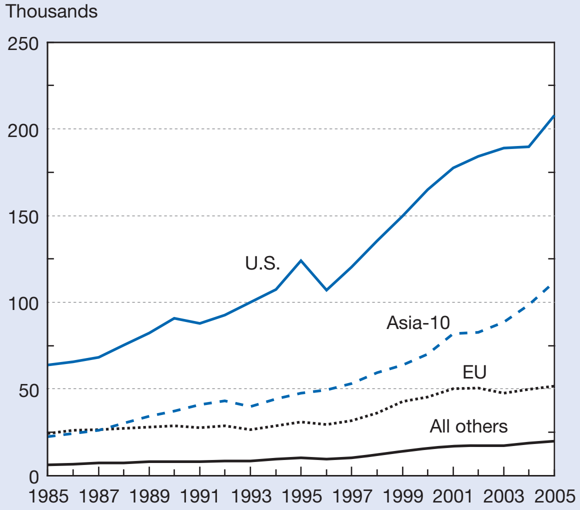
As countries strive to develop knowledge-intensive segments of their economies, they promulgate policies to strengthen domestic S&T capabilities so as to become less reliant on foreign expertise. Some results of these efforts are difficult to measure, such as the quality of rising numbers of higher education degrees awarded, but others are eventually reflected in readily quantified data. Intellectual property rights in major markets in the form of patents are generally accepted as indicating a degree of technological innovativeness and sophistication. Publication of rising numbers of scientific and technical articles in international, peer-reviewed journals is evidence of growing scientific capacity, as are increasing international collaborations. A number of governments are actively encouraging these activities and monitoring these and related indicators.

Patent applications to the U.S. Patent and Trademark Office (USPTO) seek intellectual property protection in the world's largest national economy. Applications from foreign sources reveal growing technological capabilities around the world, as well as rising incentives to protect the exploitation of potentially economically valuable inventions. Such applications have more than tripled since 1985, with U.S. applications consistently accounting for 53% or more through 2005. Over the period, applications from EU countries little more than doubled, while those from Asia increased fivefold (figure O-16).

These divergent growth rates created large shifts in the country and regional shares of U.S. patent applications. The EU, long the major non-U.S. source, lost ground in the late 1980s to a nascent Asia, as the EU's share declined from 21% to 13% of total applications registered by the USPTO; Asia's share in the meantime rose from 19% to 29%. Within Asia, Japan's share fluctuated around 18% to, briefly, 22% while that of smaller Asian economies such as South Korea, Taiwan, and Singapore rose from 1% to 9% (figure O-17). Chinese applications, however, do not yet register in any significant way, suggesting room for further development of the country's domestic technology base.

Progress in building the S&E base underlying indigenous technical advances is registered in articles published in the international peer-reviewed literature. On this measure, the U.S. and Japanese outputs grew marginally over the 1995–2005 decade, while Asia's output doubled (figure O-18). China moved to fifth place in total article output, and a number of other Asian economies, including South Korea, Singapore, and Taiwan, registered steep publications increases, suggesting improving basic scientific infrastructure. But a broad citation measure (citations received adjusted for the volume of articles available for citation) indicates a more measured pace of increasing article quality for many Asian locations.

Figure O-16
USPTO patent applications, by region/country: 1985–2005



EU = European Union; USPTO = U.S. Patent and Trademark Office

NOTES: Country of origin based on residence of first-named inventor. Asia-10 includes China, India, Indonesia, Japan, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. China includes Hong Kong.

SOURCE: USPTO, Number of Utility Patent Applications Filed in the United States, by Country of Origin, Calendar Years 1965 to Present (1), and National Science Foundation, Division of Science Resources Statistics, special tabulations.

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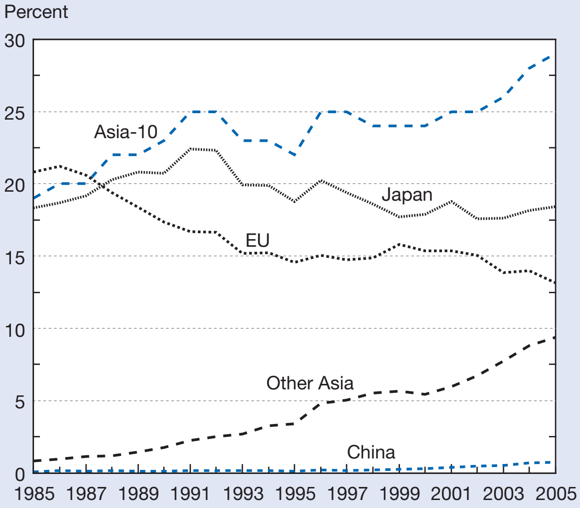
R&D in Knowledge-Intensive Economies

Knowledge-intensive economies draw on a broad range of knowledge, goods, skills, and activities, including the funding and performance of R&D. The level of R&D relative to other expenditures provides an indication of the priority given to advancing S&T relative to other public and private goals.

A growing emphasis on R&D is a measure of the development of a knowledge-intensive economy. In government accounts, R&D must compete for funding with other programs supported by discretionary spending, from education to national defense. The budget share devoted to R&D thus indicates governmental and societal investment in R&D relative to other activities. Similarly, the amount for-profit companies spend on R&D relative to other investments indicates how important they consider technological improvements to be as a basis for developing markets and exploiting demand for better processes, goods, and services.

R&D enables but does not guarantee invention, and invention does not automatically lead to innovation, the introduction of new goods, services, or business processes in the marketplace. Differences in national systems of innovation may make one country more effective than another in trans-

Figure O-17
Proportion of total USPTO patent applications from Asia and EU: 1985–2005



EU = European Union; USPTO = U.S. Patent and Trademark Office

NOTES: Country of origin based on residence of first-named inventor. Asia-10 includes China, India, Indonesia, Japan, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. China includes Hong Kong.

SOURCES: USPTO, Number of Utility Patent Applications Filed in the United States, by Country of Origin, Calendar Years 1965 to Present (1), http://www.uspto.gov/web/offices/ac/ido/oeip/taf/appl_yr.htm, accessed 21 September 2007; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

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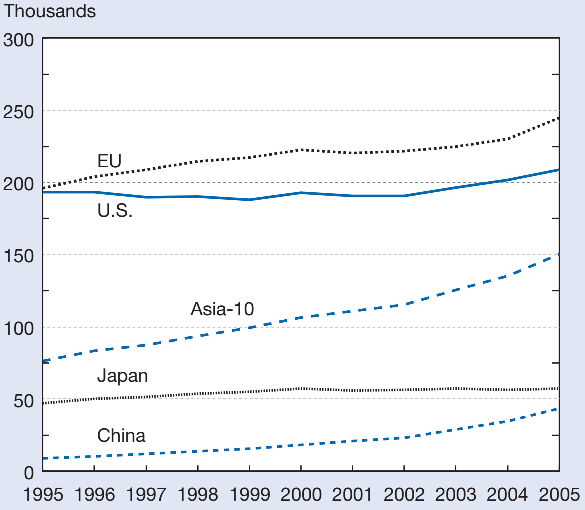
Figure O-18
Scientific and technical articles in peer-reviewed journals, by region/country: 1995–2005



NOTES: Asia-10 includes China, India, Indonesia, Japan, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. China includes Hong Kong.

SOURCES: Thomson Scientific, Science Citation Index and Social Sciences Citation Index; ipIQ Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

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lating R&D investments into economic growth or other social benefits. In the end, it is the results of R&D expenditures that matter, not their amount.

Internationally, R&D is concentrated but becoming less so. Over the past two decades, R&D has principally been performed and funded in North America, Europe, and Asia by the 30 developed member nations of the Organisation for Economic Co-operation and Development (OECD) (figure O-19).[5] The United States and Japan provided close to 60% of the estimated $772 billion OECD total in 2005, little changed from 61% of the $480 billion OECD total in 1995.

But this picture is changing (table O-2). For nearly a decade, R&D expenditures are estimated to have risen rapidly in selected Asian and Latin American economies and elsewhere. The average annual R&D growth rate of nine non-OECD economies (Argentina, China, Israel, Romania, Russian Federation, Singapore, Slovenia, South Africa, and Taiwan; there are no data for India) tracked by the OECD was about 15.5% from 1995 to 2005, compared with an OECD average of 5.8%. Over the decade, the OECD share of the combined total dropped from an estimated 92% to 82%. Likewise, the combined share of the United States and Japan, the two largest R&D-performing countries, declined from 56% of the total in 1995 to 48% in 2005.

China's expansion of R&D was by far the most rapid and sustained of all (figure O-20). According to OECD figures, it had the fourth largest expenditures on R&D in 2000 ($45 billion), which increased in 2005 to an estimated $115 billion, further moving it up in rank. Given the lack of R&D-

Table O-2
R&D expenditures for selected regions/countries: 1995, 2000, and 2005

Region/country	1995	2000	2005
	Current PPP dollars (billions)		
All selected regions/countries	480.1	687.2	939.5
OECD	440.3	606.8	771.5
U.S./Japan	266.5	366.6	455.2
U.S.	184.1	267.8	324.5
Japan	82.4	98.8	130.7
Selected non-OECD	39.8	80.5	168.0
	Percent		
All selected regions/countries	100	100	100
OECD share all	92	88	82
U.S/Japan share OECD	61	60	59
U.S./Japan share all	56	53	48

OECD = Organisation for Economic Co-operation and Development; PPP = puchasing power parity

SOURCE: OECD, Main Science and Technology Indicators, 2006 and 2007.

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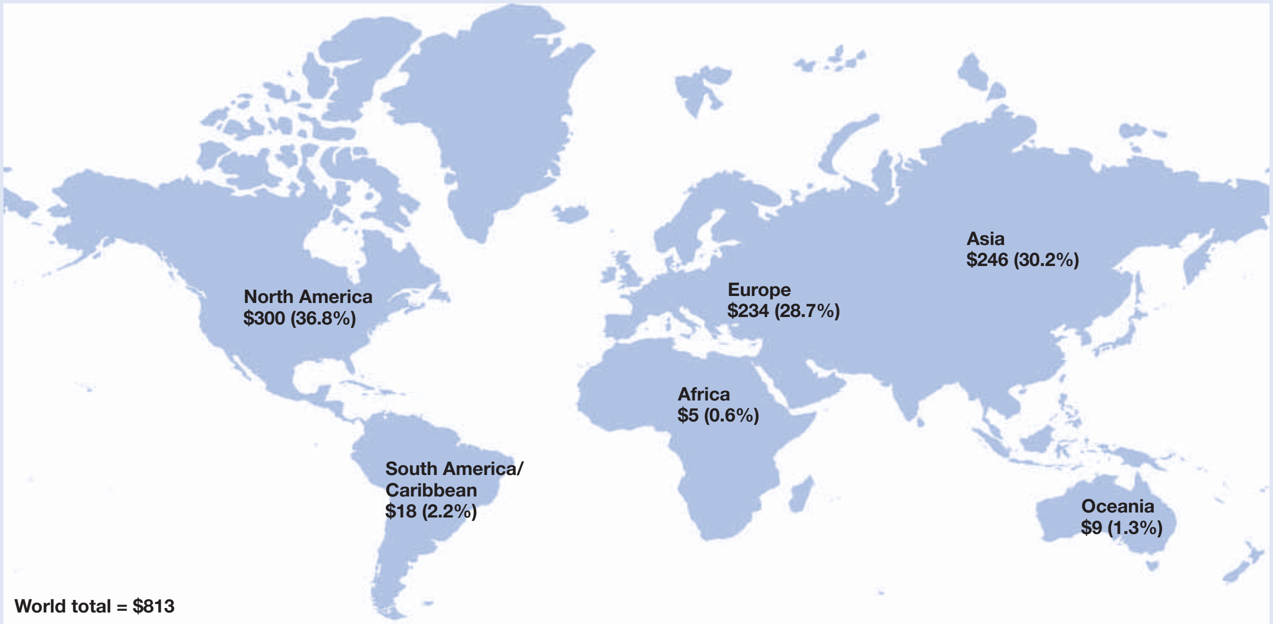
Figure O-19
Estimated R&D expenditures and share of world total, by region: 2002



NOTES: R&D estimates from 91 countries in billions of purchasing power parity dollars. Percentages may not add to 100 because of rounding.

SOURCES: Organisation for Economic Co-operation and Development, Main Science and Technology Indicators (2006); Ibero-American Network of Science and Technology Indicators, http://www.ricyt.edu.ar, accessed 5 March 2007; and United Nations Educational, Scientific and Cultural Organization (UNESCO), Institute for Statistics, http://www.uis.unesco.org.

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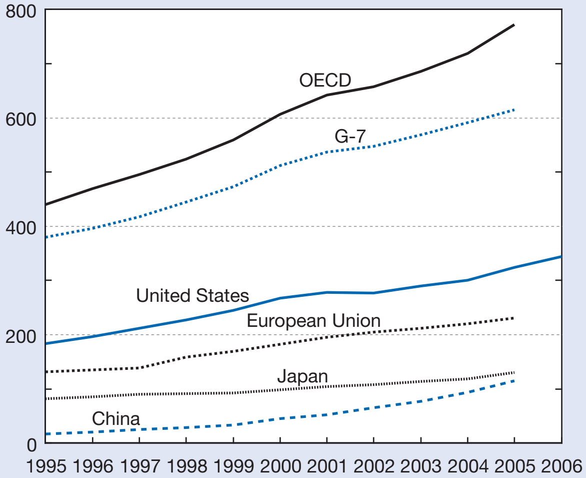
Figure O-20

Gross domestic expenditures on R&D, by selected region/country: 1995–2006

Current PPP dollars (billions)



OECD = Organisation for Economic Co-operation and Development; PPP = purchasing power parity

NOTE: European Union (EU)-25 from 1998–2000, EU-27 thereafter.

SOURCE: OECD, Main Science and Technology Indicators 2004–07.

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specific exchange rates, it is difficult to draw conclusions about China's absolute R&D volume, but its nearly decade-long, steep ramp-up of R&D expenditures and R&D intensity is unprecedented in the recent past. Other less-developed countries that appear set to become sizable R&D performers include Brazil ($14 billion in 2004) and India ($21 billion in 2000).

Industry R&D in manufacturing and services is expanding and increasingly crossing borders.

In most OECD countries, the manufacturing and services sectors account for more than 60% of total R&D funding and performance. However, sector concentration and sources of funding vary substantially among these countries.

Industrial R&D in the United States is highly diversified. No single U.S. industry accounted for more than 16% of total business R&D (table O-3 and figure O-21). 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.

Most other countries display higher sector concentrations than the United States. 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 2004. 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. 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 32% of Germany's business R&D, 26% of the Czech Republic's, and 19% of Sweden's.

The pharmaceuticals industry accounts for 20% or more of business R&D in Denmark, the United Kingdom, Belgium, and Sweden. Among OECD countries, only the Netherlands and Japan report double-digit concentration of business R&D in the office, accounting, and computing machine industry.

One of the more significant trends in both U.S. and international industrial R&D activity has been the growth of

Table O-3

R&D expenditures for selected countries, by performing sector: Most recent year

(Percent)

Country	Industry	Higher education	Government	Other nonprofit
South Korea (2005)	76.9	9.9	11.9	1.4
Japan (2004)	75.2	13.4	9.5	1.9
United States (2006)	71.1	13.7	11.0	4.2
Germany (2005)	69.9	16.5	13.6	NA
China (2005)	68.3	9.9	21.8	NA
Russian Federation (2005)	68.0	5.8	26.1	0.2
United Kingdom (2004)	63.0	23.4	10.3	3.3
France (2005)	61.9	19.5	17.3	1.2
Canada (2006)	52.4	38.4	8.8	0.5
Italy (2004)	47.8	32.8	17.9	1.5

NA = not available

SOURCES: National Science Foundation, Division of Science Resources Statistics, National Patterns of R&D Resources (annual series); and Organisation for Economic Co-operation and Development, Main Science and Technology Indicators (2006).

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Figure O-21
Share of industrial R&D, by industry sector and selected region/country: 2003 or 2004

(Percent)

EU = European Union

NOTE: Countries listed in descending order by amount of total industrial R&D.

SOURCE: Organisation for Economic Co-operation and Development, ANBERD database, http://www1.oecd.org/dsti/sti/stat-ana/stats/eas_anb.htm, accessed 1 March 2007. See appendix table 4-42.

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R&D in the service sector. ICT services account for a substantial share of the service R&D totals.

In most OECD countries, government financing accounted for a small and declining share of total industrial R&D performance during the 1980s and 1990s (figure O-22). In 1981, government provided 21% of the funds used by industry in conducting R&D within OECD countries. By 2001, government's funding share of industrial R&D had fallen below 7% and continued to fluctuate between 6.8% and 7% through 2005. Among major industrial countries, government financing of industrial R&D performance shares ranged from as little as 1.2% in Japan to 54% in Russia in 2005. In the United States in 2006, the federal government provided about 9% of the R&D funds used by industry, and the majority of that funding came from Department of Defense contracts.

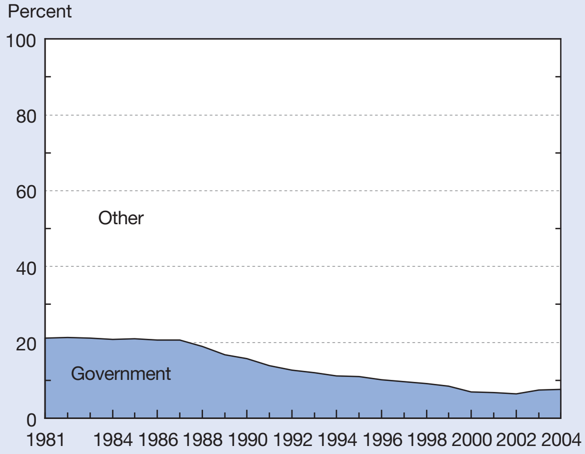
An indicator of the globalization of industrial R&D, the relative prominence of foreign sources of funding for business R&D, increased in many countries in the 1990s (figure O-23). The role of foreign funding varies by country, accounting for less than 1% of industrial R&D in Japan to as much as 23% in the United Kingdom in 2004. Directly comparable data on foreign funding sources of U.S. R&D performance are unavailable, but data on U.S. investments by foreign multinational corporations (MNCs) suggest this is rising as well. (See section on multinationals' R&D conducted abroad later in this overview.) This funding predominantly comes from foreign corporations; however, some of it also comes from foreign governments and other foreign organizations. For European countries, growth in foreign sources of industry R&D funds may reflect the expansion of coordinated EU efforts to foster cooperative shared-cost research through its European Framework Programmes for Research and Technological Development.

R&D/GDP ratio is an elusive policy goal but a useful indicator of R&D intensity.

A country's ratio of R&D to GDP depends on many things, among them the extent and structure of industrialization, orientation toward R&D in various sectors of the economy, availability of trained personnel, the nature of R&D infrastructure, and government policy. This makes meeting any specific R&D/GDP ratio an elusive policy goal. However, R&D/GDP ratios do provide a quick view of the R&D intensity of an economy relative to support of other public and private goals. Thus, emphasis on R&D can be seen as a measure of a knowledge-intensive economy.

Existing wealth generally bestows an advantage in moving toward a knowledge-intensive economy. R&D intensity indicators, such as R&D/GDP ratios, show that the developed, wealthy economies are well ahead of lesser developed economies. In many cases, this ratio heavily reflects the level of industry-funded R&D. Although industrial R&D does not generally respond directly to government policies, it thrives where favorable framework conditions exist, and these are subject to government influence.

Figure O-22
OECD industry R&D, by funding sector: 1981–2004



OECD = Organisation for Economic Co-operation and Development

SOURCE: OECD, Main Science and Technology Indicators (2006). See appendix table 4-39.

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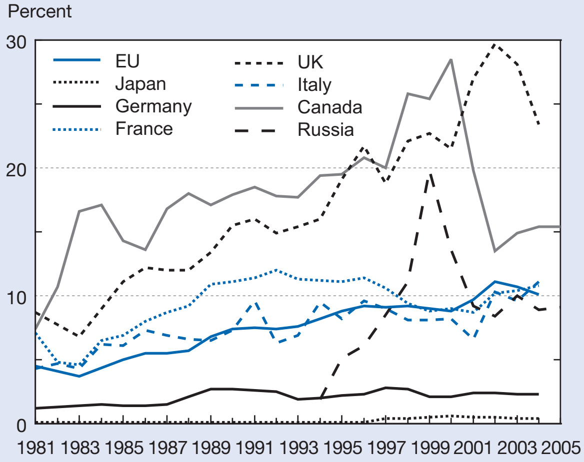
Figure O-23
Industrial R&D financed by foreign sources: 1981–2005



EU = European Union; UK = United Kingdom

NOTE: Data not available for all countries for all years.

SOURCE: Organisation for Economic Co-operation and Development, Main Science and Technology Indicators (2006). See appendix table 4-38.

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Overall, the United States ranked seventh among OECD countries in terms of reported R&D/GDP ratios (2.6% in 2005). Israel (not an OECD country), devoting 4.7% of its GDP to R&D, led all countries, followed by Sweden (3.9%), Finland (3.5%), and Japan (3.2%) (table O-4).

Most non-European, non-OECD, or developing countries invest a smaller share of their economic output in R&D than do OECD members. Despite its rapidly rising investment in

Table O-4
R&D share of GDP, by region/country/economy: Most recent year
(Percent)

Country/economy	Share
All OECD (2004)	2.25
EU-25 (2005)	1.77
Israel (2005)	4.71
Sweden (2005)	3.86
Finland (2006)	3.51
Japan (2004)	3.18
South Korea (2005)	2.99
United States (2006)	2.57
Germany (2005)	2.51
Taiwan (2004)	2.42
France (2005)	2.13
United Kingdom (2004)	1.73
China (2005)	1.34
Ireland (2005)	1.25
Argentina (2005)	0.46
Mexico (2003)	0.43

EU = European Union; GDP = gross domestic product;
OECD = Organisation for Economic Co-operation and Development

NOTE: Civilian R&D only for Israel and Taiwan.

SOURCES: National Science Foundation, Division of Science Resources Statistics, National Patterns of R&D Resources (annual series); and OECD, Main Science and Technology Indicators (2006).

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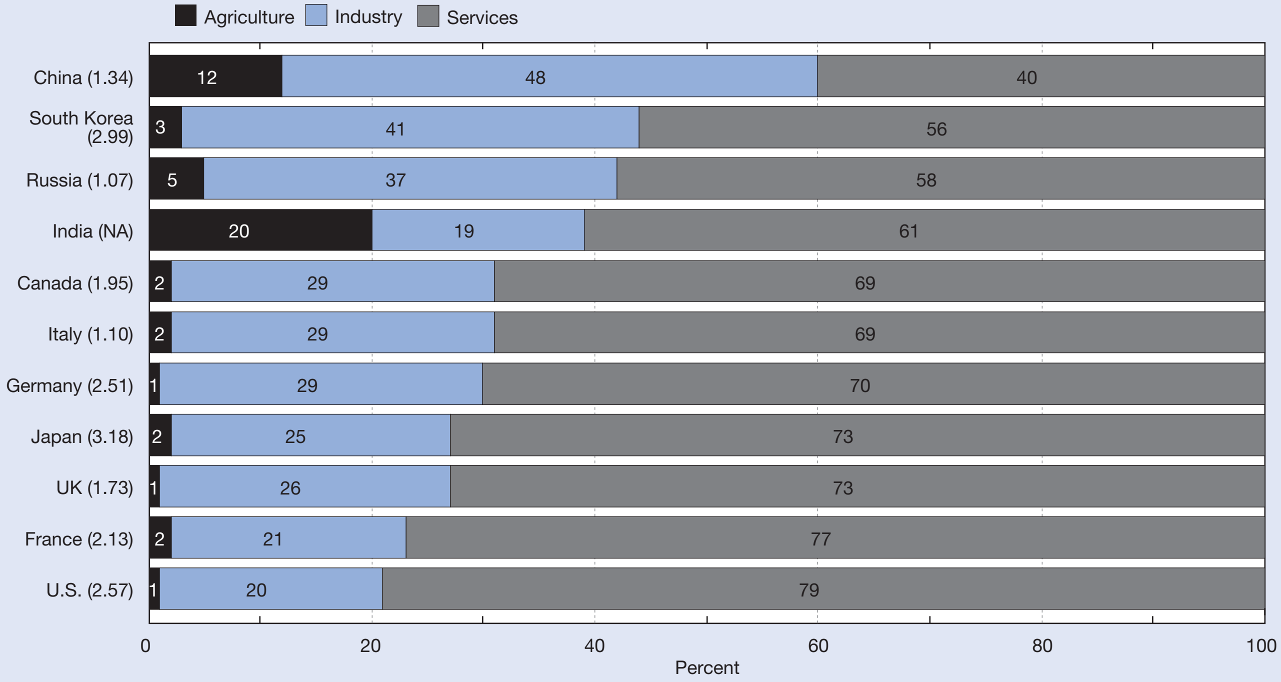
R&D, China reported an R&D/GDP ratio of just 1.3% for 2005—but relative to a GDP marked by sustained, record growth. All Latin American countries for which such data exist have R&D/GDP ratios at or below 1%. The pattern of this indicator broadly reflects the wealth and level of economic development of these countries.

High-income countries that emphasize the production of high-technology goods and services (i.e., have or are moving toward knowledge-intensive economies) are also those that tend to invest heavily in R&D activities. The private sector in low-income countries often has few high-technology industries, resulting in low overall R&D spending and therefore low R&D/GDP ratios (figure O-24).

Countries have different investment levels for national defense and associated R&D. The ratio of nondefense R&D to GDP reflects the portion of R&D that is more directly tied to scientific progress, economic competitiveness, and standard-of-living improvements. On this indicator, the United States falls below Germany and just above Canada (figure O-25). This is because the United States devotes more of its R&D than any other country to defense (16% in 2006), primarily for development rather than research. For historical reasons, Germany and Japan spent less than 1% of their R&D on defense. Approximately 10% of the United Kingdom's total R&D was defense related in 2004.

Figure O-24
Composition of GDP and R&D/GDP ratio for selected countries, by sector: 2006 or most recent year



NA = not available
GDP = gross domestic product; UK = United Kingdom

SOURCE: Central Intelligence Agency, *The World Factbook 2007,* http://www.cia.gov/cia/publications/factbook/index.html, accessed 2 March 2007. See table 4-12.

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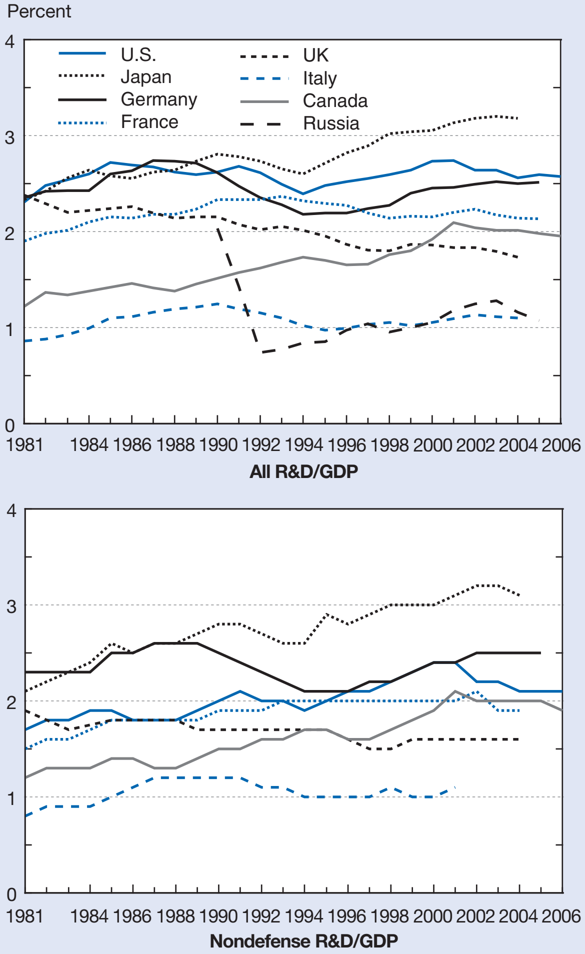
Figure O-25
R&D share of gross domestic product, by selected countries: 1981–2006



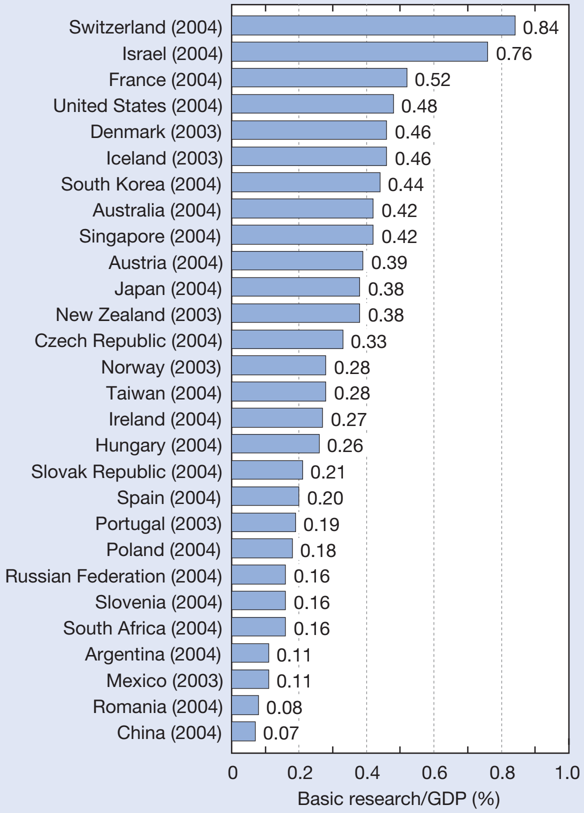
GDP = gross domestic product; UK = United Kingdom

NOTE: Data not available for all countries for all years.

SOURCE: Organisation for Economic Co-operation and Development, Main Science and Technology Indicators (2006). See appendix tables 4-35 and 4-36.

Science and Engineering Indicators 2008

Figure O-26
Basic research share of gross domestic product, by country/economy: 2003 or 2004



GDP = gross domestic product

NOTE: Countries with same values sorted alphabetically.

SOURCE: Organisation for Economic Co-operation and Development, Main Science and Technology Indicators (2006).

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Basic research plays a special role in developing new technologies.

Basic research generally has low short-term returns but builds intellectual capital and lays the groundwork for future advances in S&T.[6] High basic research/GDP ratios generally reflect the presence of robust academic research centers in the country or a concentration of high-technology industries with patterns of strong investment in basic research.

Investment in basic research relative to GDP indicates differences in national priorities, traditions, and incentive structures with respect to S&T. Among OECD countries with available data, Switzerland has the highest basic research/GDP ratio at 0.8% (figure O-26), significantly above the U.S. and Japanese ratios of 0.5% and 0.4%.

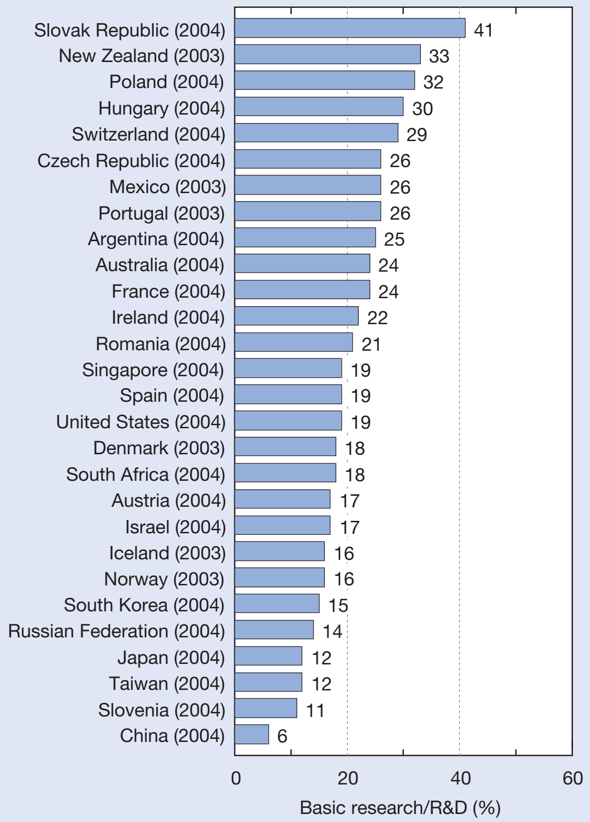
Switzerland devoted almost 30% of its R&D to basic research in 2004 (figure O-27). This small, high-income country boasts the highest number of Nobel prize winners, patents, and science citations per capita worldwide and an industrial R&D share comparable with the United States and Japan. The higher Swiss basic research share reflects the concentration of chemical and pharmaceutical R&D in Swiss industrial R&D and the "niche strategy" of focusing on specialty products adopted by many Swiss high-technology industries.

China, despite its growing R&D investment, has one of the lowest basic research/GDP ratios (0.07%), below Romania (0.08%) and Mexico (0.11%). With its emphasis on applied R&D aimed at short-term economic development, China follows the pattern of Taiwan, South Korea, and Japan whose basic research is 15% or less of total R&D (figure O-27). Singapore's basic research share, 12% in 2000, has risen to 19%, on a par with that of the United States.

Multinationals' R&D outside their home countries is growing in the United States and elsewhere.

Industrial R&D activities ceased long ago to be national in scope. Their increasingly international scope in the search

Figure O-27
Basic research share of R&D, by country/economy: 2003 or 2004



NOTE: Countries with same values sorted alphabetically.

SOURCE: Organisation for Economic Co-operation and Development, Main Science and Technology Indicators (2006).

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for useful innovations is reflected in growing direct R&D investments by foreign-based MNCs in the United States and by U.S.-based firms abroad. Much of this work is supported by firms' foreign direct investment (FDI) to majority-owned affiliates abroad, reflected in the data shown in figure O-28.

Since 1990, R&D expenditures by U.S. affiliates of foreign companies have increased faster than total U.S. industrial R&D, and for the past decade they have exceeded R&D performed overseas by majority-owned affiliates of U.S. parent companies (table O-5). U.S. affiliates of European companies accounted for three-fourths ($22.6 of $29.9 billion) of U.S. affiliates' R&D.

Overseas R&D by U.S. MNCs has started shifting away from Europe, Canada, and Japan, which received 90% of all such funds in 1994 but only 80% in 2001. Increasingly, such R&D FDI is located in emerging Asian markets. This has led to considerable shifts in the region (figure O-29), where Japan's share remains the largest but has fallen from 64% in 1994 to 35% in 2004. In contrast, the Asian R&D shares of U.S. foreign affiliates located in China (including Hong Kong) and Singapore reached 17% and 14%, respectively, in 2004. U.S. affiliates' R&D expenditures in India doubled from $81 million in 2003 to $163 million in 2004, pushing India's Asia share just above 3%.

In 2004, three manufacturing industries accounted for 70% of U.S. foreign-affiliate R&D: transportation equipment (28%), chemicals including pharmaceuticals (23%), and computer and electronic products (19%) (table O-6). Among nonmanufacturing industries, professional, technical, and scientific services (which includes R&D and computer services) expended an additional 8%. The same three manufacturing industries accounted for 58% of the R&D performed by foreign affiliates in the United States: chemicals (34%), transportation equipment (13%), and computer and electronic products (11%).

R&D in the United States is robust and dominated by industry.

R&D growth in the United States was robust after the recession-related slowdown of 2001–02. After declining in 2002 for the first time since 1953 to $277 billion, U.S. R&D surpassed $300 billion in 2004 and is projected to increase to $340 billion in 2006.

The industrial sector, including manufacturing and services, accounts for the largest share of both U.S. R&D performance and funding (figure O-30). Its share of U.S. R&D performance increased from 66% in the early 1970s to a high of 75% in 2000. Following the 2001–02 recession, many firms curtailed R&D growth, and industry's share fell to 69% of the U.S. total before rising again to 71% in 2006. Industry funding shares behaved similarly, rising from about 40% in the early 1970s to a 2000 peak at 70%, dipping to 64% in 2004 and reaching 66% in 2006.

Four manufacturing and two services industries account for more than three-fourths of all industrial R&D: computer and electronics products, chemicals, aerospace and defense manufacturing, automotive manufacturing, computer-related services, and R&D services. Their aggregate R&D intensity (R&D/net sales) was 7.7% in 2005; the comparable figure for all other industries was 1.3% (table O-7). In the manufacturing segment, nine automotive companies reported R&D expenditures of more than $100 million in 2004, representing more than 80% of this industry's R&D.

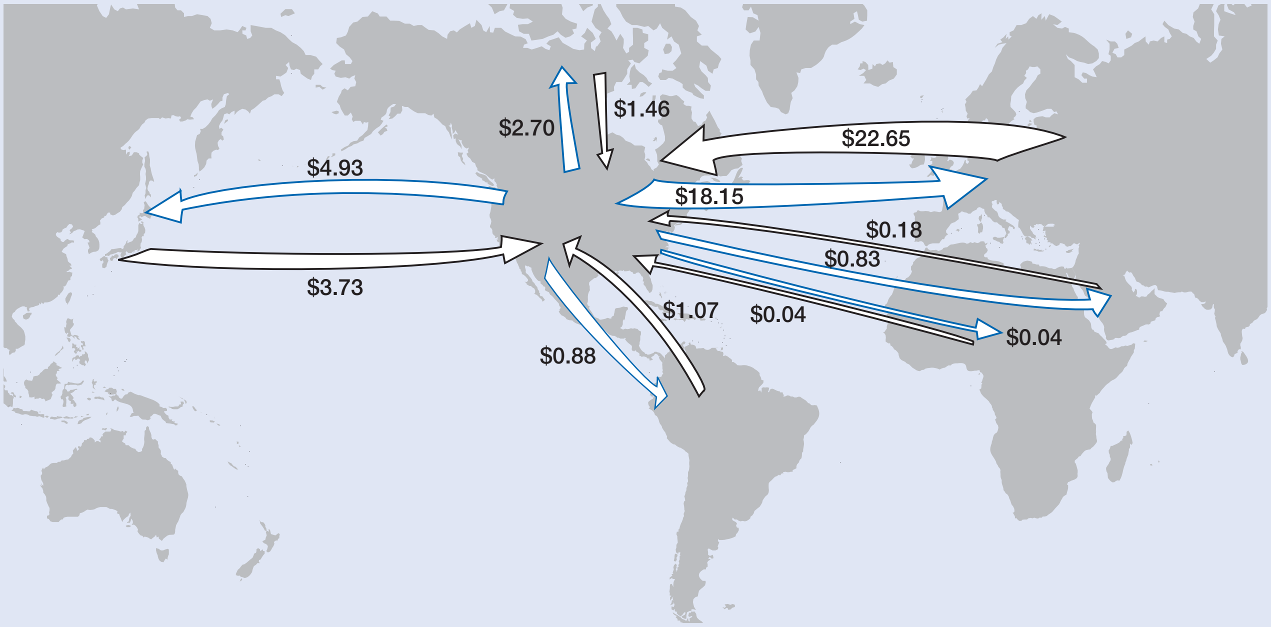
The federal government had for nearly three decades supplied half or more of the nation's total R&D funds, but in 1979 its share fell below 50%. It continued to drop to a low of 25% in 2000 but is projected to reach 28% in 2006 (figure O-31). This recent recovery mainly reflects increased health-related research spending and, more recently, rising development spending related to defense and counterterrorism. The federal government's performance share, about 20% of U.S. R&D in the early 1970s, has been declining and was 11% in 2006.

Defense-related R&D has accounted for at least half of the federal R&D funding portfolio for the past three decades. It increased from 50% of the federal R&D budget in 1980 to almost 70% in the mid 1980s, declined to 53% in 2001, and

Figure O-28

R&D performed by U.S. affiliates of foreign companies in U.S., by investing region, and performed by foreign affiliates of U.S. multinational corporations, by host region: 2004 or most recent year

Current U.S. dollars (billions)



NOTES: Preliminary estimates for 2004. 2002 data for U.S. affiliates of foreign companies from Latin America and Middle East.

SOURCES: 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 4-43 and 4-45.

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Table O-5

R&D expenditures by majority-owned affiliates in United States and R&D performed abroad by majority-owned foreign affiliates of U.S. parent companies: Selected years, 1990–2004

(Millions of dollars)

Year	U.S. affiliates of foreign MNCs	Foreign affiliates of U.S. MNCs	Balance
1990...........	8,511	10,187	-1,676
1992...........	10,745	11,084	-339
1994...........	12,671	11,877	794
1996...........	15,641	14,039	1,602
1998...........	22,375	14,664	7,711
2000...........	26,180	20,547	5,633
2002...........	27,507	22,793	4,714
2004...........	29,900	27,529	2,371

MNCs = multinational corporations

SOURCES: U.S. affiliates of foreign MNCs data from appendix table 4-43; foreign affiliates of U.S. MNCs data for 2002 and 2004 from appendix table 4-45; for 1994 to 2000 from National Science Board, *Science and Engineering Indicators 2006*, appendix table 4-51; and for 1990 and 1992 from *Science and Engineering Indicators 1998*, appendix table 4-51.

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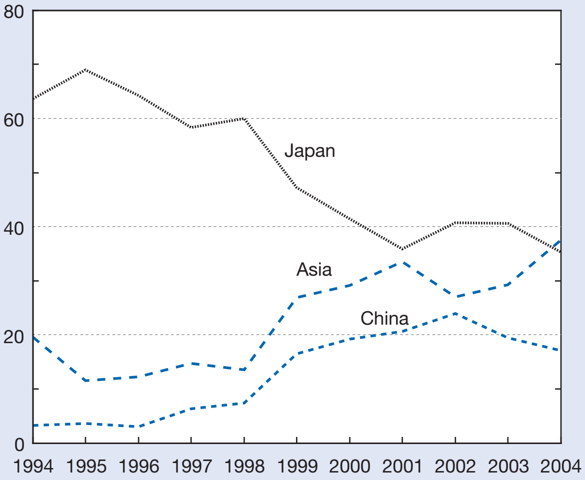
Figure O-29

R&D performed in Asia by majority-owned affiliates of U.S. parent companies, by region and selected country: 1994–2004

Percent



NOTES: Preliminary estimates for 2004. Asia includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. Data for some intervening years are extrapolated.

SOURCE: Bureau of Economic Analysis, Survey of U.S. Direct Investment Abroad (annual series). See appendix table 4-45.

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Table O-6

R&D performed abroad by majority-owned foreign affiliates of U.S. parent companies and foreign companies in United States, by selected NAICS industry of affiliate: 2004

(Millions of current U.S. dollars)

Industry/sector	Foreign affiliates	U.S. affiliates
All industries	29,900	27,529
Manufacturing	20,891	23,288
Chemicals	10,045	6,254
Machinery	1,547	791
Computer and electronic products	3,279	5,283
Electrical equipment	238	551
Transportation equipment	3,728	7,741
Nonmanufacturing	9,009	4,241
Information	898	843
Professional, technical, scientific services	1,442	2,120

NAICS = North American Industrial Classification System

SOURCE: 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 4-44 and 4-46.

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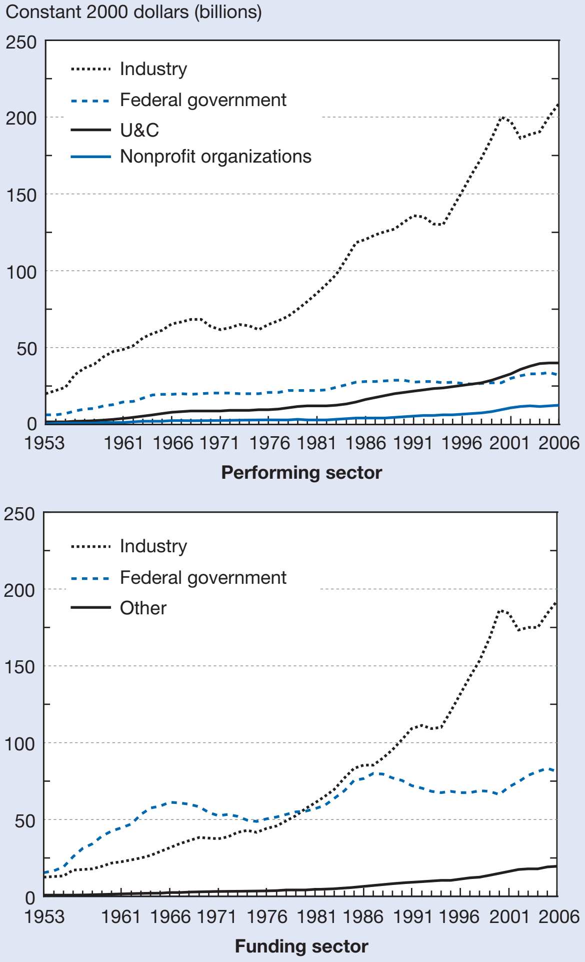
Figure O-30

National R&D, by performing and funding sectors, 1953–2006



U&C = universities and colleges; Other = U&C, nonprofit, and state and local government

NOTE: Federal performers of R&D includes federal agencies and federally funded research and development centers.

SOURCE: National Science Foundation, Division of Science Resources Statistics, National Patterns of R&D Resources (annual series). See appendix tables 4-4 and 4-6.

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increased steadily to a projected 60% in 2008. Nondefense R&D is dominated by health support (52% of the proposed FY 2008 nondefense R&D budget) (figure O-32). Health R&D has accounted for the single largest share of federal nondefense R&D since at least 1980, when its share was 25%.

U.S. R&D performance is dominated by the development function (figure O-33), which has fluctuated between 58% and 65% since 1970. Development of new and improved goods, services, and processes is dominated by industry, which funded 83% and performed 90% of all U.S. development in 2006. The federal government funded most of the remaining development performed in the United States, mostly in defense-related activities.

Basic research provides the essential underpinning for a vibrant and flexible S&T system. In the United States, well over half (58%) of all basic research is conducted at universities and colleges. Two-thirds of the funding is supplied by the federal government, but the academic institutions themselves provided 17% in 2007, the second-largest share. An additional 5% to 6% each is provided by industry and state and local governments. A key product of academic basic research, in addition to new knowledge, is the production of young researchers through the strong ties of graduate training and research.

Table O-7

R&D and domestic net sales, by selected business sector: 2004 and 2005

(Millions of current dollars)

Sector	All R&D		Federal R&D		Company R&D		Domestic net sales		All R&D/sales ratio (%)	
	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005
All industries	208,301	226,159	20,266	21,909	188,035	204,250	5,601,729	6,119,133	3.7	3.7
Highlighted sectors	163,102 L	174,970 L	19,122 L	20,867 L	143,980	154,102	2,205,651	2,268,642	7.4	7.7
Computer and electronic products[a]	40,964	43,520 L	273	1,057 L	40,691	42,463	506,103	472,330	8.1	9.2
Chemicals	39,224 L	42,995	154 L	169	39,070	42,826	595,292	624,344	6.6	6.9
Computer-related services[b]	28,117 L	30,518	410 L	578	27,707	29,939	166,545	213,574	16.9	14.3
Aerospace and defense manufacturing[c]	23,567 L	24,926 L	14,343 L	13,998 L	9,224	10,928	228,018	227,271	10.3	11.0
R&D services[d]	15,620	16,986	3,942	5,065	11,678	11,921	66,614	84,637	23.4	20.1
Automotive manufacturing[e]	15,610 L	16,025	NA	NA	15,610	16,025	643,079	646,486	2.4	2.5
All other industries	45,199 L	51,189 L	1,144 L	1,042 L	44,055	50,148	3,396,078	3,850,491	1.3	1.3

L = lower-bound estimate; NA = not available

[a] Includes all nonfederal R&D and domestic net sales for the navigational, measuring, electromedical, and control instruments industry. All federal R&D for navigational, measuring, electromedical, and control instruments industry included in aerospace and defense manufacturing sector.

[b] Includes R&D and domestic net sales for software and computer systems development industries.

[c] Includes all R&D for aerospace products and parts, plus all federal R&D for navigational, measuring, electromedical, and control instruments and automotive and other transportation manufacturing industries. Domestic net sales not included for automotive and other transportation manufacturing industries.

[d] Includes R&D and domestic net sales for architectural, engineering, and related services and scientific R&D services industries.

[e] Federal R&D for all transportation manufacturing industries (including automotive manufacturing) included in aerospace and defense manufacturing sector.

NOTE: Potential disclosure of individual company operations only allows lower-bound estimates for some sectors.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Industrial Research and Development.

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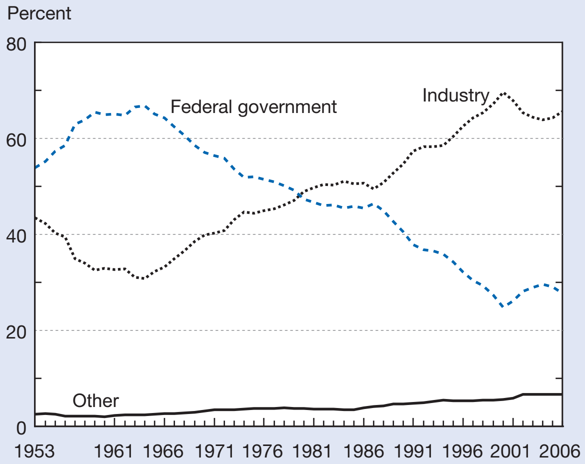
Figure O-31

National R&D expenditures, by funding sector: 1953–2006



SOURCE: National Science Foundation, Division of Science Resources Statistics, National Patterns of R&D Resources (annual series). See appendix table 4-5.

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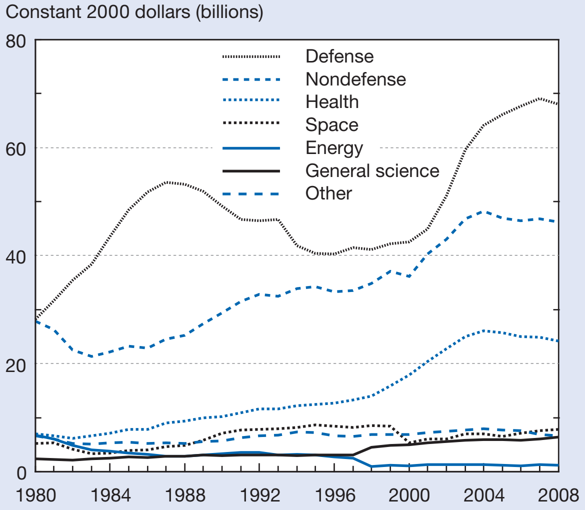
Knowledge and the S&E Workforce

The progressive shift toward more knowledge-intensive economies around the world is dependent upon the availability and continued inflow of individuals with postsecondary training to the workforce. The expansion of higher education systems in many countries that started in the 1970s and continues today has enabled this shift to occur. Such broadening of higher education availability and access in many cases entailed greater relative emphasis than in the United States on education and training in engineering, natural sciences, and mathematics.

Demographic structures, stable or shrinking populations, expanding opportunities in other fields, and declining interest in mathematics and science among the young are viewed by governments of many mature industrial countries as a potential threat to the sustained competitiveness of their economies. The topic has assumed increasing urgency in meetings of ministers of OECD member countries.

Figure O-32
Federal R&D budget authority, by budget function: FY 1980–2008



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 2006–08 (forthcoming). See appendix table 4-26.

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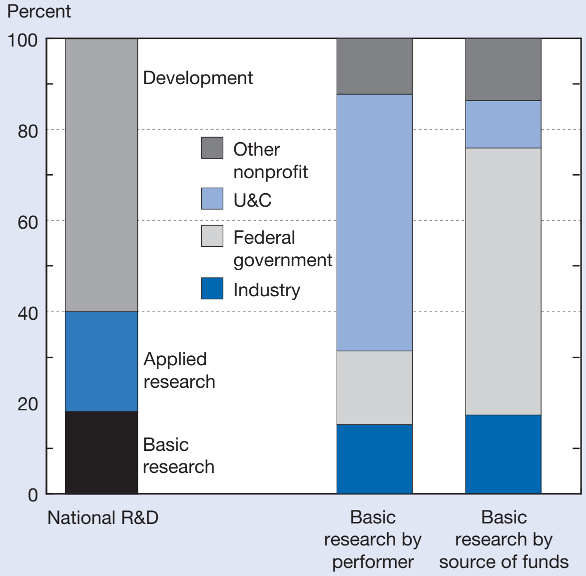
Figure O-33
National R&D expenditures, by character of work, and basic research, by performer and source of funds: 2006



U&C = universities and colleges

NOTES: Figures rounded to nearest whole number. National R&D expenditures projected at $347 billion in 2006. Federal performers include federal agencies and federally funded research and development centers.

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.

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Growing educational and technical sophistication mark international workforces and reduce traditional U.S. advantage.

Reliable, internationally comparable data on S&E labor force growth are unavailable. However, the number of individuals 15 years and older with a tertiary education, broadly comparable to at least a U.S. technical school or associate's degree, can serve as a proxy measure for the expansion of highly educated populations. A two-decade snapshot shows very rapid growth in overall numbers and considerable shifts in the geographical location of these individuals (figure O-34).

From 1980 to 2000 (the latest available estimate), the number of individuals with a tertiary education rose from 73 million to 194 million, a 165% increase. The U.S. share of these degree holders declined from 31% to 27%.

Japan's shrinking share of the tertiary educated (from 10% to just above 6%) notwithstanding, the combined total of five other Asian nations, China, India, South Korea, the Philippines, and Thailand, rose from 14% in 1980 to 34% in 2000, an increase from 10 million to 66 million. The 56 million people added by these countries alone broadly match the entire 2000 U.S. total.

Worldwide, researcher numbers are rising robustly.

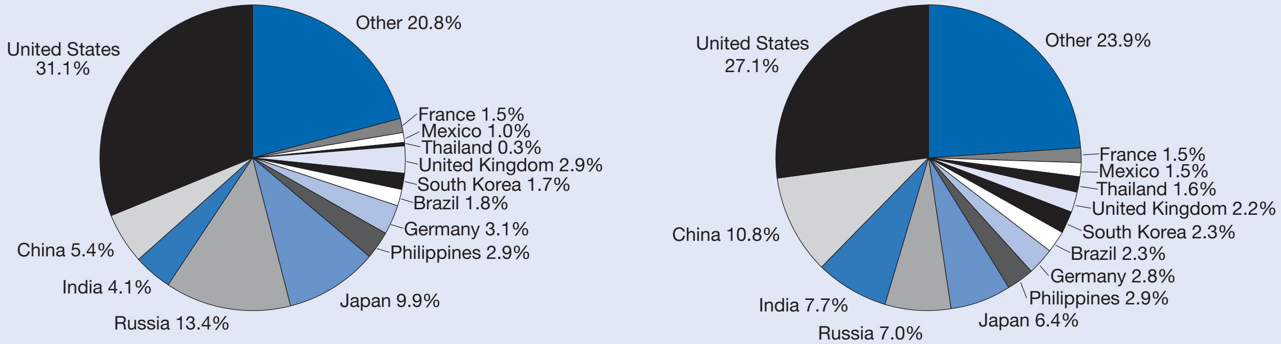
The size of the research workforce is another indicator of the economic importance of efforts to develop new knowledge and innovative products and processes. As is the case with S&E workforce numbers, reliable, internationally comparable data about individuals actively engaged in R&D are unavailable for much of the world. However, OECD captures such figures for its member countries and selected other economies. For all these combined, the data show robust 50% growth from 1995 to 2005 (figure O-35).

This overall growth was uneven, with the number of researchers doubling in selected non-OECD economies including China,[7] slower growth in the United States (35%) and the EU (29%), stagnation in Japan (5%), and faster-than-average growth in the other OECD member countries (60%). The overall trend is toward an increase in personnel dedicated to R&D functions in the world's economies. According to OECD, a strong countervailing trend persists in the Russian Federation, where the number of researchers dropped from 610,000 in 1995 to 465,000 in 2005.

In the United States, S&E occupations have long grown faster than others.

Long-term data on the U.S. workforce show a trend toward increasing numbers of workers in S&T-related occupations (figure O-36). Although different data sources yield somewhat different estimates of the size of the S&E labor force, there is no doubt that overall growth has been large

Figure O-34
Population 15 years old or older with tertiary education, by country/region: 1980 and 2000



1980 (73 million) **2000 (194 million)**

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

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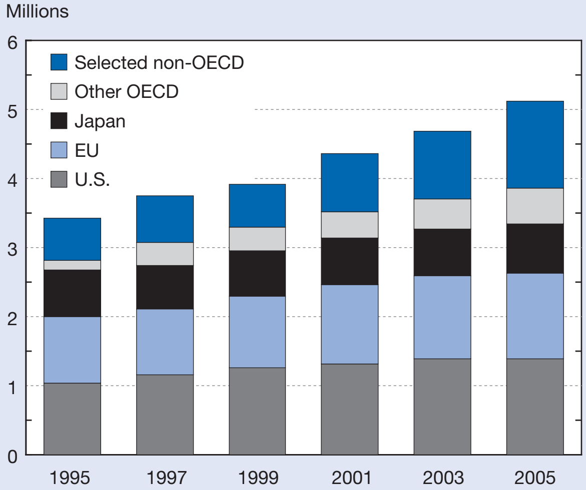
Figure O-35
Researchers in OECD and selected non-OECD locations: 1995–2005



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

NOTES: Selected non-OECD includes China, Romania, Singapore, Slovenia, and Taiwan. 1996 data for Taiwan substituted for 1995. EU data for 1999 and beyond reflect enlarged EU-25 membership.

SOURCE: OECD, Main Science and Technology Indicators (2007) and various earlier volumes.

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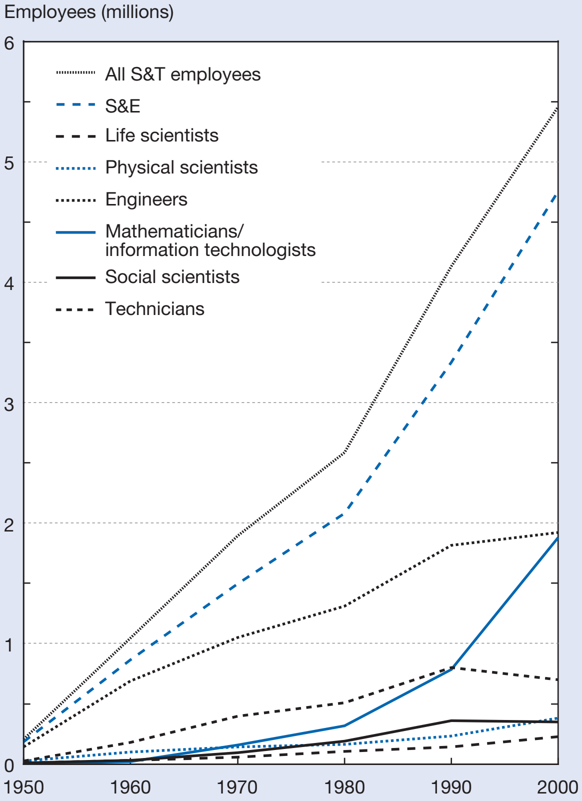
Figure O-36
Science and technology employment: 1950–2000



S&T = science and technology

NOTE: Data include 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: Adapted from Lowell BL, Regets MC, A Half-Century Snapshot of the STEM Workforce, 1950 to 2000, Commission on Professionals in Science and Technology (2006).

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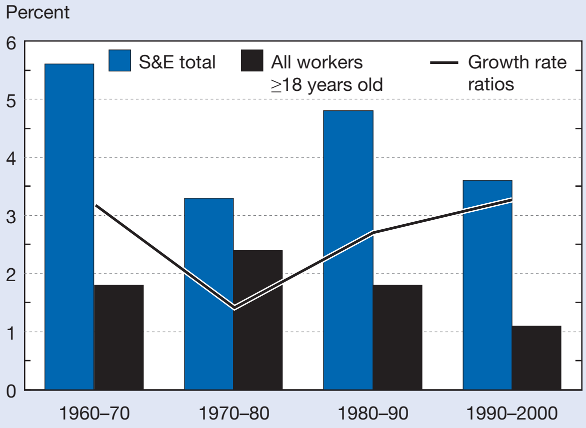
and steady for more than a half century. During this period, growth patterns within individual occupations have varied. In the 1990s, for example, widespread computerization was accompanied by a sharp rise in the numbers of people working as mathematicians and information technologists, while the number of workers classified as engineers or technicians changed relatively little.

For decades, the workforce growth rates in S&E occupations have exceeded those in the general labor force (figure

O-37); consequently, the proportion of the workforce in S&E occupations has risen by 60% since the early 1980s. Nonetheless, S&E employees still represent a small fraction of the total U.S. workforce: the Census Bureau's Current Population Survey estimates that jobs in S&E occupations increased from 2.6% in 1983 to 4.2% in 2006 (figure O-38).

Individuals in S&E occupations are distributed throughout the economy (figure O-39). Economic sectors with large proportions of workers in S&E occupations tend to have higher average salaries for both S&E workers and those in other occupations (table O-8). The association between sectors with relatively large amounts of S&T-related work and sectors that enable many workers to enjoy middle-class incomes has fueled government efforts to encourage development of industries in which S&E work is important.

Figure O-37
Average annual growth rates of S&E occupations versus all workers: 1960–2000



SOURCE: National Science Foundation, Division of Science of Science Resources Statistics, Decennial Census data, special tabulations.

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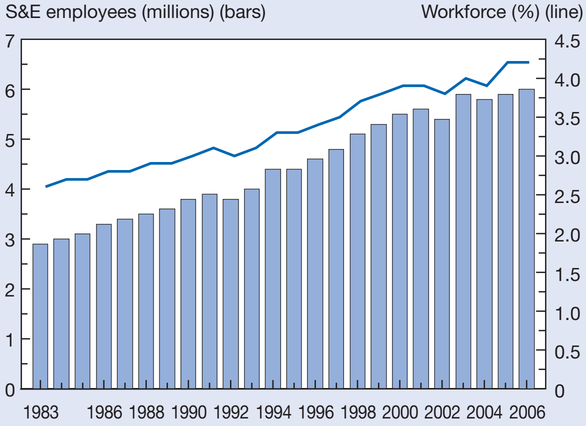
Figure O-38
U.S. workforce in S&E occupations: 1983–2006



SOURCE: National Science Foundation, Division of Science Resources Statistics, special tabulations from Bureau of Labor Statistics, Current Population Survey Monthly Outgoing Rotation files (1983–2006).

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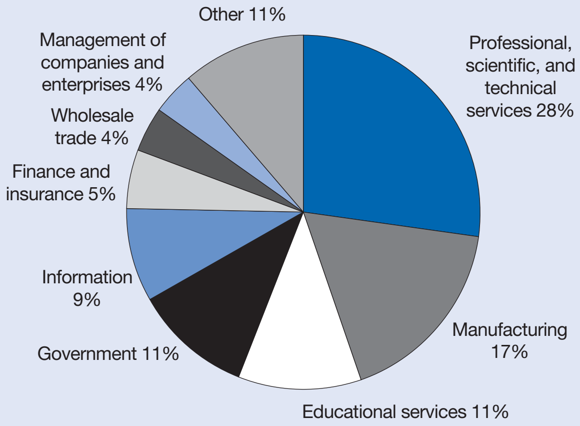
Successive cohorts entering the U.S. workforce have higher proportions in S&E occupations.

As productive uses of knowledge become more central to economic activity, larger percentages of young workers find jobs in S&E occupations. Census data show how this movement toward a more knowledge-intensive economy is reflected in the changing profile of the workforce (Figure O-40). Since 1950, workers in S&E occupations have been found disproportionately in the younger cohorts of the prime working-age population (ages 25–64). Among workers 25–34 years old, the proportion of S&E workers increased from 1.7% in 1950 to 5.2% in 2000. Similar increases occurred in the other prime working-age groups, with the proportion of workers in S&E occupations approximately tripling in each group between 1950 and 2000 (figure O-40).

Over a lifetime, workers move both into and out of S&E jobs. Those moving into S&E jobs may have acquired the necessary skills through workforce experience or adult education to respond to the growing demand for S&E workers; those moving out of these jobs may acquire managerial roles, change occupations, or fail to maintain or acquire S&E-related skills that are in demand. For each generation of workers, the numbers in S&E occupations increase until some time in midlife and then decrease as workers near or reach retirement. In the generations born before or during World War II, the proportion of workers who were in S&E occupations at different ages did not follow a consistent pattern. For example, for those born between 1936 and 1945,

Figure O-39
Largest sectors of employment for individuals in S&E occupations, by NAICS sector: May 2005



NAICS = North American Industry Classification System

SOURCE: Bureau of Labor Statistics, Occupational Employment Statistics Survey (2005).

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Table O-8
Employment distribution and average earnings of 4-digit NAICS industry classifications, by proportion of employment in S&E occupations: 2005

Workers in S&E occupations (%)	All occupations	All S&E occupations	Average worker salary ($) Non-S&E occupations	S&E occupations
>40	1,987,910	918,400	66,980	74,335
20–40	3,384,810	952,320	51,350	75,195
10–20	9,951,540	1,444,490	51,588	69,819
4–10	13,728,020	880,540	44,260	64,578
<4	99,480,140	988,950	33,489	59,713

NAICS = North American Industry Classification System

NOTE: NAICS is a hierarchical structure that uses 2–4 digits; 4-digit NAICS industries are subsets of 3-digit industries, which are subsets of 2-digit sectors.

SOURCE: Bureau of Labor Statistics, Occupational Employment Statistics Survey (May 2004 and May 2005).

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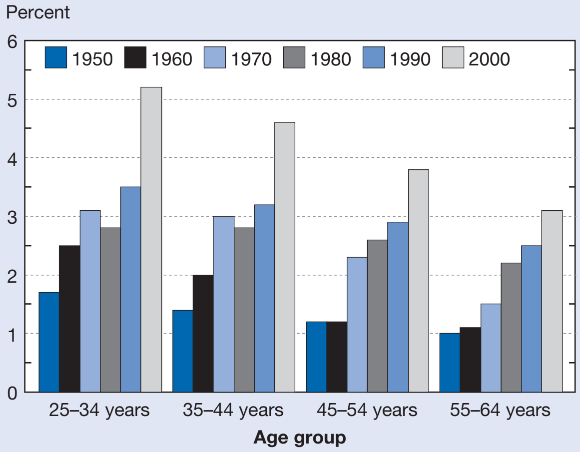
Figure O-40
Workers in S&E occupations, by age group: 1950–2000



SOURCE: Census Bureau, decennial census, various years.

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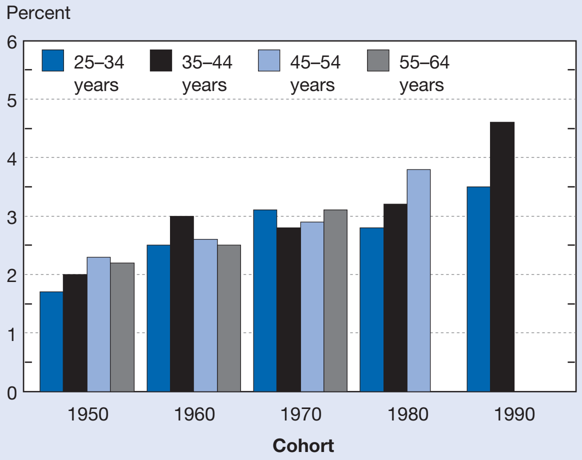
the proportion was almost constant for four decades, a pattern shown by no other generation.

With accelerating movement toward a knowledge-intensive economy, however, younger generations appear to experience a net movement into S&E occupations over the course of their working lives. Beginning with the "baby boom" generation of workers born after World War II (1946–55), the proportion in S&E occupations increased substantially with time. Thus, 2.8% of baby boomers were in S&E occupations in 1980, rising to 3.8% in 2000; for workers born in the next decade, the proportion increased from 3.5% in 1990 to 4.6% in 2000 (figure O-41). Immigrant S&E workers partly account for the increasing proportion of S&E workers over time in this cohort, but the number increases among the native-born as well.

Figure O-41
S&E workers by cohort and age group



NOTES: Cohort is group of workers who were 25–34 years old in same decennial census year. 1950 cohort, for example, was 25–34 years old at 1950 census. Each group of bars presents data for a different cohort, using data from successive decennial censuses to show proportion of cohort in S&E workforce at different ages.

SOURCE: Census Bureau, decennial census, various years.

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A knowledge-intensive economy requires skills of S&E-trained persons in a wide range of sectors and positions.

The relevance of S&E knowledge goes beyond narrowly defined S&E occupations. Although most people with S&E degrees do not work in S&E occupations, a large majority of degree holders say that they need at least a bachelor's degree-level knowledge of S&E in their jobs (figure O-42).

Most S&E degree holders work in for-profit companies. In 2003, about three of five individuals whose highest degree was in S&E worked in this sector. Education (16%) and government (13%) were the next largest employers of workers with S&E degrees. Among those with S&E doctoral degrees, the higher education sector is the largest employer (44%), but the for-profit sector share is also large (33%) (figure O-43). These data suggest that many for-profit companies find S&T-related skills, including the advanced skills associated with doctoral education, useful for competing in the private economy.

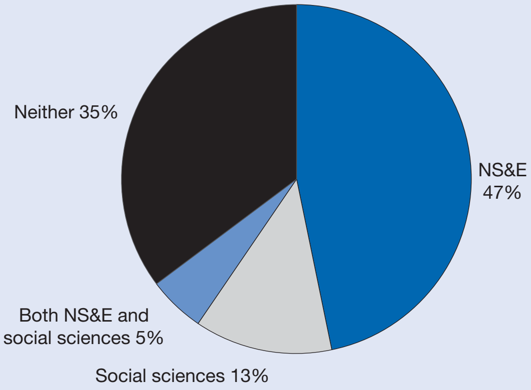
Almost 40% of R&D workers are found in non-S&E occupations.

Workers with S&E degrees for whom R&D is a significant work activity have backgrounds in a variety of S&E fields, suggesting that R&D skills relevant to a knowledge-intensive economy can develop through multiple paths. Substantially more of these R&D workers are trained in engineering than in any other field. A sizeable proportion of S&E-trained workers for whom R&D is a major work activity are not in S&E occupations (39%), and many of them (26%) are not in S&E-related occupations. For workers who devote at least 10% of their work time to R&D, the comparable proportions (55% and 40%) are even higher (figure O-44).

Higher Education

As knowledge becomes more central to economic activity in both developed and developing economies, large segments of the population complete some form of higher education. Government programs designed to advance the development of a knowledge-intensive economy bolster private incentives to obtain knowledge and skills that may lead to better, higher-paying jobs. Lifelong learning, including acquisition of additional formal education, becomes both more possible and more necessary even for people with significant workforce experience.

Figure O-42
Bachelor's degree-level S&E knowledge needed by individuals in workforce with highest degree in S&E: 2003



NS&E = natural sciences and engineering

SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), 2003, http://sestat.nsf.gov.

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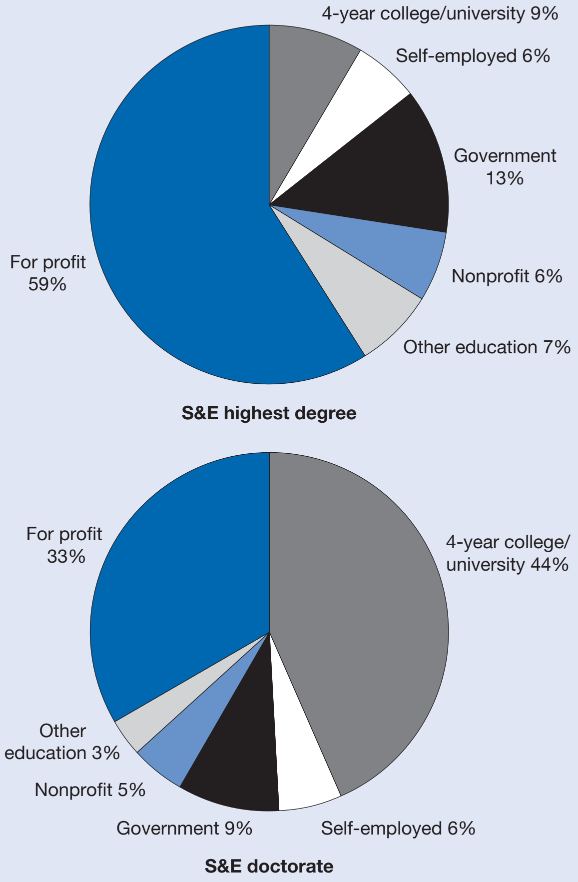
Educational credentials are only an approximate indicator of useful labor force skills. They do not register quality differences, skills acquired through job experiences or informal learning, or skills decay brought on by the progress of knowledge and economic change. In addition, workers may take advantage of publicly supported educational opportunities to gain labor market advantages, but may not use the additional skills at work, while employers may hire readily available workers without using their most advanced skills.

Human capital development responds to incentives of the knowledge-intensive economy.

In international comparison, the United States has a larger proportion of the working-age population with a higher education degree (39%) than most other countries (figure O-45). Only the Russian Federation (55%), Israel (45%), and Canada (45%) have higher percentages for this indicator.

Figure O-43
Employment sector for individuals with highest degree in S&E and S&E doctorate holders: 2003



SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), 2003, http://sestat.nsf.gov.

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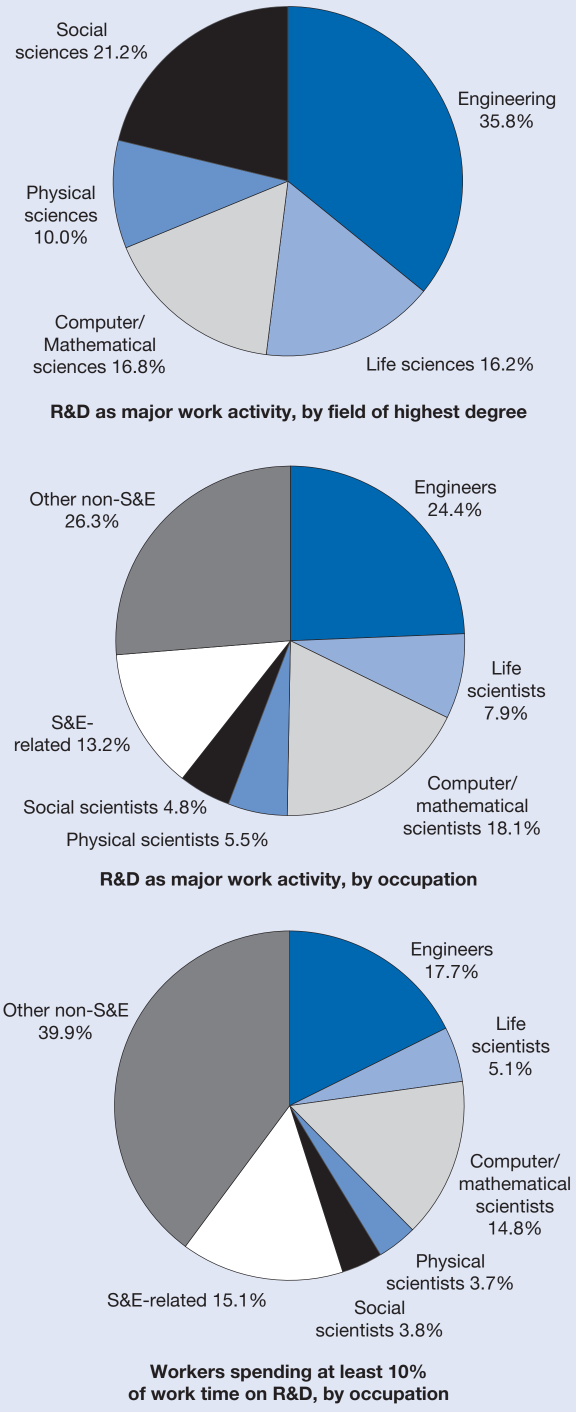
Figure O-44

Distribution of S&E degree holders with R&D as major or significant work activity, by field of highest degree and occupation: 2003



SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), 2003, http://sestat.nsf.gov.

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Figure O-45

Total tertiary degree attainment by 25–64-year-olds, by country: 2004

OECD = Organisation for Economic Co-operation and Development

NOTES: Tertiary education includes International Standard Classification of Education (ISCED) levels 5A, 5B, and 6 programs. ISCED 5A programs largely theory-based and designed to provide sufficient qualifications for entry into advanced research programs and professions with high skill requirements. ISCED 5B programs focus on practical, technical, or occupational skills for direct entry into labor market. ISCED 6 programs devoted to advanced studies and original research leading to award of an advanced research qualification. In United States, ISCED 5B corresponds to associate's, ISCED 5A corresponds to bachelor's and master's, and ISCED 6 corresponds to doctoral degrees.

SOURCE: OECD, Education at a Glance: OECD Indicators 2006.

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More recent age cohorts obtain higher postsecondary degree rates than earlier ones.

In almost all countries, higher education is more common in the younger cohorts entering the workforce than in older cohorts, mirroring the trend toward knowledge-intensive economies. For OECD member countries, the average difference between the youngest cohort with generally completed formal schooling and the working-age population as a whole is about 6 percentage points; in several nations the difference is more than 10 percentage points. Differences are especially large for South Korea and Japan, the two Asian OECD members, but some European countries (France, Ireland, Spain, and Belgium) also recorded substantial differences.

The United States and Germany are exceptions to the overall OECD pattern: in these two countries there is no substantial difference between the 25–34-year-olds and the working-age population as a whole. These age patterns in educational attainment suggest that, in the future, other developed countries will more closely resemble the United States in the availability of workers with postsecondary credentials (figure O-46).

Substantial advanced training prepares the U.S. workforce for high-skill work.

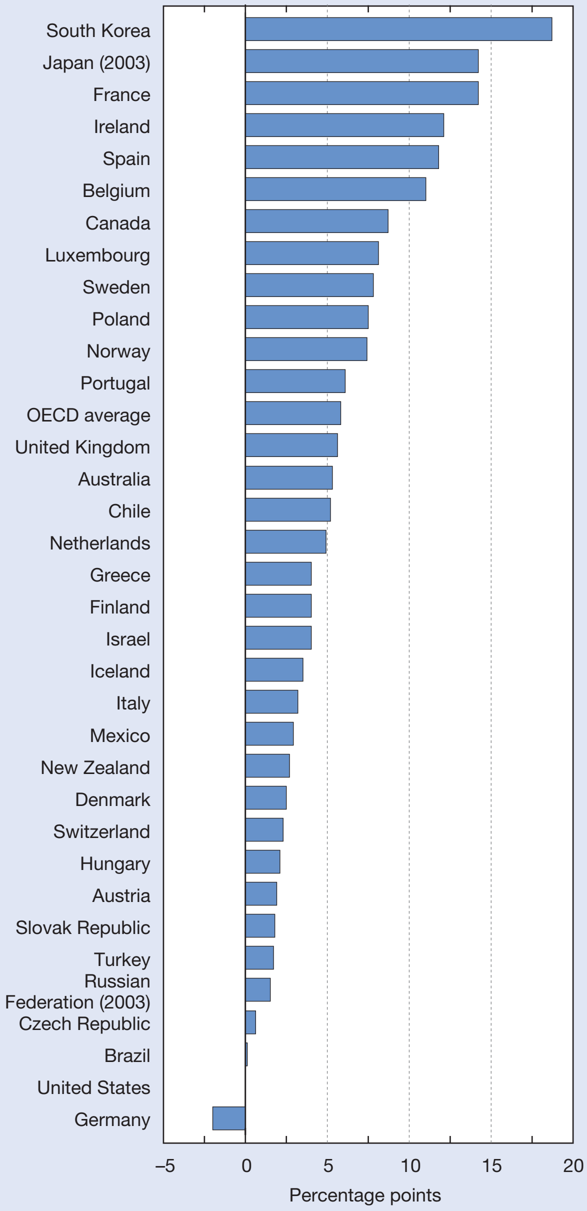
The proportion of 25–64-year-olds with advanced[8] education, as evidenced by a bachelor's degree or beyond, is an indicator of the workforce that is equipped to develop and apply knowledge in innovative ways. In the United States, a substantially higher proportion than in other large, developed economies has completed such a course of study, although a few smaller countries have proportions that match or nearly match the U.S. percentage (figure O-47). Such additional training can prepare students for high-skill work and more advanced training in research.

Throughout the developed world, the proportion of the population in the youngest working cohort with education at or beyond the bachelor's level is higher than for the working-age population as a whole. Again, however, this difference is smaller in the United States and Germany than in any of the other countries for which data are available. As younger cohorts of workers enter the labor forces in the future, the U.S. lead on this indicator can be expected to shrink. Nonetheless, the United States ranks behind only a few small countries—Norway, Israel, the Netherlands, and South Korea—in the proportion of the cohort that is entering the labor force that receives this kind of education (figure O-48).

Advanced training in natural sciences and engineering is becoming widespread, eroding the U.S. advantage.

The number of first university degrees a nation awards in natural sciences and engineering (NS&E) is a workforce indicator that is more specifically focused on a nation's capacity to innovate in S&T. Because of its population size, the United States has seen much larger numerical increases in first university NS&E degrees than other countries. China

Figure O-46
Difference in total tertiary degree attainment between 25–34-year-olds and 25–64-year-olds, by country: 2004



OECD = Organisation for Economic Co-operation and Development

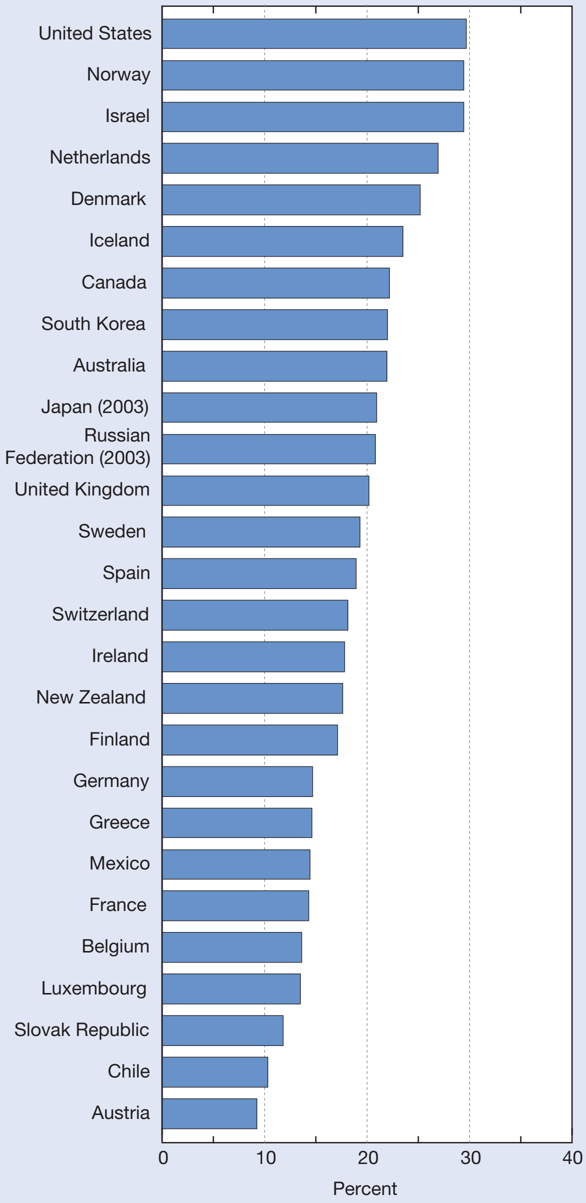
NOTES: Tertiary education includes International Standard Classification of Education (ISCED) levels 5A, 5B, and 6 programs. ISCED 5A programs largely theory-based and designed to provide sufficient qualifications for entry into advanced research programs and professions with high skill requirements. ISCED 5B programs focus on practical, technical, or occupational skills for direct entry into labor market. ISCED 6 programs devoted to advanced studies and original research leading to award of an advanced research qualification. In United States, ISCED 5B corresponds to associate's, ISCED 5A corresponds to bachelor's and master's, and ISCED 6 corresponds to doctoral degrees.

SOURCE: OECD, Education at a Glance: OECD Indicators 2006.

Science and Engineering Indicators 2008

Figure O-47

Attainment of tertiary-type A and advanced research degrees by 25–64-year-olds, by country: 2004



NOTES: Tertiary-type A programs (International Standard Classification of Education [ISCED] 5A) largely theory-based and designed to provide sufficient qualifications for entry to advanced research programs and professions with high skill requirements such as medicine, dentistry, or architecture and have a minimum duration of 3 years' full-time equivalent, although typically last 4 years. In United States, correspond to bachelor's and master's degrees. Advanced research programs are tertiary programs leading directly to award of an advanced research qualification, e.g., doctorate.

SOURCE: Organisation for Economic Co-operation and Development (OECD), Education at a Glance: OECD Indicators 2006 (2006).

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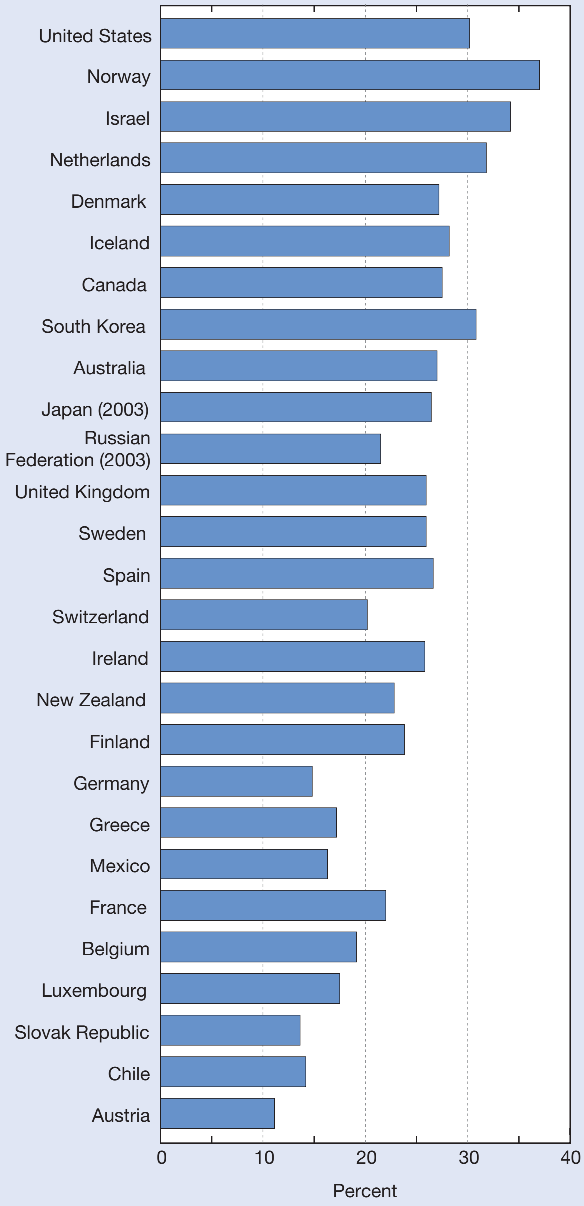
Figure O-48

Attainment of tertiary-type A and advanced research degrees by 25–34-year-olds, by country: 2004

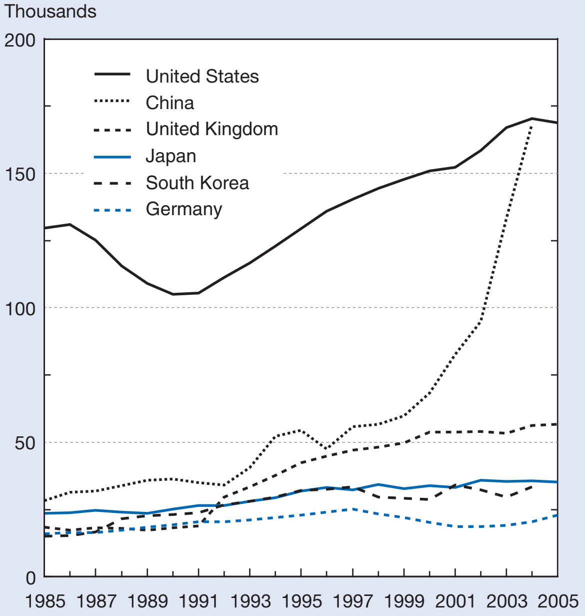


NOTES: Tertiary-type A programs (International Standard Classification of Education [ISCED] 5A) largely theory-based and designed to provide sufficient qualifications for entry to advanced research programs and professions with high skill requirements such as medicine, dentistry, or architecture and have a minimum duration of 3 years' full-time equivalent, although typically last 4 years. In United States, correspond to bachelor's and master's degrees. Advanced research programs are tertiary programs leading directly to award of an advanced research qualification, e.g., doctorate.

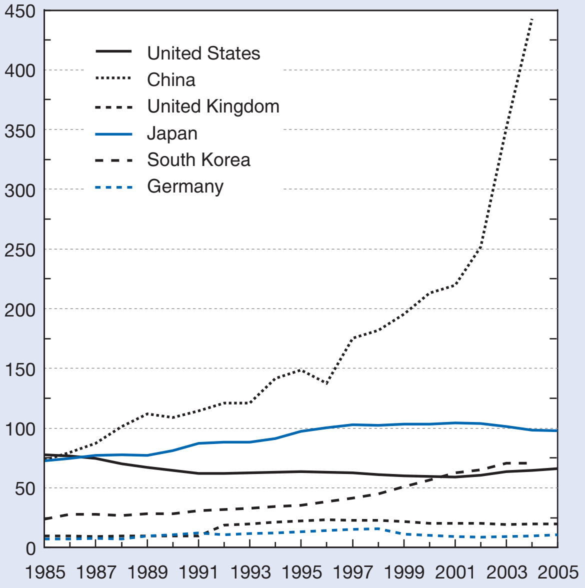
SOURCE: Organisation for Economic Co-operation and Development (OECD), Education at a Glance: OECD Indicators 2006 (2006).

Science and Engineering Indicators 2008

Figure O-49
First university natural sciences and engineering degrees, by selected country: 1985–2005



Natural Sciences



Engineering

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, Ministry of Education, Culture, Sports, Science and Technology, Higher Education Bureau, Monbusho Survey of Education; South Korea—Organisation for Economic Co-operation and Development, Education Online Database, http://www.oecd.org/education/database; United Kingdom—Higher Education Statistics Agency; Germany—Federal Statistical Office, Prüfungen an Hochschulen; and United States—National Science Foundation, Division of Science Resources Statistics, WebCASPAR database, http://webcaspar.nsf.gov. See appendix table 2-38.

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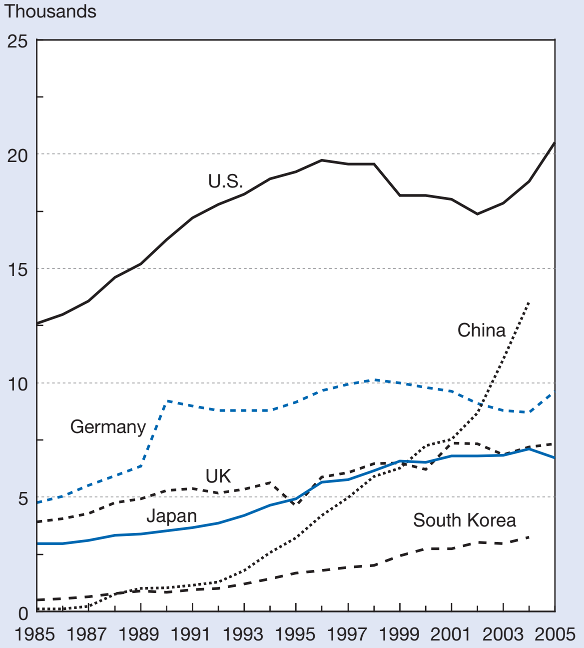
is an exception. It has experienced a huge recent increase in NS&E degree recipients, although there are questions about the quality of some of its graduates. The rising number of Chinese-trained engineers is similarly striking, especially in contrast with declining numbers of U.S. engineering graduates (Figure O-49).

Many countries have also increased the numbers of individuals they train in NS&E at the doctoral level over the past 20 years (Figure O-50). Most of the U.S. growth occurred during the first half of this period, when the number of doctorates awarded by U.S. institutions increased steadily; although the number peaked in 2005, this was the first year in which it exceeded the 1997 total. However, virtually all of the recent U.S. growth reflected rising proportions of degrees to non-U.S. citizens: more than half in engineering and computer science and nearly 45% in the physical sciences. In contrast, China's growth was most marked after 1993 and its growth rates after 2000 were especially high. Over the course of the entire period, China surpassed numerous other

Figure O-50
Natural sciences and engineering doctoral degrees, by selected country: 1985–2005



UK = United Kingdom

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, Ministry of Education, Culture, Sports, Science and Technology, Higher Education Bureau, Monbusho Survey of Education; South Korea—Organisation for Economic Co-operation and Development, Education Online database, http://www.oecd.org/education/database/; United Kingdom—Higher Education Statistics Agency; and Germany—Federal Statistical Office, Prüfungen an Hochschulen. See appendix tables 2-42 and 2-43.

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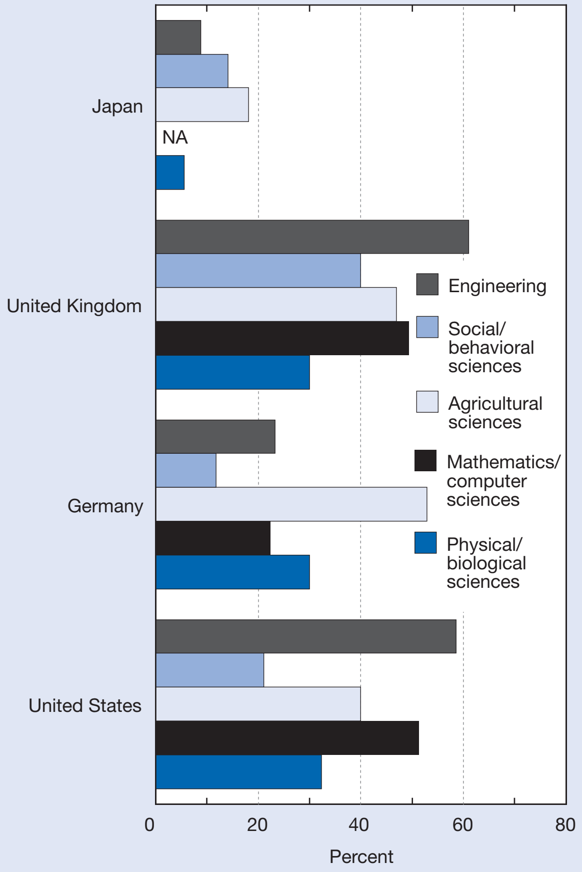
Figure O-51
S&E doctoral degrees earned by foreign students, by selected industrialized country and field: 2005 or most recent year



NA = not available

NOTES: Physical sciences include earth, atmospheric, and ocean sciences. Japanese data for university-based doctorates only; exclude *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 2005; Japan—Government of Japan, Ministry of Education, Culture, Sports, Science and Technology, special tabulations; United Kingdom—Higher Education Statistics Agency, special tabulations (2007); United States—National Science Foundation, Division of Science Resources Statistics, Survey of Earned Doctorates, WebCASPAR database, http://webcaspar.nsf.gov. See appendix table 2-49.

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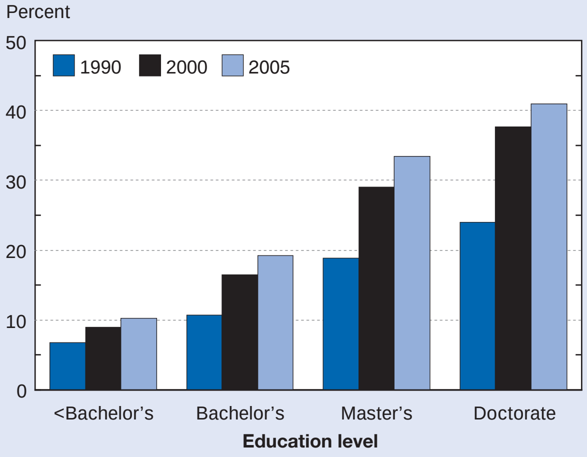
countries in doctorate production, and the U.S.-China difference is narrowing.

High-skilled knowledge workers are increasingly internationally mobile, and many come to the United States for training or work.

Knowledge workers are increasingly mobile across national boundaries, especially at the doctoral level. As is the case in the United States, in highly developed countries many S&E doctoral degrees are awarded to foreign students, often from the developing world (Figure O-51). Experienced in adapting to life in a different culture and equipped with flexible skills, these workers are well positioned to compete in a global market for knowledge workers.

Figure O-52
Foreign-born individuals in U.S. S&E workforce, by degree level: 1990, 2000, and 2005



SOURCES: Census Bureau, decennial census, various years; and American Community Survey (2005).

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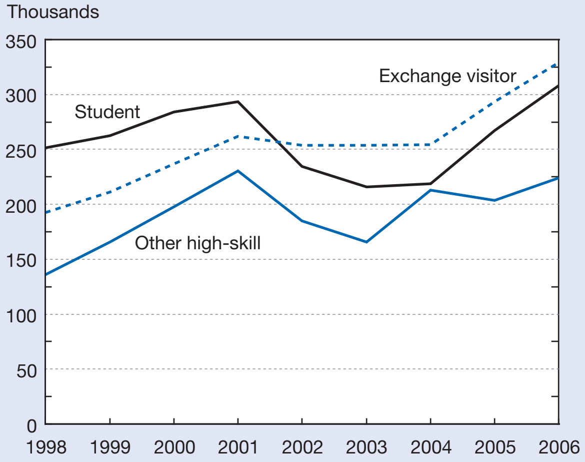
In the United States, increasing proportions of S&E workers are foreign born and/or foreign educated, a fact that has been interpreted from a variety of perspectives. Some observers stress strengths of the U.S. economy that pull in foreign workers, including the attractiveness of living in the United States and the favorable opportunities for high incomes and career advancement in the S&E workforce. Other observers express concern about the inability of U.S. society to prepare and interest young Americans in the S&E jobs that the economy makes available (see section on U.S. K–12 education).

According to census data, the number of foreign-born workers in the U.S. S&E workforce more than quadrupled between 1980 and 2000, with most of the increase taking place in the 1990s. As a result, the percentage of foreign-born workers in the U.S. S&E workforce increased from nearly 10% in 1980 to 12% in 1990 and 18% in 2000.

Increases occurred among S&E workers at all educational levels but were especially pronounced among the more highly educated (figure O-52). Thus, the proportion of foreign-born doctorate-level workers rose from 24% in 1990 to 38% in 2000, and the corresponding figures for master's-level workers were 19% and 29%. Census data for 2005 shown in figure O-52, although not fully comparable to the earlier data, suggest that the percentage of foreign-born workers is continuing to increase. In addition, a growing proportion of S&E doctoral faculty, who are not included in the census data counts, are also foreign born. Their proportion increased from 21% in 1992 to 28% in 2003.

Figure O-53
Student, exchange, and other high-skill-related U.S. temporary visas issued: 1998–2006



NOTE: Student = F-1; exchange visitor = J-1; other high-skill-related visas = L-1, H-1B, H-3, O-1, O-2, and TN.

SOURCE: Immigrant Visa Control and Reporting Division administrative data, special tabulations.

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High-skill-related visa issuances have increased to, or beyond, their pre-9/11 record.

The 2001 terrorist attacks, subsequent government responses, and reactions abroad combined to depress previously rising visa issuances for foreign students, exchange visitors, and other high-skill-related visa categories (figure O-53). Student visas in particular dropped by 25% in the immediately succeeding years, a decline that prompted concern about the long-term impact on the United States' ability to attract the best foreign talent.

The latest data show an upswing in high-skill-related visas issued, starting in 2004 and carrying into 2006, with record numbers of temporary high-skill-related visas issued. The number of student and exchange-visitor visas issued in 2006 was higher than ever before, and the sum of the other high-skill-related visa categories was near the 2001 high, suggesting a continuing attractiveness of the United States to those with advanced education.

U.S. K–12 Education

Concern about the relationship of science and mathematics achievement to American global competitiveness, workforce preparation, and development of an educated citizenry has drawn intensive public scrutiny to the achievement levels of American students in mathematics and science in recent years.

Mathematics and science performance of U.S. students: both disappointing and encouraging.

The current performance of U.S. elementary and secondary students in mathematics and science is both disappointing and encouraging. A national study that followed the same student cohort found that students from different demographic groups entered kindergarten with varied mathematics knowledge and skills, that all groups made gains during elementary school, and that gains were uneven. Thus most mathematics achievement gaps remained or had grown by the time students reached grade 5 (table O-9 and appendix table 1-2). A second national cohort study that assessed mathematics knowledge in both grades 10 and 12 mirrored the findings of the previous study.

Repeated cross-sectional studies of mathematics and science performance provide information about trends in the performance of different student cohorts. In 2005, students

Table O-9
Average mathematics scores of students from beginning kindergarten to grade 5, by race/ethnicity: 1998, 2000, 2002, and 2004

Race/ethnicity	Fall 1998 kindergarten	Spring 2000 grade 1	Spring 2002 grade 3	Spring 2004 grade 5	Gain from kindergarten to grade 5
All students	22	39	91	112	89
White, non-Hispanic	25	43	97	118	93
Black, non-Hispanic	19	33	79	99	80
Hispanic	19	36	85	108	89
Asian	25	39	94	118	93
Other[a]	20	38	86	107	86

[a] Includes non-Hispanic Native Hawaiians, Pacific Islanders, American Indians, Alaska Natives, and children of more than one race.

NOTES: Early Childhood Longitudinal Survey (ECLS) mathematics scale ranged from 0 to 153. In 2004 followup for ECLS kindergarten class of fall 1998, 86% of cohort was in grade 5, 14% was in a lower grade, and <1% was in a higher grade. For simplicity, students in ECLS followups referred to by modal and expected grade, i.e., first graders in spring 2000 assessment, third graders in spring 2002 assessment, and fifth graders in spring 2004 assessment.

SOURCES: National Center for Education Statistics, ECLS, fall 1998 and spring 2000, 2002, and 2004; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

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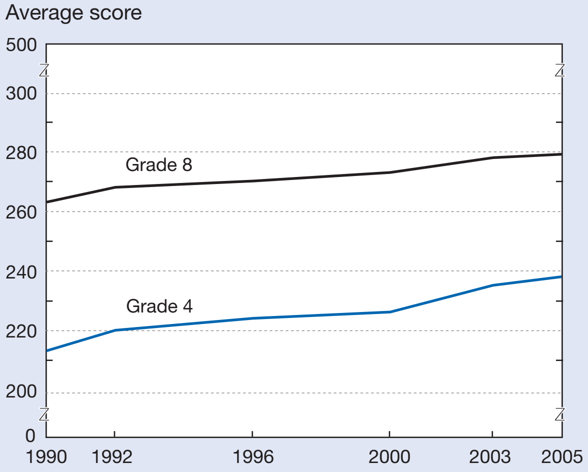
Figure O-54
Average mathematics score of students in grades 4 and 8: Selected years, 1990–2005



NOTE: Scores on 0–500 scale across grades 4 and 8. 2005 grade 12 mathematics assessment not comparable with previous assessments; therefore mathematics trend information for grade 12 not available.

SOURCES: National Center for Education Statistics (NCES), The Nation's Report Card: Mathematics 2005, NCES 2006-453 (2006); and National Assessment of Educational Progress, 1990, 1996, 2003, and 2005 mathematics assessments. See appendix table 1-5.

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in grades 4 and 8 posted higher mathematics scores than students in those same grades in 1990 (figure O-54). This trend was evident for both males and females, across racial/ethnic and income groups, and for students in different performance ranges (table O-10). In science, average scores increased for fourth grade students, largely reflecting improvements among lower- and middle-performing students; held steady for eighth graders; but declined for 12th graders between 1996 (the first year the assessments were given) and 2005 (table O-11). The latest (2007) assessment results for mathematics and science show continuing improvement for students in grades 4 and 8.

International assessments offer a mixed picture.

In the 2003 Trends in International Math and Science Study (TIMSS), which sought to measure mastery of curriculum-based knowledge and skills, U.S. students in the lower and middle grades performed above the international average of the mixture of developed and developing countries in which the test was administered (figure O-55). Performance scores for U.S. eighth graders in mathematics and science were improved over those in the 1995 TIMSS, but scores for fourth graders showed no change.

However, U.S. 15-year-olds scored below the international average in both mathematics and science on the 2003 Programme for International Student Assessment (PISA) tests, which were intended to measure students' ability to apply

Table O-10
Changes in mathematics performance of students in grades 4 and 8, by student characteristics and other factors: 1990–2005 and 2003–05

Student characteristic	Grade 4		Grade 8	
	1990–2005	2003–05	1990–2005	2003–05
Average score				
Total	▲	▲	▲	▲
Sex				
Male	▲	▲	▲	▲
Female	▲	▲	▲	▲
Race/ethnicity				
White, non-Hispanic	▲	▲	▲	▲
Black, non-Hispanic	▲	▲	▲	▲
Hispanic	▲	▲	▲	▲
Asian/Pacific Islander[a]	NA	▲	NA	▲
American Indian/Alaska Native[b]	NA	▲	NA	•
Percentile scores[c]				
10th	▲	▲	▲	▲
25th	▲	▲	▲	▲
50th	▲	▲	▲	▲
75th	▲	▲	▲	▲
90th	▲	▲	▲	▲

▲ = increase; • = no change; ▼ = decrease (based on *t*-tests using unrounded numbers); NA = not available

[a] Insufficient sample size in 1990 for Asian/Pacific Islanders precluded calculation of reliable estimates.

[b] Insufficient sample size in 1990 for American Indians/Alaska Natives precluded calculation of reliable estimates.

[c] Percentage of students whose scores fell below a particular score, e.g., 75% of students had scores <75th percentile.

SOURCES: National Center for Education Statistics (NCES), The Nation's Report Card: Mathematics 2005, NCES 2006-453 (2006); National Assessment of Educational Progress, 1990, 1996, 2003, and 2005 mathematics assessments; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix table 1-5.

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Table O-11
Changes in science performance of students in grades 4, 8, and 12, by student characteristics and other factors: 1996–2005 and 2000–05

Student characteristic	Grade 4		Grade 8		Grade 12	
	1996–2005	2000–05	1996–2005	2000–05	1996–2005	2000–05
Average score						
Total	▲	▲	•	•	▼	•
Sex						
Male	▲	▲	•	•	▼	•
Female	•	▲	•	•	▼	•
Race/ethnicity						
White, non-Hispanic	▲	▲	•	•	•	•
Black, non-Hispanic	▲	▲	▲	•	•	•
Hispanic	▲	▲	•	•	•	•
Asian/Pacific Islander[a]	▲	NA	•	•	•	•
American Indian/Alaska Native	•	•	▼	▼	•	•
Percentile scores[b]						
10th	▲	▲	•	•	▼	•
25th	▲	▲	•	•	▼	•
50th	▲	▲	•	•	•	•
75th	•	•	•	•	▼	•
90th	•	•	•	•	▼	•

▲ = increase; • = no change; ▼ = decrease (based on *t*-tests using unrounded numbers); NA = not available

[a] National Center for Education Statistics (NCES) did not publish 2000 science scores for grade 4 Asians/Pacific Islanders because of accuracy and precision concerns.

[b] Percentage of students whose scores fell below a particular score, e.g., 75% of students had scores <75th percentile.

SOURCES: NCES, The Nation's Report Card: Mathematics 2005, NCES 2006-453 (2006); National Assessment of Educational Progress,1996, 2000, and 2005 science assessments; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix table 1-7.

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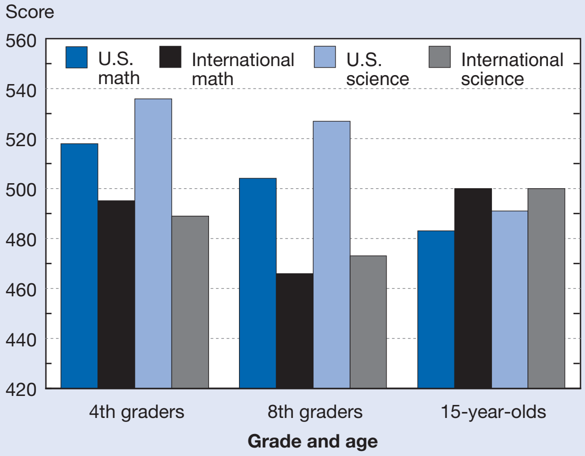
Figure O-55
U.S. and international math and science scores for grades 4 and 8 and 15-year-old students: 2003



NOTES: For 15-year-old students, international average from Organisation for Economic Co-operaton and Development average. For fourth and eighth graders, results from Trends in International Mathematics and Science Study. For 15-year-olds, results from Programme for International Student Assessment.

SOURCE: National Science Board, *Science and Engineering Indicators 2006*, appendix tables 1-9 through 1-14.

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scientific and mathematical concepts and skills to problems they might encounter outside the classroom (figure O-55). The PISA averages are based on scores from 30 industrialized OECD member countries.

Conclusion

The world of S&T is undergoing rapid changes along trends that emerged in the late 1990s. Increased government recognition of the importance of knowledge-intensive segments of their economies often led to the implementation of strategic policies to promote their development, and the expansion of education and advanced training in support of this goal. MNCs, seeking new markets and a broad range of operating efficiencies and responding to opportunities abroad, increasingly took advantage of and drove these developments, resulting in a shift in the epicenter of world S&T activities, led by China's emergence, toward several rapidly growing Asian economies.

These pronounced shifts have occurred over a relatively short time and have had a differential impact on mature, developed countries. In Asia, China's rapid rise economically and across the S&T spectrum has made it the world's second-largest economy, and certain other smaller Asian economies are increasingly prominent on the world stage.

By comparison Japan appears stagnant and, in fact, has lost world market share in a number of S&T areas. The EU's world position has also degraded, including in areas linked to high-technology trade. The United States is broadly holding its own, thanks, in part, to its large, mature, and diversified S&T system. But it, too, faces robust challenges affecting its education, workforce, R&D, and S&T systems that arise from the far-reaching and rapid worldwide changes.

Afterword: Data Gaps and Needs

Science and Engineering Indicators leaves many questions about the state of the S&E enterprise unanswered. Nationally representative or internationally comparable information is lacking about significant factual aspects of the S&T community in the United States and abroad. Following are some examples.

Chapter 1. Elementary and Secondary Education

- Informal learning experiences in K–12 education, including advanced courses taken in local colleges or via distance learning; participation in research, science or technology competitions, or internships; advanced coursetaking in engineering; and involvement in informal S&E learning through museums, science centers, zoos, planetariums, aquariums, and similar community-based institutions
- Teacher preparation and quality, including elementary teacher qualifications in science, technology, engineering, and mathematics (STEM) disciplines and STEM teacher test scores on subject matter knowledge
- STEM teacher career paths, including better data on teacher mobility across different kinds of schools and districts, reentry into teaching, and teachers on temporary visas or other noncitizen teachers
- Teacher involvement in informal learning

Chapter 2. Higher Education in Science and Engineering

- Emergence of multidisciplinary degree programs, new fields, and new institutional forms
- Student involvement in research experiences or in cooperative learning programs
- Undergraduate involvement in R&D work
- Quality indicators for postsecondary STEM teaching

Chapters 1 and 2

- Internationally comparable indicators of curriculum content or rigor
- Indicators of achievement or interest in STEM for gifted students at all education levels

Chapter 3. Science and Engineering Labor Force

- Internationally comparable data on S&T workforce characteristics
- Worldwide data, including industry breakdowns, on international flows of workers with S&T training, in S&T-related occupations, and/or performing R&D
- S&T-related skills used in the workforce and non-S&T skills that S&E workers use in their jobs
- Data on the role of postdoctorates in the nonacademic S&E workforce
- Employer-provided training and other forms of lifelong learning for S&E workers
- S&E workforce location relative to employer location

Chapters 4. Research and Development: National Trends and International Linkages, and 6. Industry, Technology, and the Global Marketplace

- R&D by line of business (For companies with more than one line of business, current industry R&D data attribute R&D to the company as a whole and not necessarily to the part of the company for which the work is done.)
- R&D in relation to firm or line-of-business characteristics, including profitability, productivity, growth, etc.
- R&D performance data on very small companies (fewer than five employees), state and local governments, nonprofit organizations, and individuals performing R&D independent of a corporation, university, or other organization
- Non-S&E R&D outside academic institutions (Other countries collect these data and include them in their national statistics.)
- R&D in international commerce, including R&D performed in the United States that is financed from foreign sources, characteristics (e.g., basic, applied, or development work; location) of R&D expenditures by U.S. affiliates of foreign multinational corporations, characteristics of R&D expenditures by foreign affiliates of U.S. multinational corporations, and trade in knowledge-intensive service industries
- Innovation indicators, including technology licensing; numbers, characteristics, R&D activities, and other operations data for business technology alliances; and technology parks, clusters, and incubators
- Outsourcing and offshoring of S&E jobs

Chapter 5. Academic Research and Development

- R&D funded from institutional or departmental resources and not separately budgeted, including use of funds for infrastructure, equipment, student support, and other purposes, and ultimate source of institutional or departmental funds

- R&D expenditures by U.S. corporations at foreign universities and by foreign corporations at U.S. universities
- Individuals who author S&E articles (Current data attribute articles to institutions or departments and do not include information about the characteristics of individual authors [e.g., employer, employment sector, disciplinary background, national origins, collaborative patterns, career stage, main work activities])
- Indicators of multidisciplinary S&E research
- Accessibility, use, and other characteristics of large, curated academic databases

Chapters 4 and 5

- Indicators of the spread, development, and use of R&D-related cyberinfrastructure
- Worldwide centers of R&D excellence by discipline and industry

These gaps are descriptive and could be addressed with new data. However, in many cases, gaps are as much analysis gaps as they are data gaps. To understand the global flow of S&E workers, for example, will require not only better, more internationally comparable data about credentials, skills, and migration patterns, but will also require developing models and testing hypotheses based on data that already exist (Regets 2007). Similarly, understanding the determinants of technological innovation involves building theories of innovation, testing them against existing data, and identifying and collecting new data that would be necessary to elaborate and test promising theoretical models (Nelson 1993). Accordingly, as part of a recent White House Office of Science and Technology Policy initiative, the National Science Foundation (NSF) has begun a program to support fundamental research aimed at developing a Science of Science and Innovation Policy. The initial emphases of the program are on analytic tools and model building.

Many other questions relevant to science policy involve a similar interplay among theory, analysis, and data. In addition, compelling answers to the "why" and "what if" questions that policymakers often ask can remain uncertain even when data bearing on these questions are available.

The federal government and its statistical agencies continuously engage in efforts to address significant data gaps or enhance the quality of the data generated from ongoing collections. Current examples include:

- Redesign of NSF's Survey of Industrial Research and Development to collect data on the line of business to which R&D is attributable in diversified firms, foreign R&D activities of companies that do R&D in the United States, technology licensing activities, and demographic and educational characteristics of the U.S. R&D workforce.
- A project of NSF's Division of Science Resources Statistics (SRS) to count nonacademic postdoctorates and collect data on the work roles and demographic, career, and educational characteristics of postdoctorates.
- Collaboration between the Department of Homeland Security and SRS to examine whether immigration records can be made available for use as a basis for collecting more timely and complete data on foreign-educated scientists and engineers.
- A Department of Commerce advisory committee effort to identify "holes" in the national data collection system that limit the nation's ability to measure innovation.

Collecting high-quality data can be exceedingly expensive, and governments cannot afford to collect all the data they could use productively. Beyond cost, however, there are numerous other persistent obstacles to remedying data gaps:

- Many concepts in the list of data gaps are difficult to measure. Informal learning experiences, teaching quality, S&E-related workplace training, multidisciplinary research, and innovation are less readily classified and quantified than many of the S&E indicators reported in this volume.
- For difficult-to-measure concepts, a succession of small-scale studies is usually necessary to refine measures and test them in a variety of situations before national or international data collection is possible. This kind of development work takes time.
- For S&T data to be meaningful, organizations and individuals must be willing and able to supply reasonably accurate information. In some cases, the burden on survey respondents of supplying such information makes it impossible to secure the necessary cooperation and collect good data.
- As S&T becomes increasingly globalized, internationally comparable data become increasingly important for mapping personnel and resource flows. Successful efforts under the auspices of the Organisation for Economic Co-operation and Development to coordinate the collection of R&D data across numerous national statistical systems indicate that coordination is feasible, but also that it is difficult and resource intensive.
- Data are most valuable when they extend back in time as well as outward across national boundaries. New data will not be able to address many questions until several data collection cycles have been completed.
- Legal and technical obstacles limit opportunities for merging data from different sources and making merged data widely available for analysis. Obstacles associated with merging datasets from different countries are especially daunting.

Notes

1. Data drawn from Conference Board and Groningen Growth and Development Centre, Total Economy Database (January 2007), http://www.ggdc.net, are measured in constant 1990 purchasing power parities (PPPs) converted into

U.S. dollars. World Bank data are based on different conversion factors but show congruent trends.

2. No internationally comparable data on in-country inequality are available.

3. The growth rate of real per capita GDP is measured in constant 1990 PPPs.

4. The estimated total is extended backwards to 1985.

5. Data in the overview are more current than those available in chapter 4.

6. Distinctions between basic and applied research often involve a greater element of subjective assessment than other R&D indicators, and about 40% of the OECD countries do not report these data at the national level. Nonetheless, where these data exist, they help differentiate national innovation systems in terms of how their R&D resources contribute to advancing scientific knowledge and developing new technologies.

7. Time-series data are available for China, Taiwan, Singapore, Romania, and Slovenia.

8. "Advanced" degrees are defined as International Standard Classification of Education Degrees, tertiary-type A and advanced research programs only.

Glossary

Affiliate: A company or business enterprise located in one country but owned or controlled (in terms of 10% or more of voting securities or equivalent) by a parent company in another country; may be either incorporated or unincorporated.

Applied research: The objective of applied research is to gain 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.

Asia-10: Includes China, India, Indonesia, Japan, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand.

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. Although basic research may not have specific applications as its goal, it can be directed in fields of present or potential interest. This is often the case with basic research performed by industry or mission-driven federal agencies.

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.

EU-25: Includes the EU-15 countries Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, and the United Kingdom. In 2004 the EU expanded to 25 members with the addition of 10 more countries: Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia, and Slovenia.

EU-27: Bulgaria and Romania joined the EU-25 (see definition above) in January 2007, for a total of 27 EU member countries.

Foreign affiliate: Company located overseas but owned by a U.S. parent.

Foreign direct investment (FDI): Ownership or control of 10% or more of the voting securities (or equivalent) of a business located outside the home country.

G-7: The group of seven industrialized nations: Canada, France, Germany, Italy, Japan, the United Kingdom, and the United States.

Gross domestic product (GDP): 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.

Knowledge-intensive economies: Economies with a large number of industries that incorporate science, engineering, and technology into their products and services.

Multinational corporation (MNC): A parent company and its foreign affiliates.

R&D: According to the Organisation for Economic Co-operation and Development, 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 2002, p. 30).

R&D intensity: Measure of R&D expenditures relative to size, production, or other characteristic of a country or R&D-performing sector. Examples include company-funded R&D to net sales ratio, R&D to GDP ratio, and R&D per employee.

U.S. affiliate: Company located in the United States but owned by a foreign parent.

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Highlights

Student Learning in Mathematics and Science

All student groups made gains in mathematics and science during elementary and high school, but performance disparities were evident, and some gaps widened as students progressed through school.

- Studies that follow the same groups of students as they progress through school reveal performance disparities among demographic subgroups starting when they enter kindergarten. Students from financially poorer families or whose mother had less formal education entered kindergarten with lower levels of mathematics skills and knowledge than their more advantaged peers. Substantial racial/ethnic gaps in mathematics performance were also observed. Although all subgroups made gains in mathematics and science during elementary school, the rates of growth varied and some of the achievement gaps widened.
- Mathematics performance gaps among demographic subgroups were evident in 10th grade and some continued to widen through 12th grade.

In 2005, U.S. fourth and eighth grade students outperformed those tested in the 1990s in mathematics, and fourth grade students improved in science.

- Increases in fourth and eighth grade mathematics scores from 1990 to 2005 were widespread, occurring among males and females, all racial/ethnic groups, students from financially disadvantaged and advantaged families, and students performing at all levels of achievement. Some mathematics achievement gaps did decrease over the same period.
- Widespread increases in mathematics from the 1990s to 2005 were not matched in science. Since 1996, the first year the current national science assessment was given, average science scores increased for 4th graders, held steady for 8th graders, and declined for 12th graders.

Standards and Student Coursetaking

In 2006, slightly more than half the states required 3 or more years of both mathematics and science courses for high school graduation.

- Students in more than 40 states were required to complete at least 2 years of both mathematics and science in high school; 3 years was the most common requirement for both subjects, in effect in just over half the states. Very few states required 4 years in either subject, and only one state required 4 years in both.

State development of course content standards has progressed in recent years and standards continue to be reviewed and revised.

- All states had issued content standards in mathematics and science by 2006–07, and 35 states had schedules for reviewing and revising those standards.

Trends from 1990 to 2005 show increases in advanced coursetaking; growth was especially strong in mathematics.

- Class of 2005 graduates completed mathematics courses at far higher rates than their 1990 counterparts in all categories except trigonometry/algebra III. The proportion of students completing courses in precalculus/analysis, calculus, and Advanced Placement/International Baccalaureate (AP/IB) calculus at least doubled since 1990. Nonetheless, completion of advanced mathematics courses remained below 20% in 2005 except for precalculus/analysis.
- Student course completion rates have increased since 1990 in advanced biology, chemistry, and physics, although they leveled off between 2000 and 2005.
- For AP/IB courses, coursetaking rates have not changed significantly for chemistry or physics, but increased slightly for biology and doubled for calculus and environmental science. Despite this growth, just less than 10% of graduates completed an AP/IB calculus course, the highest rate for any AP/IB course.

Course completion rates differed in the graduating class of 2005 by several demographic and school characteristics.

- Males and females completed advanced mathematics courses at about equal rates, except for precalculus/analysis, where females had a slight advantage. Females studied biology and chemistry at higher rates, whereas males studied physics, engineering, and engineering/science technologies at higher rates.
- Asian/Pacific Islanders were the most likely of all racial/ethnic groups to earn credits in many mathematics and science subjects, especially in AP/IB classes in calculus, biology, chemistry, and physics.

Mathematics and Science Teacher Quality

Most mathematics and science teachers have the basic teaching qualifications of a college degree and full state certification.

- Virtually all public school mathematics and science teachers had at least a bachelor's degree and half had an advanced degree such as a master's or doctorate.
- A large majority of mathematics and science teachers (84% in 2003) held standard or advanced certification issued by their state.

- At least 75% of 2003 mathematics and science teachers with less than 5 years of teaching experience participated in practice teaching before their first teaching job. Although practice teaching contributes to new teachers' confidence in their ability to perform their first jobs, practice teaching declined from 1999 to 2003.

The majority of public high school mathematics and science teachers had a college major or certification in their subject field, that is, they were "in-field" teachers. In-field teaching was less common in middle schools than in high schools.

- In 2003, 78%–92% of mathematics, biology, and physical science teachers in public high schools were teaching in field. Out-of-field teachers (that is, teachers teaching their subject with neither a major nor certification in the subject matter field, a related field, or general education) ranged from 2% of physical science teachers to 8% of mathematics teachers.
- The proportion of in-field mathematics and science teachers in middle schools was lower (33%–55%) than in high schools (78%–92%). About 3%–10% were teaching out of field.

Teachers in schools with low concentrations of minority and low-income students tended to have more education, better preparation and qualifications, and more experience than teachers in schools with high concentrations of such students.

- Mathematics and science teachers in low-minority and low-poverty schools were more likely than their colleagues in high-minority and high-poverty schools to have a master's or higher degree and to hold full certification.
- Mathematics and science teachers in low-minority and low-poverty schools were more likely to teach in field than their colleagues in high-minority and high-poverty schools.
- New mathematics and science teachers (those with 3 or fewer years of teaching experience) were more prevalent in high-minority and high-poverty schools than in low-minority and low-poverty schools.

Professional Development of Mathematics and Science Teachers

Participation in induction and mentoring programs was widespread.

- In 2003, 68%–72% of beginning mathematics and science teachers in public middle and high schools reported that they had participated in a formal teacher induction program or had worked closely with a mentor teacher during their first year of teaching.

Teacher participation in professional development was common. However, various features of professional development identified as being effective in bringing about changes in teaching practices were not widespread.

- In 2003, more than 70% of mathematics and science teachers in public middle and high schools participated in professional development focusing on the content of their subject field. About two-thirds attended professional development in using computers for instruction. Professional development most frequently took the form of workshops, conferences, and training sessions (91% in 2003).
- Recent research has found that intensive participation of at least 60–80 hours may be necessary to bring about meaningful change in teaching practice. In 2003, 4%–28% of mathematics and science teachers in public middle and high schools attended professional development programs for 33 hours or more over the course of a school year.

Teacher Salaries, Working Conditions, and Job Satisfaction

Attrition from teaching was typically lower than from other professions and attrition rates of mathematics and science teachers were no greater than the overall rate. Many were satisfied with being teachers and planned to stay in the profession as long as they could.

- Among all college graduates working in 1994, 34% were working in the same occupational category in 2003 and 54% had made a change in occupation. In contrast, 61% of college graduates entering K–12 teaching in 1994 were still teaching in 2003 and 21% had left teaching for nonteaching jobs.
- Between academic years 2003 and 2004, about 6%–7% of mathematics and science teachers in public schools left teaching, compared with 8% of all teachers.
- In 2003, 90% of mathematics and science teachers said that they were satisfied with being teachers in their schools, 76% planned to remain in teaching as long as they could or until retirement, and more than 66% expressed their willingness to become teachers again if they could start over.

Public secondary schools experienced varying degrees of difficulty in finding teachers in mathematics and science.

- About 80% of public secondary schools reported teaching vacancies (i.e., teaching positions needing to be filled) in one or more fields in academic year 2003. Among these schools, 74% had vacant positions in mathematics and 52%–56% had vacant positions in biology/life sciences and physical sciences.
- About one-third of public secondary schools with vacancies in mathematics or physical sciences reported great difficulty in finding teachers to fill openings in these

fields, whereas 22% of schools reported that this was the case in biology/life sciences.

Science and mathematics teacher salaries continue to lag behind salaries for individuals working in comparable professions and the gaps have widened substantially in recent years.

- In 2003, the median salary for full-time high school mathematics and science teachers was $43,000, lower than the salaries of professionals with comparable educational backgrounds such as computer systems analysts, engineers, accountants or financial specialists, and protective service workers ($50,000–$72,000). From 1993 to 2003, full-time high school mathematics and science teachers had a real salary gain of 8%, compared with increases of 21%–29% for computer systems analysts, accountants or financial specialists, and engineers.
- In 2003, 53% of public middle and high school mathematics and science teachers said that they were not satisfied with their salaries.

Most public school teachers had favorable perceptions of their working conditions.

- In 2003, at least 79% of mathematics and science teachers in public middle and high schools reported strong leadership from the administration in their school, a great amount of collaboration among their colleagues, and sufficient instructional materials.
- Relatively few of them viewed various student problems as “serious” in their schools. The problems that teachers rated most often as serious were students arriving at school unprepared to learn (37%) and student apathy (32%).

Transition to Higher Education

A majority of young people in the United States finished high school with a regular diploma or an equivalent credential.

- In 2005, 88% of 18–24-year-olds not enrolled in high school had received a high school diploma or earned an equivalent credential such as a General Equivalency Diploma (GED) certificate.
- Completion rates showed an upward trend for each racial/ethnic group between 1975 and 2005. The rates increased faster for blacks than for whites, narrowing the gaps between the two groups. The gaps between whites and Hispanics remained wide.
- The on-time graduation rate, which measures the rates at which high school freshmen graduate with a regular diploma 4 years later, ranged from 72%–74% in the early 2000s.

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

- Between 1975 and 2005, the percentage of students ages 16–24 enrolling in college immediately following high school graduation rose from 51% to 69%.
- Increases in rates of immediate college enrollment have occurred among all subgroups of students. However, wide gaps among these subgroups have persisted, with black and Hispanic students and those from low-income and poorly educated families trailing behind their white counterparts or those from high-income and well-educated families.

Introduction

This chapter examines recent trends in student achievement and factors influencing the quality of U.S. mathematics and science education at the elementary and secondary levels. Public concern about the achievement of American students in mathematics and science has intensified in recent years. In response, the education community has developed and implemented various approaches to improving K–12 education (NSB forthcoming). Targets of reform include standards and curriculum, knowledge assessments, teacher qualification, professional development, and working conditions.

The chapter begins by summarizing the most recent data on U.S. student learning in mathematics and science. New indicators of achievement include changes during the first 6 years of schooling, focusing on whether gaps between groups grew over that time. Another new topic is learning from 10th to 12th grades. The achievement section also puts U.S. student performance in mathematics and science in an international context.

The chapter next examines high school coursetaking in mathematics and science. This edition includes new data on coursetaking in environmental science, engineering, and engineering/science technologies. It also discusses the latest information on state academic course requirements for high school graduation and the status of statewide assessments.

Turning next to teachers, the chapter examines their qualifications, professional development, salaries, and working conditions, all issues that affect hiring and retaining professionals with backgrounds in mathematics and science. All teacher indicators in this chapter have been updated since *Science and Engineering Indicators 2004* (NSB 2004), using the latest data from the 2003–04 Schools and Staffing Survey (SASS) and parallel data from the 1999–2000 SASS where relevant. New teacher indicators include comparisons between teacher and other professional salaries, teacher job satisfaction and plans for continuing to teach, the link between various aspects of teachers' work environments and their long-term commitment to teaching, school reports of the degree of difficulty filling teaching vacancies in mathematics and science, and comparisons of attrition among teachers and other professionals. In addition, a section on teacher professional development includes new data on content, duration, and format. The chapter closes with indicators of secondary students' transitions into higher education.

The chapter focuses primarily on overall patterns but also reports variations in access to educational resources by minority concentration and school poverty level, and in student performance by sex, race/ethnicity, and family characteristics.

Whenever a difference or change over time is cited in this chapter, it is statistically significant at the 0.05 probability level.[1]

Student Learning in Mathematics and Science

This section presents indicators of student performance in mathematics and science from two types of studies: longitudinal studies and repeating cross-sectional studies. *Longitudinal studies* follow the same group of students over time; for example, from kindergarten through fifth grade. These studies can show achievement gains in a particular subject from grade to grade. *Repeating cross-sectional studies* provide a snapshot of how certain students perform in a particular year and then take another snapshot of a similar group of students in a later year; for example, comparing fourth graders in 1990 to fourth graders in 2005.

Performance as Students Progress Through Elementary School

The Early Childhood Longitudinal Study (ECLS) followed a group of students who entered kindergarten in fall 1998 until spring 2004, when most were in fifth grade.[2] The 2006 volume of *Science and Engineering Indicators* provided data from ECLS through third grade (NSB 2006). Those indicators showed that mathematics achievement differences among subpopulations already existed when students entered kindergarten. Although all groups made gains by third grade, some gaps widened over the 4-year period (Rathbun, West, and Germino Hausken 2004). This volume updates those indicators of early mathematics learning to fifth grade. It also presents the first longitudinal data from ECLS on science learning, from third through fifth grade.

Mathematics: Fifth Grade Performance

The ECLS mathematics assessments provide indicators of student proficiency in nine specific skill areas that represent a progression of skills and knowledge (see sidebar "Mathematics Skills Areas for Elementary Grade Students"). This volume of *Science and Engineering Indicators* focuses on the skill areas assessed in fifth grade, whereas the 2006 volume focused on the lower-order skill areas assessed in kindergarten through third grade.

By the end of fifth grade, almost all students (92%) could solve simple multiplication and division problems, and about three-quarters demonstrated understanding of place value in integers to the hundreds place (figure 1-1; appendix table 1-1) (Princiotta, Flanagan, and Germino Hausken 2006). Other topics proved more challenging, with less than half of fifth graders (43%) able to solve word problems using knowledge of measurement and rate, 13% able to solve problems using fractions, and 2% able to solve problems using area and volume. However, in each of the mathematics skills areas assessed at both time points, the percentages of students demonstrating proficiency increased since the third grade (appendix table 1-1).

Mathematics Skill Areas for Elementary Grade Students

ECLS measures student proficiency at nine specific mathematics skill levels. These skill levels were identified based on frameworks from other national assessments and advice from a panel of education experts and represent a progression of mathematics skills and knowledge. Levels 6, 7, and 8 were first assessed in third grade, and level 9 was first assessed in fifth grade. By the fifth grade, levels 1 through 4 were not assessed. Each level 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 hundreds place.

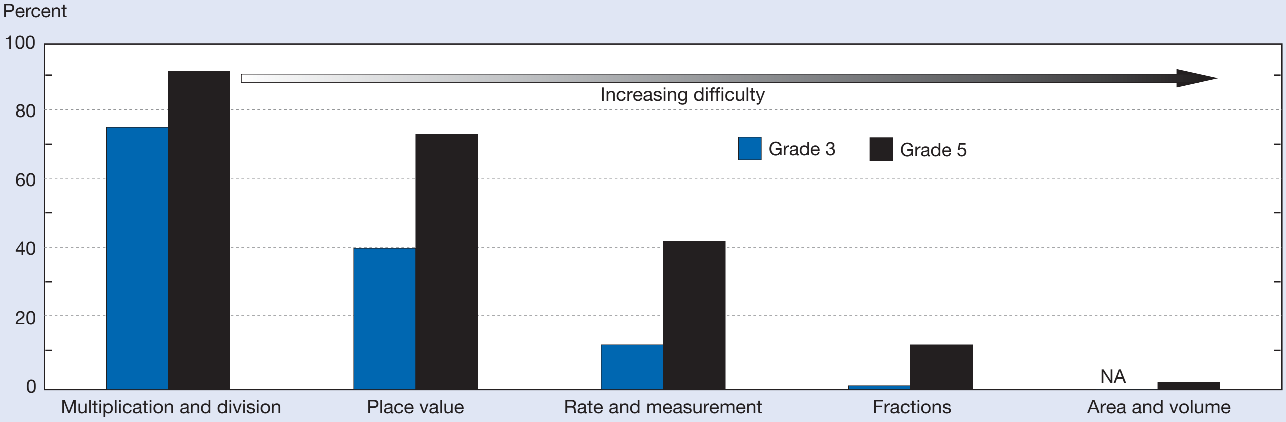
Level 7 Rate and measurement: Use knowledge of measurement and rate to solve word problems.

Level 8 Fractions: Solve problems using fractions.

Level 9 Area and volume: Solve problems using area and volume.

Sources: Princiotta, Flanagan, and Germino Hausken 2006; West, Denton, and Reaney 2000.

Figure 1-1
Proficiency in specific mathematics knowledge and skill areas of students in grades 3 and 5: 2002 and 2004



NA = not available

NOTES: In 2004 followup for Early Childhood Longitudinal Study (ECLS) kindergarten class of fall 1998, 86% of cohort was in grade 5, 14% was in lower grade, and <1% was in higher grade. For simplicity, students in ECLS followups referred to by modal and expected grade, i.e., third graders in spring 2002 assessment and fifth graders in spring 2004 assessment.

SOURCES: National Center for Education Statistics, ECLS, spring 2002 and 2004; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix table 1-1.

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Mathematics: Achievement Gaps During Elementary School

Fifth grade mathematics performance was related to several student background factors (Princiotta, Flanagan, and Germino Hausken 2006). For each of the mathematics skill levels mentioned above, lower proportions of black and Hispanic students were proficient compared with their white and Asian peers (appendix table 1-1). Students whose mothers had less formal education and students who were living in poverty[3] also generally demonstrated lower proficiency rates than their peers.

Although many of these mathematics achievement differences were evident when these children started kindergarten, the ECLS data suggest that at least some gaps widened as students progressed through elementary school, and that other gaps, such as those between boys and girls, emerged that were not present when students started school (Princiotta, Flanagan, and Germino Hausken 2006; Rathbun, West, and

Germino Hausken 2004). Changes in achievement gaps are most easily summarized by examining average scale scores, which place students on a continuous ability scale based on their overall performance. Results indicate that all demographic groups gain mathematical skills and knowledge during elementary school but the rate of progress varies.

Gender Gaps. Boys and girls started kindergarten at the same overall mathematics performance level (appendix table 1-2), but by the end of fifth grade, boys had made larger mathematics gains than girls, resulting in a small but observable gender gap of four points.

Race/Ethnicity Gaps. Gaps between white and black students and between white and Hispanic students existed when students started kindergarten and they widened over time. In mathematics, from kindergarten to fifth grade, white students posted a gain of 93 points; Hispanics, a gain of 89 points; and blacks, a gain of 80 points (table 1-1; appendix table 1-2). By fifth grade, the gap between white and black students in average mathematics scores was 19 points, and the average score of black fifth grade students was equivalent to the average third grade score of white students.

Mother's Education and Family Income Gaps. Students whose mothers had higher levels of education entered kindergarten with higher average mathematics scores than their peers whose mothers attained less formal education and these gaps increased as students progressed through elementary school (appendix table 1-2). By grade 5, the gaps in mathematics scores were substantial, with students whose mothers had dropped out of high school posting a lower average mathematics score than students whose mothers had graduated from college had posted at grade 3. Students living in families with incomes below the poverty threshold also entered school with lower mathematics skills than their peers from higher income families, and those discrepancies in scores grew by fifth grade.

Other research suggests that widening achievement gaps as students progress through school are, 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.

Science: Performance Gains and Gaps From Third to Fifth Grade

ECLS began assessing students in science in the third grade and tested those students' science knowledge again in fifth grade (Princiotta, Flanagan, and Germino Hausken 2006; Rathbun, West, and Germino Hausken 2004). The science assessments placed equal emphasis on life science, earth and space science, and physical science, asking students to demonstrate understanding of the physical and natural world, make inferences, and understand relationships. Assessments also required students to interpret scientific data, form hypotheses, and develop plans to investigate scientific questions. ECLS science assessments were not designed to measure proficiency in specific skill areas and therefore do not lend themselves to proficiency levels; results are instead summarized by average scale scores.

Gains in science skills and knowledge between third and fifth grade were seen across each demographic group, but performance gaps persisted (appendix table 1-3). Gaps were evident the first time students were assessed in science, in third grade. Boys had slightly higher average science scores

Table 1-1

Average mathematics scores of students from beginning kindergarten to grade 5, by race/ethnicity: 1998, 2000, 2002, and 2004

Race/ethnicity	Fall 1998 kindergarten	Spring 2000 grade 1	Spring 2002 grade 3	Spring 2004 grade 5	Gain from kindergarten to grade 5
All students	22	39	91	112	89
White, non-Hispanic	25	43	97	118	93
Black, non-Hispanic	19	33	79	99	80
Hispanic	19	36	85	108	89
Asian	25	39	94	118	93
Other[a]	20	38	86	107	86

[a] Includes non-Hispanic Native Hawaiians, Pacific Islanders, American Indians, Alaska Natives, and children of more than one race.

NOTES: Early Childhood Longitudinal Survey (ECLS) mathematics scale ranged from 0 to 153. In 2004 followup for ECLS kindergarten class of fall 1998, 86% of cohort was in grade 5, 14% was in a lower grade, and <1% was in a higher grade. For simplicity, students in ECLS followups referred to by modal and expected grade, i.e., first graders in spring 2000 assessment, third graders in spring 2002 assessment, and fifth graders in spring 2004 assessment.

SOURCES: National Center for Education Statistics, ECLS, fall 1998 and spring 2000, 2002, and 2004; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

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than girls and they maintained this small difference in performance in fifth grade. In third grade, white and Asian students had higher average science scores than did blacks and Hispanics, and Hispanics outperformed their black peers. By fifth grade, none of these gaps had narrowed and the black-Hispanic gap had increased. The average score for black fifth graders was lower than the average score for white third graders.

Third graders whose mothers had more formal education performed better in science than did their peers with mothers who were less educated, and students who lived above the poverty threshold did better in science than those who lived below it (appendix table 1-3). By fifth grade these gaps in science performance by mothers' education and poverty status either remained constant or grew wider. Students from families below the poverty threshold had average fifth grade science scores equivalent to the third grade scores of students above the poverty threshold.

Mathematics Performance as Students Progress Through High School

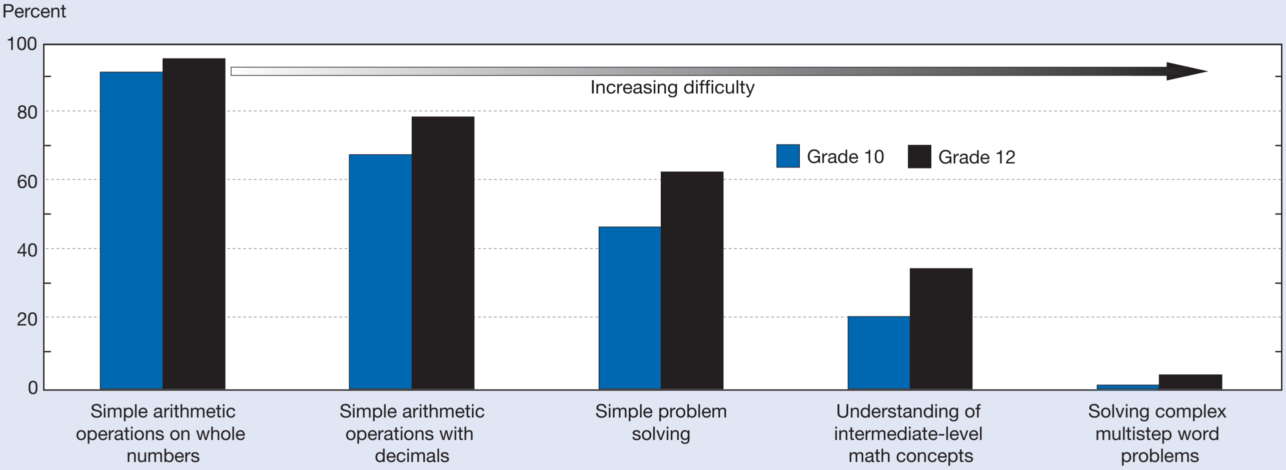
Another longitudinal study, the Education Longitudinal Study (ELS), provides indicators of student learning during high school by following a nationally representative sample of students who were in 10th grade in 2002 (NCES 2007a). These students were assessed again in 2004 in 12th grade. ELS includes an assessment of student performance in mathematics, which provides information both on specific skills and on overall mathematics performance. The specific skills are divided into levels representing a progression of mathematics skills: (1) simple arithmetical operations with whole numbers; (2) simple operations with decimals, fractions, powers, and roots; (3) simple problem solving requiring the understanding of low-level mathematical concepts; (4) understanding of intermediate-level mathematical concepts and multistep solutions to word problems; and (5) complex multistep word problems and advanced mathematics material (NCES 2007a).

In 2004, almost all 12th grade students (96%) were proficient in simple arithmetical operations with whole numbers and 79% were also proficient in simple operations with decimals, fractions, roots, and powers (figure 1-2; appendix table 1-4). However, the proportions demonstrating proficiency in more advanced mathematics skills were lower and decreased as more advanced skills were tested. Only 4% of 12th grade students reached proficiency at the highest level (solving complex multistep word problems). Nevertheless, at each level, the percentages of students demonstrating proficiency increased from the 10th to the 12th grade.

Each demographic subgroup examined improved in mathematics skills from 10th to 12th grade, but achievement disparities were evident. The ECLS data reviewed in the previous section found that boys and girls entered kindergarten with similar overall mathematics performance, but by the fifth grade, boys demonstrated slightly higher performance. This small gender gap favoring boys was also observed in the 10th and 12th grades in ELS, with the gap holding steady between those 2 years (appendix table 1-4).

Substantial differences among racial/ethnic groups were found in mathematics achievement at grade 10, with white and Asian/Pacific Islander students posting higher average scores than black and Hispanic students, and Hispanic students scoring slightly higher than black students (appendix table 1-4). After 2 additional years of schooling, white-Hispanic and Hispanic-black gaps held steady, and the white-black, Asian-black, and Asian-Hispanic gaps increased. By 12th grade, the average performance of black students was slightly lower than the average 10th grade performance of white and Asian students.

Figure 1-2
Proficiency in specific mathematics knowledge and skill areas of students in grades 10 and 12: 2002 and 2004



SOURCES: National Center for Education Statistics, Education Longitudinal Study, spring 2002 and 2004; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix tables 1-1 and 1-4.

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The mathematics skill gaps observed in kindergarten (and found to be greater in fifth grade) between students whose mothers had lower levels of education compared with students whose mothers were more educated were evident among ELS 10th graders (appendix table 1-4). These differences generally increased through the 12th grade. Students from low socioeconomic families[4] had lower average 10th grade mathematics scores than their peers in middle socioeconomic families, who in turn had lower scores than students in high socioeconomic families. By 12th grade these gaps had grown.

Performance of 4th, 8th, and 12th Grade Students Since the 1990s

The two longitudinal studies described above showed that students start school with different levels of knowledge and skills and that some of those differences grow as the same students move through the educational system. Notably, none of the achievement gaps reviewed above between historically privileged and underprivileged groups narrowed during elementary or high school.

Another type of assessment, a well-known repeating cross-sectional study, provided indicators that showed a somewhat more positive trend. As will be detailed below, fourth and eighth grade students in 2005 (including most subgroups) performed better on mathematics tests on average than fourth and eighth graders a decade and a half earlier. However, fewer gains were observed in science and substantial achievement gaps among subgroups of students in these grades persisted in both mathematics and science.

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. Previous *Science and Engineering Indicators* reports described trends in mathematics and science results dating back to the first NAEP assessments.[5] This volume focuses on more recent trends, from 1990 to 2005 for mathematics (grades 4 and 8) and from 1996 to 2005 for science (grades 4, 8, and 12) (NCES 2006a, b). Twelfth graders were assessed in mathematics in 2005 but the assessment was not comparable with previous NAEP assessments, and therefore trend data are not available for grade 12 mathematics.[6]

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 2006a, 2007b). The mathematics grades 4 and 8 assessments contain five broad content strands (number sense, properties, and operations; measurement; geometry and spatial sense; data analysis, statistics and probability; and algebra and functions). The mathematics grade 12 assessment contains four content strands that are similar to the grade 4 and 8 strands, but with measurement and geometry collapsed together. The science framework includes a content dimension divided into three major fields of science: earth, life, and physical.

Student performance on the NAEP is measured with scale scores as well as achievement levels. Scale scores place students on a continuous ability scale based on their overall performance. For grades 4 and 8, the mathematics scales range from 0 to 500 across the two grades. For grade 12, the mathematics scale ranges from 0 to 300. For science, the scales range from 0 to 300 for each of the three grades.

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 for each grade (NCES 2006b and 2007b). The *basic* level represents partial mastery, *proficient* represents solid academic performance, and *advanced* represents superior performance on assessments measuring mastery of knowledge and skills for each grade level. This review of NAEP results focuses on the percentage of students deemed proficient (for more detailed definitions of the proficient levels, see *Science and Engineering Indicators 2006*, pp. 1–13 and 1–14 [NSB 2006 and NCES 2007b]).

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. They warn readers to use and interpret the levels with caution (NCES 2006b).

In this section, NAEP results are examined in various ways, including changes in average scale scores and in the proportion of students reaching the *proficient* level both overall and among various 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 does 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 one or a few groups of students, or whether it reflected broader improvements.

Mathematics Performance From 1990 to 2005

The average mathematics scores of fourth and eighth grade students have steadily increased since 1990 (the first year in which the current assessment was given), including small improvements during the more recent period 2003–05 (NCES 2006a) (figure 1-3; table 1-2; appendix table 1-5). The pattern of higher average mathematics scores among fourth and eighth grade students was widespread (table 1-2; appendix table 1-5). At grades 4 and 8, average mathemat-

Table 1-2

Changes in mathematics performance of students in grades 4 and 8, by student characteristics and other factors: 1990–2005 and 2003–05

	Grade 4		Grade 8	
Student characteristic	1990–2005	2003–05	1990–2005	2003–05
Average score				
Total	▲	▲	▲	▲
Sex				
Male	▲	▲	▲	▲
Female	▲	▲	▲	▲
Race/ethnicity				
White, non-Hispanic	▲	▲	▲	▲
Black, non-Hispanic	▲	▲	▲	▲
Hispanic	▲	▲	▲	▲
Asian/Pacific Islander[a]	NA	▲	NA	▲
American Indian/Alaska Native[b]	NA	▲	NA	•
Free/reduced-price lunch[c]				
Eligible	▲	▲	▲	▲
Not eligible	▲	▲	▲	▲
Percentile scores[d]				
10th	▲	▲	▲	▲
25th	▲	▲	▲	▲
50th	▲	▲	▲	▲
75th	▲	▲	▲	▲
90th	▲	▲	▲	▲
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 (based on *t*-tests using unrounded numbers); NA = not available

[a] Insufficient sample size in 1990 for Asian/Pacific Islanders precluded calculation of reliable estimates.

[b] Insufficient sample size in 1990 for American Indians/Alaska Natives precluded calculation of reliable estimates.

[c] Information on student eligibility for free/reduced-price lunch first collected in 1996: comparisons in 1990s columns from 1996 to 2005.

[d] Percentage of students whose scores fell below a particular score, e.g., 75% of students had scores <75th percentile.

NOTES: 2005 grade 12 assessment not comparable with previous assessments; therefore mathematics trend information for grade 12 not available.

SOURCES: National Center for Education Statistics (NCES), The Nation's Report Card: Mathematics 2005, NCES 2006-453 (2006); National Assessment of Educational Progress, 1990, 1996, 2003, and 2005 mathematics assessments; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix table 1-5.

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ics scores were higher for both male and female students in 2005 compared with both 1990 and 2003. This was also true for students regardless of eligibility for free or reduced-price lunch (a commonly used measure of poverty).[7] Generally, improvements were observed for white, black, Hispanic, and Asian/Pacific Islander populations.[8]

Examining trends for students at the lower, middle, and higher ranges of performance can uncover whether overall trends are driven by changes in only one or two of these groups. However, NAEP mathematics results indicate that the overall increase in mathematics performance was not driven by students at any one performance level (table 1-2; appendix table 1-5). Average scores for students in the 10th, 25th, 50th, 75th, and 90th percentiles in 2005 were all higher than those recorded in 1990 and 2003, providing evidence that gains in mathematics were widespread. (*Percentiles* are scores below which a specified percentage of the population falls. For example, among eighth graders in 2005, the 75th percentile score for mathematics was 304. This means that 75% of eighth graders had mathematics scores at or below 304, and 25% scored above 304).

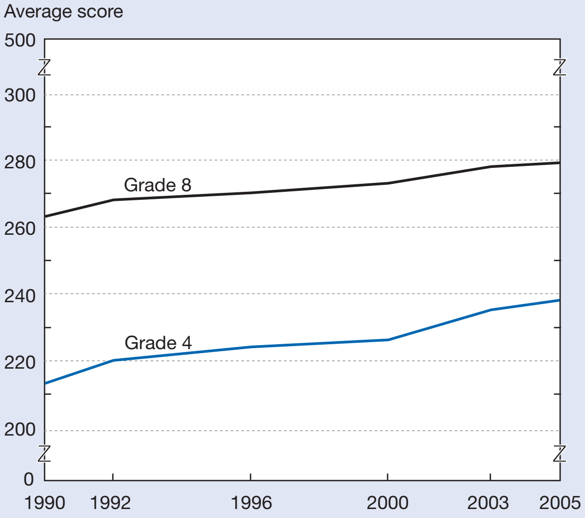
The percentage of students reaching the proficient level for their grade also rose (figure 1-4; appendix table 1-6). In 1990, 13% of fourth graders were deemed proficient in mathematics compared with 36% in 2005. Among eighth graders the percentage increased from 15% to 30%.

Mathematics Performance From 2005 to 2007

The NAEP 2007 fourth and eighth grade mathematics assessment results were released too late to incorporate more than a brief summary in this volume. Both fourth and eighth grade students registered continued improvements in mathe-

Figure 1-3

Average mathematics score of students in grades 4 and 8: Selected years, 1990–2005



NOTES: Scores on 0–500 scale across grades 4 and 8. 2005 grade 12 mathematics assessment not comparable with previous assessments; therefore mathematics trend information for grade 12 not available.

SOURCES: National Center for Education Statistics (NCES), The Nation's Report Card: Mathematics 2005, NCES 2006-453 (2006); and National Assessment of Educational Progress, 1990, 1996, 2003, and 2005 mathematics assessments. See appendix table 1-5.

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matics achievement between 2005 and 2007 (Lee, Grigg, and Dion 2007). Improvements occurred across all performance percentiles and income levels in both grades. Among fourth graders, scores increased for whites, blacks, Hispanics, and Asians/Pacific Islanders but no significant increase could be reported for American Indians/Alaska Natives because of insufficient sample size. Among eighth graders, whites, blacks, and Hispanic students improved their scores but Asians/Pacific Islanders and American Indians/Alaska Natives registered no gain. The percentage of students scoring at or above *proficient* in both grades increased from 36% to 39% among fourth graders and 30% to 32% among eighth graders.

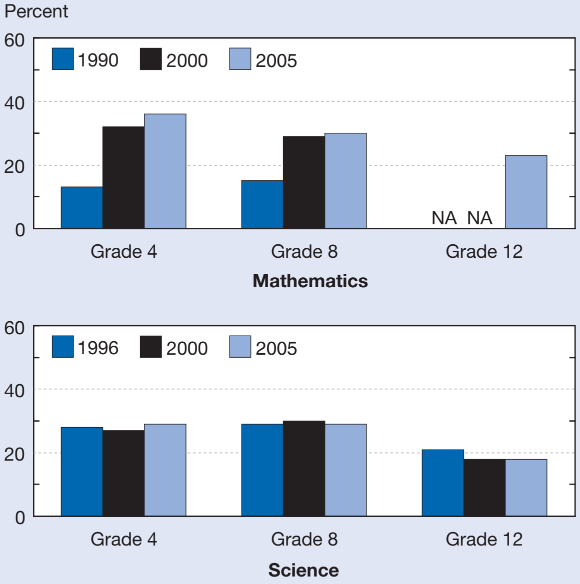
Although most groups showed improved performance from 2005 to 2007, performance gaps were resistant to improvement. In the fourth grade, the white-black and white-Hispanic gaps did not change between 2005 and 2007. In the eighth grade, the white-black gap decreased but the white-Hispanic gap remained about the same.

Science Performance From 1996 to 2005

Since 1996, the first year the current NAEP science assessment was given, average scores increased for 4th graders, held steady for 8th graders, and declined for 12th graders (table 1-3, appendix table 1-7) (NCES 2006b). Trends in percentile scores suggest the increase in average scores at grade 4 was driven by lower- and middle-performing students: scores at the 10th, 25th, and 50th percentiles increased in 2005 compared with both 1996 and 2000, while scores at the 75th and 90th percentiles did not change over the same periods (appendix table 1-7).

Figure 1-4

Proficiency in mathematics and science, grades 4, 8, and 12: Selected years, 1990–2005



NA = not available

NOTE: 2005 grade 12 mathematics assessment not comparable with previous assessments; therefore mathematics trend information for grade 12 not available.

SOURCES: National Center for Education Statistics (NCES), The Nation's Report Card: Mathematics 2005, NCES 2006-453 (2006); The Nation's Report Card: Science 2005, NCES 2006-466 (2006); and National Assessment of Educational Progress, 1990, 1996, 2003, and 2005 mathematics assessments and 1996, 2000, and 2005 science assessments. See appendix tables 1-6 and 1-8.

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The proportion of students reaching the *proficient* level for their grade in science did not change for grades 4 and 8, and declined slightly for grade 12 (figure 1-4; appendix table 1-8). In 2005, 29% of fourth and eighth grade students reached the proficient level. Rates were lower among 12th graders (18% scored at or above the proficient level).

Changes in Achievement Gaps Since the 1990s

The longitudinal studies outlined in the beginning of this chapter reveal racial/ethnic gaps in mathematics and science performance as students start kindergarten, some of which grow as students progress through elementary and high school. NAEP, with snapshots of three grades over time, paints a slightly different picture. Since 1990, the white-black gap in mathematics achievement decreased among fourth graders and held steady for eighth graders (table 1-2; appendix table 1-5). The white-Hispanic mathematic gaps held steady over this time for students in grades 4 and 8. In science, fourth grade black students narrowed the achievement gap with white students from 1996 to 2005 (table 1-3; appendix table 1-7). Despite some narrowing, substantial racial/ethnic gaps

Table 1-3

Changes in science performance of students in grades 4, 8, and 12, by student characteristics and other factors: 1996–2005 and 2000–05

	Grade 4		Grade 8		Grade 12	
Student characteristic	1996–2005	2000–05	1996–2005	2000–05	1996–2005	2000–05
Average score						
Total	▲	▲	•	•	▼	•
Sex						
Male	▲	▲	•	•	▼	•
Female	•	▲	•	•	▼	•
Race/ethnicity						
White, non-Hispanic	▲	▲	•	•	•	•
Black, non-Hispanic	▲	▲	▲	•	•	•
Hispanic	▲	▲	•	•	•	•
Asian/Pacific Islander[a]	▲	NA	•	•	•	•
American Indian/Alaska Native	•	•	▼	▼	•	•
Free/reduced-price lunch						
Eligible	▲	▲	•	▲	NA	NA
Not eligible	▲	▲	▲	•	NA	NA
Percentile scores[b]						
10th	▲	▲	•	•	▼	•
25th	▲	▲	•	•	▼	•
50th	▲	▲	•	•	•	•
75th	•	•	•	•	▼	•
90th	•	•	•	•	▼	•
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	•	▼	•	▼	NA	NA

▲ = increase; • = no change; ▼ = decrease (based on *t*-tests using unrounded numbers); NA = not available

[a] National Center for Education Statistics (NCES) did not publish 2000 science scores for grade 4 Asians/Pacific Islanders because of accuracy and precision concerns.

[b] Percentage of students whose scores fell below a particular score, e.g., 75% of students had scores <75th percentile.

SOURCES: NCES, The Nation's Report Card: Mathematics 2005, NCES 2006-453 (2006); National Assessment of Educational Progress,1996, 2000, and 2005 science assessments; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix table 1-7.

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in mathematics and science remained. For example, among 12th grade students in 2005, 24% of white students and 23% of Asian/Pacific Islander students were *proficient* in science compared with 13% of American Indian/Alaska Native students, 5% of Hispanic students, and 2% of black students (appendix table 1-8). Although grade 12 trends are not available for mathematics, the 2005 data reveal substantial racial/ethnic gaps in this subject as well: 36% of Asian/Pacific Islander 12th graders, 29% of white 12th graders, 8% of Hispanic 12th graders, and 6% each of black and American Indian/Alaska Native 12th graders reached the proficient level in mathematics (appendix table 1-6).

In 2005, boys in grades 4, 8, and 12 performed slightly better than girls in both mathematics and science (appendix tables 1-5, 1-6, 1-7, and 1-8). These small gender gaps have remained stable since 1990 in mathematics (for grades 4 and 8) and 1996 in science (for grades 4, 8, and 12). In 2005, students in grades 4 and 8 who were eligible for the federal subsidized lunch program had lower average mathematics scores than their peers who were not eligible (appendix table 1-5). However, the grade 4 gap with regard to subsidized lunch was slightly less in 2005 than it had been in 1996 (table 1-2; appendix table 1-5). Achievement differences with regard to subsidized lunch eligibility were also found in science, with fourth and eighth grade students eligible for the lunch program performing below their ineligible peers (appendix table 1-7). Between 2000 and 2005, these science gaps by subsidized lunch eligibility in grades 4 and 8 decreased somewhat (table 1-3; appendix table 1-7).

International Comparisons of Mathematics and Science Performance

Two assessments help compare mathematics and science performance in the United States to other countries: the Trends in International Mathematics and Sciences Study (TIMSS) and the Program for International Student Assessment (PISA). Results from the most recent administration of these assessments are included in more detail in *Science and Engineering Indicators 2006* and are only summarized here.

In 2003, U.S. students scored above international averages on the TIMSS assessment and below international averages on the PISA assessment, differences that may be explained, in part, by each test's focus and the set of countries participating in each assessment (Neidorf et al. forthcoming). TIMSS tests primary and middle grade students on curriculum-based knowledge and skills. PISA tests 15-year-olds on their ability to apply scientific and mathematical concepts and thinking skills to real-world problems. Although TIMSS includes results from 46 industrialized and developing countries, PISA results reported here include 30 countries, all of which are industrialized.

According to TIMSS data, U.S. fourth and eighth graders performed above the international average in mathematics and science in 2003 (Gonzales et al. 2004). However, because TIMSS includes many developing countries in its international average, it also can be helpful to compare U.S. performance to two similarly industrialized countries, the United Kingdom and Japan. Japan outperformed U.S. fourth and eighth graders in both mathematics and science. The United Kingdom outperformed U.S. fourth graders in both subjects, but had insufficient numbers participating in eighth grade to make a comparison. According to PISA results, U.S. 15-year-olds performed below the average for industrialized countries in both mathematics and science (Lemke et al. 2004). Of 30 participating industrialized nations, 20 outperformed the United States in mathematics and 15 outperformed it in science (see sidebar "Achievement Negatively Correlated With Confidence in Learning Across Countries/Economies").

Summary

Two national longitudinal studies found that students enter kindergarten with varied mathematics knowledge and skills, and all groups made gains during elementary and high school but at different rates. The result is that most mathematics achievement gaps remain, or have grown, by the time students graduate from high school. The national longitudinal data for science report achievement gaps in third grade (the first time students are assessed) and gains among all groups from third to fifth grade, but also no narrowing

Achievement Negatively Correlated With Confidence in Learning Across Countries/Economies

TIMSS measured a concept less frequently reported with standardized test results: whether students are self-confident in learning. Correlating achievement with self-confidence reveals surprising results. When comparing mathematics score averages across countries/economies, those with higher percentages of students reporting higher confidence in learning mathematics scored *lower* than countries/economies with lower percentages of students reporting such confidence (Loveless 2006; Mullis et al. 2004).

On eighth grade mathematics assessments, 39% of U.S. students reported that they usually do well in mathematics, compared with 4% in Japan (table 1-4). However, the average national test score for the United States was 66 points lower than Japan's. Within a given country, however, students who were more self-confident in learning did score *higher* than other students in their country (Loveless 2006).

Table 1-4
Eighth-grader's confidence in mathematics, by mathematics achievement score and country/economy: 2003

Country/economy	Students who "agree a lot" (%)	Average score	Score above international average
Jordan	48	424	
Egypt	46	406	
Israel	43	496	x
Ghana	41	276	
Bahrain	40	401	
Tunisia	39	410	
Cyprus	39	459	
Palestinian Authority	39	390	
United States	39	504	x
South Africa	38	264	
International average	27	467	
Romania	18	475	x
Singapore	18	605	x
Latvia	17	508	x
Moldova	17	460	
Netherlands	16	536	x
Malaysia	13	508	x
Chinese Taipei	11	585	x
Hong Kong	10	586	x
Korea	5	589	x
Japan	4	570	x

NOTE: Countries/economies ranked by percentage of students who "agree a lot" that *I usually do well in mathematics*.

SOURCES: Loveless T, How Well are American Students Learning? The Brown Center on Education Policy, Brookings Institution (2006), figure 2-1; and International Association for the Evaluation of Educational Achievement Trends in International Mathematics and Science Study (2003).

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and even some widening of the achievement gaps over this 2-year period.

Repeating cross-sectional studies of mathematics and science performance provide different types of indicators. In 2005, students in grades 4 and 8 posted higher mathematics scores than students in those same grades in 1990. The pattern of higher scores was widespread, occurring among males and females, across racial/ethnic groups, for students from financially advantaged and disadvantaged families, and for students in the lower, middle, and higher ranges of performance. Additionally, some achievement gaps narrowed. In science, average scores increased for fourth grade students, held steady for eighth graders, and declined for 12th graders between 1996 (the first year the assessments were given) and 2005. Trends in percentile scores suggest the increase in overall science scores of fourth graders were driven by improved scores among lower- and middle-performing students.

Despite the gains made in mathematics (and to a lesser extent, science) from the 1990s to 2005, most 4th, 8th, and 12th graders do not perform at levels considered proficient for their grade. Just more than one-third of fourth graders reached the proficient level in mathematics in 2005, and the rates were lower for mathematics at grades 8 and 12, and at all three grades for science. International comparisons of student mathematics and science performance indicate U.S. students perform below average in mathematics and science for industrialized countries.

Standards and Student Coursetaking

Standards provide a foundation of support for other key components of any educational accountability system, for example, courses and curriculum, teacher skills and professional development, and assessments. In the face of generally flat performance trends in the upper high school grades even after curricular standards were raised over the past two decades,[9] policymakers and educators are seeking new ways to revise standards and courses to help effectively educate young people (Achieve, Inc. 2004; Achieve, Inc., and National Governors Association 2005; Hurst et al. 2003). Currently, revisions focus on adding specific college-preparatory requirements and on making high school standards congruent with the expectations of colleges and employers by involving their representatives in the revision process.

The courses that students take, along with the curricula and teaching methods used, strongly influence what they learn and how well they are able to apply that learning. Research has linked completing more challenging courses with stronger academic performance, and coursework may play a direct role in increasing student achievement (Bozick, Ingels, and Daniel 2007; Chaney, Burgdorf, and Atash 1997; Lee, Croninger, and Smith 1997; and Schmidt et al. 2001). In their 1990 study, Bryk, Lee, and Smith concluded that coursetaking was the "principal determinant of achievement."

Links Between Coursetaking and Learning

Researchers have uncovered an association between courses completed and achievement scores, but not all have controlled for student ability. Students with strong academic skills are likely to take more challenging courses, but if they learn more than other students over time, researchers would like to know how much of the additional gain is attributable to skill and how much to coursework.

Two recent studies that applied controls for ability are described here. Using data from students who took its college entrance exams in 2004, an ACT study found that students who completed a recommended core curriculum scored higher on the ACT tests, regardless of sex, race/ethnicity, family income, or ability (ACT 2006). ACT defined that core curriculum as 3 years each of mathematics, science, and social studies and 4 years of English. Taking advanced courses beyond the core requirements, including additional courses in mathematics and science, was linked to larger score gains, even after controlling for students' prior achievement. Completing the core curriculum also led to higher rates of college enrollment and success in first-year courses like college algebra. Core curriculum graduates were also more likely to be prepared for further workforce training, according to tests of applied learning.

In another study, Bozick, Ingels, and Daniel (2007) used student 10th-grade mathematics proficiency scores as one control measure in examining associations between the mathematics courses taken in 11th and 12th grades and test score gains from 10th to 12th grades. The analysis found that mathematics achievement test scores in 12th grade and achievement gains from 10th to 12th grades were positively related to student mathematics course sequences during the last 2 years of high school. The largest overall gains, and the greatest gains in advanced skills such as derivations and making inferences from algebraic expressions, were made by students who took precalculus in 11th grade plus an additional mathematics course in 12th grade (in most cases, calculus). The largest gains in intermediate skills (such as simple operations and problem solving) were made by those who followed the geometry/algebra II sequence. The smallest gains were made by students who took one mathematics course or no mathematics courses during their last 2 years of secondary school. The analyses controlled for students' prior skill levels and demographic characteristics, including socioeconomic status, educational aspirations, family composition, and school sector.

This section presents several indicators of standards and coursetaking, including increases in state academic course requirements for high school graduation and revisions of content standards. In addition, high school course completion trends are shown from 1990 through 2005 for advanced mathematics, science, and engineering, as well as for engineering/science technologies, which are generally not considered advanced courses. The section concludes by examining course completion rates for 2005 graduates with various characteristics.

State Coursetaking and Curriculum Standards

Completing advanced courses in high school, particularly in mathematics, not only contributes to increased learning, but also predicts college enrollment and degree completion (Adelman 1999, 2006; Rose and Betts 2001). Students who complete such courses increase their college acceptance chances, are better prepared for college study, and have a higher likelihood of earning a bachelor's degree (see sidebar "Links Between Coursetaking and Learning"). However, a recent American College Test (ACT) report (2006) found that close to half of students who planned to attend college had not completed the academic courses necessary to enroll in credit-bearing college courses. Raising course requirements for graduation provides one method of bridging such gaps in preparation; if preparation is strengthened, not only would college completion rates increase, but many students also would earn degrees more quickly and college remediation costs would decline.

Furthermore, studying high-level mathematics in secondary school, particularly calculus, may increase the likelihood of choosing a mathematics or science major in college (Federman 2007). After adjusting for ability and course preferences, Federman found that the number of high school mathematics courses completed was positively related to propensity to major in a technical field, including all science, technology, engineering, and mathematics (STEM) and some high-level medical fields. Mathematics coursetaking as a stepping stone into such fields may be especially applicable to young women (Trusty 2002). Completing a range of advanced mathematics courses in high school was associated with women's majoring in mathematics and science subjects at higher rates. However, for men, high school physics was the only predictor for majoring in mathematics or science in college.[10] Increasing course completions in advanced mathematics and science may therefore help enlarge the college graduate pool and the workforce in these fields as well as increase women's participation in occupations in which they have been traditionally underrepresented.

Core Subject Requirements

In 2006, 3 years was the most common state requirement for both mathematics (26 states) and science (27 states) courses for high school graduation. In 12 states, the mathematics requirement was two or fewer years and 16 states required 2 or fewer years or science. The shift from a predominant requirement of 2 years in each subject in the mid-1980s is notable (table 1-5). Few states (six for mathematics and one for science) required 4 years of study in these subjects, and one state required 4 years in both.

Six states left course requirements up to local districts, whose standards apply to all high school students in the district. In practice, districts generally require the courses that students need for admission to the state's public universities. Therefore, these states may not differ substantially from those with published statewide requirements. (Districts may also add requirements above state minimums.)

Table 1-5
States requiring various years of mathematics and science study for high school graduation: 1987, 1996, and 2006

	Mathematics			Science		
State/local standard	1987	1996	2006	1987	1996	2006
Local decision	6	7	6	6	7	6
1–2 years[a]	33	26	12	40	33	16
3 years	10	15	26	3	8	27
4 years	0	2	6	0	2	1

[a] In 2006, all states with statewide requirements required ≥2 years of mathematics courses, and only one state required 1 year of science.

NOTES: Data included for all states for 2006 and for all states plus District of Columbia for years before 2006, with two exceptions: in 1987, Arkansas and Vermont required total of 5 mathematics and science credits (2 or 3 credits in each) so not assigned to a category; in 1996, Vermont alone not counted for this reason. Some states had separate requirements for different kinds of diplomas. For these, states categorized by requirements for "standard" diploma or for type most students likely receive, if more than one type and none called standard. In some states and some years, a new requirement enacted by year in column head but did not necessarily apply to graduating class of that year.

SOURCES: Council of Chief State School Officers, Key State Education Policies on PK-12 Education: 2006 (2007); and National Center for Education Statistics, *Digest of Education Statistics*, 1988 and 1998 editions (1988 and 1999).

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Rising standards have increased the number of required academic courses since the mid-1980s. In the past decade or so, the policy focus has expanded to include listing specific courses that must be completed and improving course content. A primary goal of adding requirements for more mathematics and science study is to direct students into more challenging courses, particularly those intended to prepare them for success in college. To that end, in 2006, 21 states required completion of specific mathematics courses (with algebra the most common) and 22 states required specific science courses (most often biology) (CCSSO 2007). Nearly all states that required specific courses in mathematics also required them in science. Another five states required students to complete a science course with laboratory work but required no specific course.

Course Content Standards and Testing

In addition to specifying key courses that must be completed, states have developed and applied new standards for course content. All states had adopted content standards in mathematics and science by 2006–07, and 35 states had schedules for reviewing and revising those standards (Editorial Projects in Education 2007).

In light of continuing dissatisfaction on the part of employers and college professors with high school graduates' skill levels (see sidebar "Attitudes of Parents, Students, and School Staff Toward Standards") and the overall lack of substantial achievement gains for 12th graders on national and international tests, some policymakers want additional standards revisions and are seeking input from stakeholders outside of K–12 education. Reforms are intended to address the primary problems that critics lodge against standards: they are vague and lack focus, they cover too much and thus cause teachers

Attitudes of Parents, Students, and School Staff Toward Standards

Prominent business and education organizations have continued to underscore the need for high schools to raise standards so that students will gain the skills and knowledge base required by employers and postsecondary institutions. Among these organizations are the Gates Foundation and the American Diploma Project (ADP), a consortium that includes Achieve, Inc., many state leaders, the Education Trust, and the Thomas B. Fordham Foundation. In addition, majorities of employers and professors surveyed in 1998–2002 reported that many or most high school graduates (depending on the specific question) lacked skills needed for successful job performance and course completion. For example, in 2001 nearly two-thirds of both groups thought that graduates' basic mathematics skills were fair or poor, and 73%–75% rated student writing ability fair or poor (Public Agenda 2002).

However, these views contrast with those of parents and students. A 2006 survey of parents and students in public school grades 6–12 showed that most do not believe that their local schools need much improvement or that more mathematics and science instruction is necessary. For example, 32% of parents thought their child's school should be teaching more mathematics and science, whereas 57% thought the current amounts were fine (Public Agenda 2006). At 70%, parents of high school students were the most likely (compared with parents of younger students) to think that no increases were needed. Concern about this issue has decreased since 1994, when 52% of parents identified not learning enough mathematics and science as a serious problem, compared with 32% in 2006. This change may partly reflect increases over time in student coursetaking in these subjects.

On academic standards, students in grades 6–12 also expressed some complacency. Only 35% thought it was a problem at their school that "academic standards are too low and kids are not expected to learn enough," and it was not a high priority among 13 problems rated by students. More were concerned about fellow students lacking respect and using bad language, cheating, skipping school/classes, and "too much pressure to make good grades." Even fewer parents (15%) identified "low academic standards and outdated curricula" as a source of the most pressing problems in schools (in a question with different wording).

Active support from school leaders and teachers is also necessary for reforms to be effective. However, many educators (particularly leaders) do not agree that schools need to raise standards or enact other fundamental reforms. Nearly 80% of both principals and superintendents called it "not a serious problem" that academic standards were too low and students were not expected to learn enough. On a related question, 93% of superintendents and 80% of principals evaluated current educational quality as better than the education they received.

Most parents rated their children's public schools highly in 2006. The majority believed that when their children graduate from high school they will have the skills needed for employment or success in college (61% and 69%, respectively). Nearly two-thirds (65%) of parents said that their children were learning more difficult material in school than they had in their school days, and 61% thought their children's schooling was better than their own at that age. Despite their satisfaction with schools overall, parents of different income levels tended to have divergent opinions. For example, over half of low-income parents in a 2002 survey (56%) worried a lot about the low quality of public schools, compared with just 38% of high-income parents (Public Agenda 2002).

to rush through material, and they differ widely across states (Peterson and Hess 2006; Ravitch 2006; Smith 2006).

Disagreement also exists about whether a single set of standards should apply to all students regardless of their intention to attend college after high school. Whereas standards defining college readiness generally include specific courses, standards for work readiness instead tend to focus on skills, including those specific to a career or industry and broader skills required for any job (Lloyd 2007).

In 2006 the National Council of Teachers of Mathematics (NCTM) called for greater classroom focus on fewer high-priority "focal points" and provided a limited number of specific skill goals for each grade level (NCTM 2006). Similarly, a committee of the National Research Council (NRC) recently urged educators to place continued emphasis on a few fundamental concepts over a span of many grades, and to introduce more complex material related to these concepts as students mature (NRC 2007). Such strategies enable students to develop a deeper understanding of the concepts over time. These recommendations build on curriculum standards documents published earlier by NCTM (2000), the American Association for the Advancement of Science (1993), and NRC (1996).

Despite years of work on standards, a substantial gap still exists in most states between the skills and knowledge required for high school graduation and those needed for college study and work (Achieve, Inc. 2007; Cohen et al. 2006). Efforts to bridge these gaps state by state include the High School Honor States program, which is sponsored by the National Governors Association (NGA), and the American Diploma Project (ADP).

The Honor States program awards grants to states to improve high schools by revamping standards and taking other related actions under NGA leadership (NGA 2007). Funds support developing exemplary practices using NGA's guidelines, and NGA disseminates findings to policymakers in other states. One primary goal is to align state standards at all school levels, including postsecondary, so that students are prepared to succeed in college courses and the workplace after they graduate from high school. Among promising practices noted so far in the Honor States program is providing financial incentives to support coordination between secondary and postsecondary educators. A practical example of collaboration between these sectors is administering college placement tests in high school to make college academic expectations clear to students. Also, some states have implemented broad media campaigns to raise students' and others' awareness of the need to prepare adequately for college and work.

The ADP initiative, sharing the Honor States program goals, provides technical assistance to help educators raise standards and increase consistency across districts. Tracking progress toward aligned standards requires developing and using data systems that follow students from kindergarten or pre-K through their college years. State education agency staff were working in 29 states in 2006 with leaders from elementary, secondary, and postsecondary education (including representatives of the American Council on Education, the National Association of System Heads, and State Higher Education Executive Officers) and business leaders to upgrade curriculum standards. Once in place, such "real-world standards" would help students choose courses and guide them to expend sufficient effort in high school, reducing the need for remedial courses in college (Achieve, Inc. 2007) (see sidebar "The State of State Assessments").

In 2006, 12 states surveyed by Achieve had curriculum standards in place that met ADP's college- and work-readiness benchmarks for both mathematics and English curricula (Achieve, Inc. 2007; Cohen et al. 2006). In addition, 27 more states were working to align graduation requirements with these benchmarks and another 5 states had plans to do so. Another element of the program covers requiring all students to complete specific courses for graduation. The ADP minimum levels for course requirements include 4 years of mathematics (including 1 year of algebra II) and 4 years of college-preparatory or equivalent English courses. On this measure, 13 states had adopted such requirements by 2006 and another 16 states had plans to do so within a few years (Achieve, Inc. 2007).

Course Completions by High School Students

Indicators of advanced coursetaking are based on data from the NAEP High School Transcript Study for the graduating class of 2005 and for earlier cohorts when examining trends. The transcript studies gather coursetaking data for a subset of the overall NAEP sample of 12th graders. (See sidebar "Advanced Mathematics and Science Courses" for an explanation of which courses are included as advanced.)

Trends in Course Completions

On average, high school students have completed more mathematics and science courses since 1990 (appendix tables 1-9 and 1-10), including more advanced courses in these subjects. In mathematics in particular, class of 2005 graduates completed courses at higher rates than their 1990 counterparts in all advanced mathematics categories except trigonometry/algebra III[11] (figure 1-5). For example, the proportion of students completing courses in statistics/probability increased eightfold (to about 8%), and for precalculus/analysis, any calculus, and AP/IB calculus, it doubled over the 15-year period. (These jumps were from small initial bases in 1990.) Such increases likely result from a combination of higher state requirements, students' rising postsecondary aspirations, and growing demand for mathematics and logic skills in the workplace. Nevertheless, relatively small proportions of 2005 graduates had studied most of these subjects; at 29%, precalculus/analysis had the highest completion rate of mathematics courses shown.

Students also have registered higher course completion rates since 1990 in advanced biology, chemistry, and physics, although rates leveled off between 2000 and 2005 for these subjects (figure 1-6; appendix table 1-10). Except for environmental science, the rates of increase were not as sharp as for most mathematics categories. Whereas 4%

The State of State Assessments

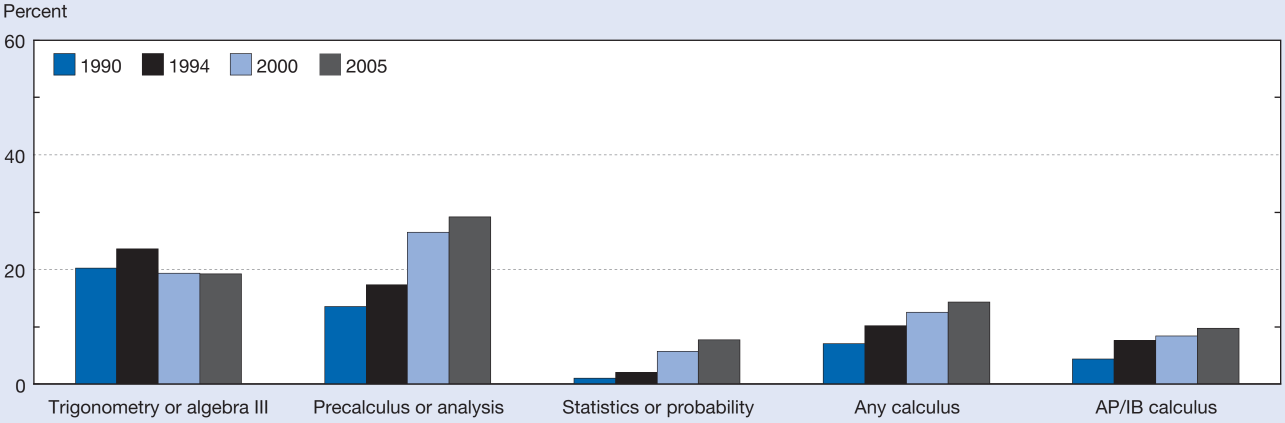
State-administered tests seek to demonstrate whether students are achieving at the level required by state standards; they are also used to track progress in meeting federal requirements for student proficiency. In the 2006 academic year, 47 states and the District of Columbia administered mathematics assessments aligned with state standards at the elementary, middle, and high school levels (Editorial Projects in Education 2007). The No Child Left Behind (NCLB) Act requires assessments in mathematics by academic year 2005 in each grade 3–8 and one in grades 10–12; and in science by 2007 in at least one grade in elementary, middle, and high school. State-approved science assessments were thus commonly given but somewhat less widespread in 2006; for example, 20 states lacked them at the high school level. In addition, to graduate from high school in many states, students must surpass a cutoff score on upper grades tests that include mathematics.

How closely tests are aligned with course standards and curriculums remains a contested issue (Barton 2006). The American Federation of Teachers (AFT) recently reviewed state assessments and concluded that in some states, some tests are not sufficiently aligned with the standards (AFT 2006). Students in these states may therefore be tested on some skills and material that their teachers either did not address or covered inadequately, and their test results would not accurately reflect learning differences among groups or gains over time. Even tests with closely aligned content may have other drawbacks, particularly in science. Although written tests can determine whether students understand elements like scientific concepts, methods of inquiry, and terminology, they cannot test hands-on laboratory skills.

Experts have also questioned the quality of state achievement tests, pointing to both the validity of test items and the scores set for reaching certain achievement levels. For example, critics charge that some states may set the minimum score for *proficient* too low (Petrilli and Finn 2006; Ravitch 2005). The percentage of students reaching *proficient* on many state tests is close to the percentage reaching the *basic* level on NAEP, whereas in other states, percentages for the two tests are similar (Center for Public Education 2006; NCES 2007c). (See chapter 8 for recent NAEP scores by state.) Moreover, in an effort to increase the percentage of students considered proficient (a measure specified in NCLB), and facing pressure to make continuing progress toward the goal of universal proficiency by 2014, some state agencies have lowered the proficient cutoff scores on their tests over time (Petrilli and Finn 2006), thus undermining progress toward higher student achievement.

Discrepancies existed between state and NAEP test results even before NCLB took effect (Fuller et al. 2006). Although setting and reviewing standards and developing aligned tests are widely viewed as effective mechanisms for increasing learning, the details of implementation may still need to be evaluated and improved over time.

Figure 1-5
High school graduates completing advanced mathematics courses, by subject: Selected years, 1990–2005



AP = Advanced Placement; IB = International Baccalaureate.

SOURCES: National Center for Education Statistics, National Assessment of Educational Progress, 1990, 1994, 2000, and 2005 High School Transcript Studies; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix table 1-9.

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Advanced Mathematics and Science Courses

Advanced courses referenced in this section are defined as courses that not all students complete and that are not, as a rule, 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, any calculus, and any environmental science.

The "any advanced biology" category is slightly different from the other categories labeled "any" in that it includes second- and third-year biology courses and those designated honors, accelerated, or Advanced Placement/International Baccalaureate (AP/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. Similarly, earth science courses are not counted here because they are often (1) required and (2) not advanced, taking the form of basic survey courses that most students take in 9th or 10th grade. On the other hand, certain courses that are clearly advanced are not measured here because they are so rarely studied in high school (for example, space science/astronomy).

AP/IB courses are all advanced; they aim 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 isolates the subset of courses that meet either of these programs' guidelines.

of 1990 graduates studied environmental science, this rate grew to 10% for 2005.

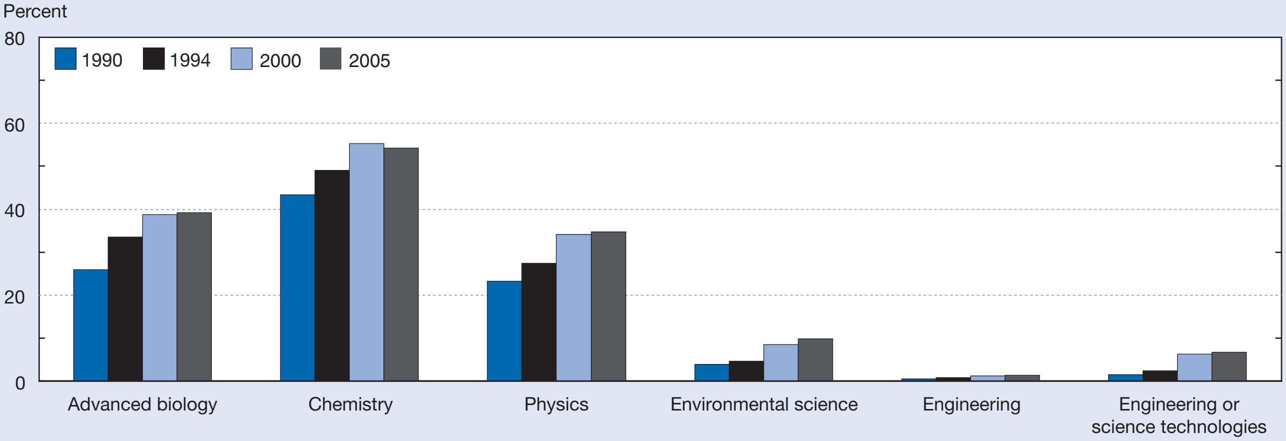
Study of engineering was rare in all years examined, reaching 1.4% in 2005, but it did exhibit a strong growth trend between 1990 and 2005 (appendix table 1-10). The proportion of students taking courses in engineering/science technologies more than quadrupled over this time period, reaching nearly 7% in 2005.

Among the AP/IB courses, coursetaking rates doubled (or more) for calculus and environmental science (since 2000 for the latter) and increased slightly for biology.[12] Overall, just less than 10% of graduates completed an AP/IB calculus course and smaller proportions completed other AP/IB courses.

That course completions were rising while high school student test performance showed a mostly flat trend may appear puzzling. However, the increases in coursetaking may not yet be sufficient, particularly in science, to significantly raise average performance or the overall percentage of students reaching proficiency. (The increases in coursetaking have been less pronounced for science than for mathematics.) Also, the 2005 NAEP mathematics scores cannot fairly be compared with earlier scores because of the new test framework for 2005. Therefore, it is unclear whether mathematics achievement has recently gone up.

Any number of other factors may also contribute to this apparent discrepancy, including changes in student characteristics, teacher skills, course content, and how closely the tests align with curriculum taught. For example, some students who in the past would have been unlikely to take these more advanced courses may have lower cognitive ability, less motivation, weaker study skills, and, for recent immigrants, lesser English skills than the more traditional advanced course takers. All of these factors could impede test performance. In addition, teachers of newly added courses may lack sufficient training to teach those courses effectively or may reduce coverage of material or complexity of

Figure 1-6
High school graduates completing advanced S&E courses, by subject: Selected years, 1990–2005



SOURCES: National Center for Education Statistics, National Assessment of Educational Progress, 1990, 1994, 2000, and 2005 High School Transcript Studies; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix table 1-10.

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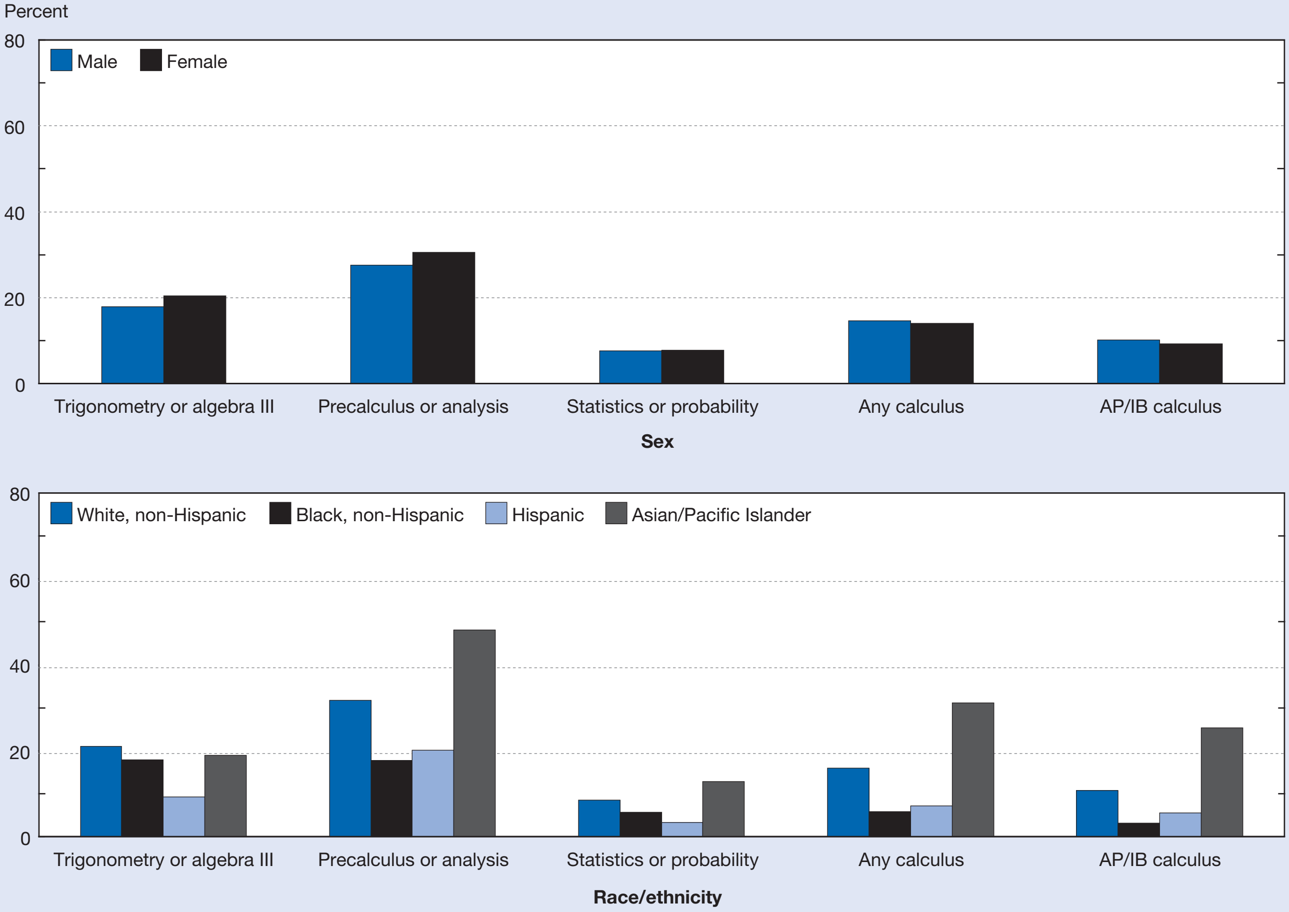
assignments when some students struggle. Students in such classes may have a reduced opportunity to learn some of the relevant material and skills.

Course Completions by Class of 2005

Course completion rates differed in the graduating class of 2005 by several demographic and school characteristics. Female graduates had a slight edge over males in completing courses in precalculus/analysis, and historical differences favoring boys for the other advanced mathematics topics disappeared by 2005 (figure 1-7; appendix table 1-9). Thirty-seven percent of males studied physics compared with 33% of females; males were also more likely to complete an AP/IB physics course but these differences were not great. Females studied advanced biology, AP/IB biology, and any chemistry at higher rates (figure 1-8; appendix table 1-10). For example, about 45% of young women studied advanced biology, compared with 33% of young men.

Among 2005 graduates, coursetaking rates also differed by racial/ethnic group for most course categories. In general, Asian/Pacific Islanders were the most likely to complete advanced mathematics and science courses (figures 1-7 and 1-8).[13] For example, 25% of Asian/Pacific Islander graduates studied AP/IB calculus, compared with 11% of whites and less than 10% of other groups. Asian/Pacific Islander students were the most likely of all groups to earn credits in precalculus/analysis, statistics/probability, calculus, chemistry, physics, and AP/IB classes in calculus, biology, chemistry, and physics. Black and Hispanic graduates were consistently less likely than Asian/Pacific Islander and white graduates to complete most of these advanced courses in mathematics and science; some exceptions to this pattern occurred with trigonometry/algebra III, chemistry, environmental science, engineering, and engineering/science technologies. Black graduates were the most likely to study environmental science, at 14%,

Figure 1-7
High school graduates completing advanced mathematics courses, by sex and race/ethnicity: 2005



AP = Advanced Placement; IB = International Baccalaureate.

SOURCES: National Center for Education Statistics, National Assessment of Educational Progress, 2005 High School Transcript Study; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix table 1-9.

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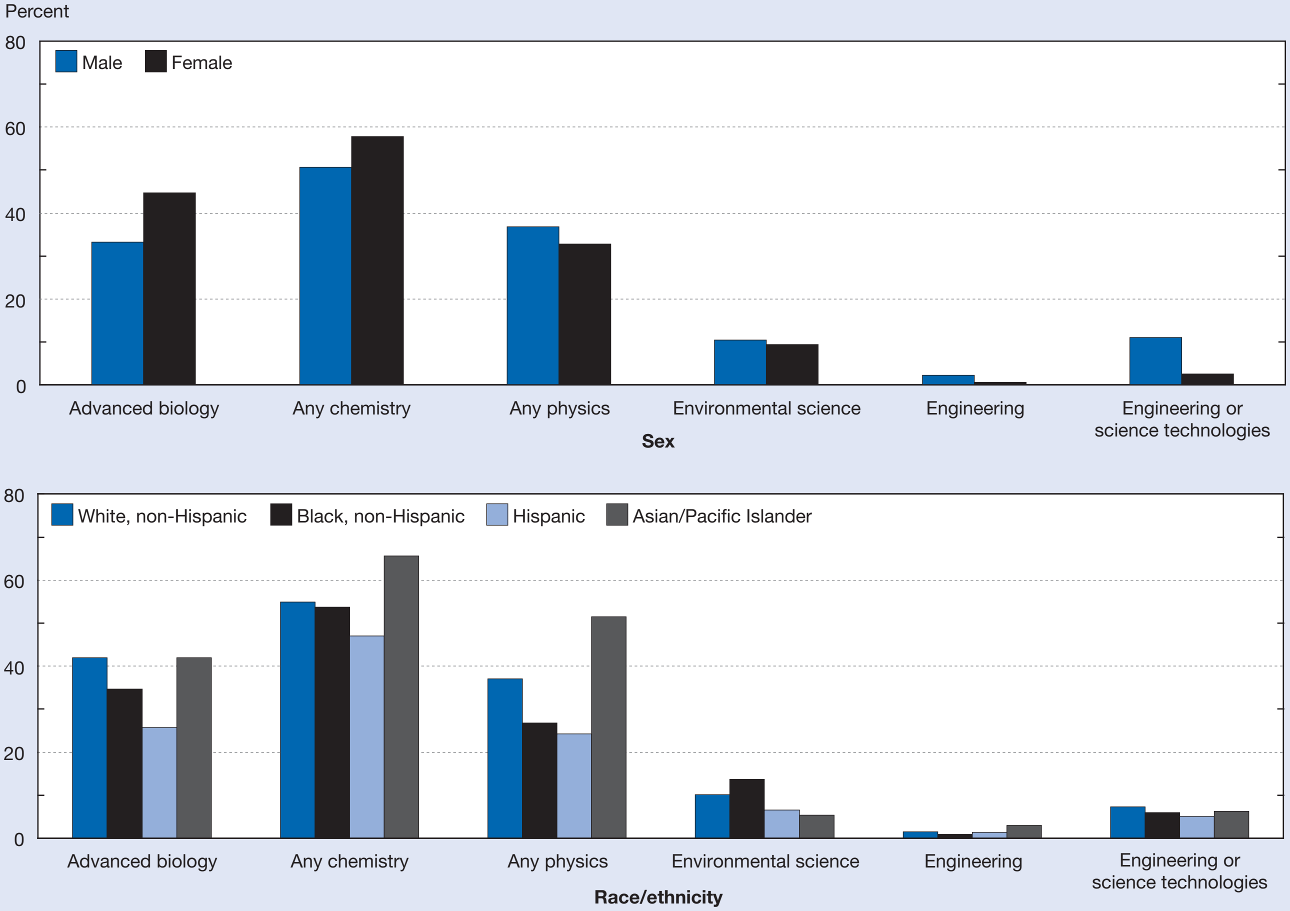
Figure 1-8
High school graduates completing advanced S&E courses, by sex and race/ethnicity: 2005



SOURCES: National Center for Education Statistics, National Assessment of Educational Progress, 2005 High School Transcript Study; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix table 1-10.

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compared with 10% for whites and lower percentages for other groups.

Coursetaking rates for engineering and engineering/science technologies differed less by race/ethnicity than they did for other course categories. The introduction of engineering-related courses in secondary schools is fairly recent and they remain uncommon; one national organization that promotes and supports such courses, Project Lead The Way, includes in its goals achieving proportionate racial/ethnic and sex composition of program participants (see sidebar "Project Lead The Way").

In addition to graduates' own demographic characteristics, certain characteristics of their high schools were linked to the chances that they studied advanced mathematics and science topics. Graduates of private schools were more likely than those of public schools to study each of the advanced mathematics subjects except statistics/probability, and each of the science subjects except advanced and AP/IB biology, environmental science (regular and AP/IB), and engineering-related courses (appendix tables 1-9 and 1-10), where apparent differences were not significant. As the school's poverty rate diminished, graduates were more likely to complete many of the advanced mathematics, science, and engineering courses (figure 1-9). For some subjects, a significant difference existed only between schools with very low poverty rates and all other schools.

Summary

In 2006, nearly all states required at least 2 years of both mathematics and science for a high school diploma; 3 years was the most common requirement for both subjects. Standards governing coursework have expanded in some states to require specific courses and to raise course difficulty levels to prepare students for college and employment.

Project Lead The Way

Some prominent STEM professionals have expressed concern that, as members of the current engineering and science workforce retire, they will not be replaced in adequate numbers (Business Roundtable 2005; Committee on Prospering in the Global Economy of the 21st Century 2006). In the former report, 15 leading business organizations called for the nation to double the number of STEM graduates by 2015.* These organizations argue that not only has the total number of engineering degrees awarded in the United States decreased in recent years (NSB 2006), but the proportion of doctoral degrees in engineering earned by U.S. citizens or permanent residents has also been dropping.†

Project Lead The Way (PLTW) is a pre-engineering program that aims to attract more students to engineering and train them for college study. It requires students to tackle challenging academic content in middle and high school to prepare for postsecondary study in engineering and related technologies. The program, started in 1997–98 in a few schools, has expanded to more than 1,300 schools in 45 states plus the District of Columbia.

PLTW seeks participation by students of both sexes and all racial/ethnic groups roughly in proportion to their share of the population. Evaluation data show that in 2004–05, Asian/Pacific Islander and white students were overrepresented, and black and Hispanic students underrepresented, when compared with their proportions in the sampled schools. However, compared with the distribution of students completing postsecondary degrees in engineering, each group (particularly Hispanics) had closer to proportional representation in PLTW. Females are seriously underrepresented among PLTW completers, constituting about 15% of the total. Program planners expect that female participation will increase as they introduce four new biomedical science courses in 2008–09. The biomedical courses will address topics in microbiology, physiology, public health, and legal issues.

The curriculums reinforce high-level mathematics and science content aligned with national standards using engineering applications in electronics, robotics, and manufacturing processes. PTLW participants are required to study college-preparatory mathematics every year in grades 9–12. Students work, often in teams and using computers, on challenging problemsolving and analysis tasks. Students can qualify for college credit through performance on course exams, final grades, and project portfolios. The project provides curriculums for five 9-week units for grades 6–8 and eight high school courses. Middle-grade units address topics such as modeling, electrons, automation, robotics, the science of technology, and flight. High school courses offered currently include foundation courses such as Principles of Engineering, Engineering Design, and Digital Electronics; and specialization courses including Civil Engineering and Architecture, Computer Integrated Manufacturing, Aerospace Engineering, and Biotechnical Engineering. A capstone course requires advanced students to develop a solution to a complex engineering problem with guidance from a mentor and to defend their project to external reviewers.

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* Organizations contributing to the report (Tapping America's Potential) include the Business Roundtable, the U.S. Chamber of Commerce, the National Association of Manufacturers, and the Council on Competitiveness.

† Although the report presents a dire picture of sharp declines in STEM degrees earned (particularly in engineering), in reality STEM degrees as a percentage of all degrees has fluctuated in a fairly narrow range from 1994 to 2004 at the bachelor's, master's, and doctoral levels, and near the top of the four-decade range for all but master's degrees (NSB 2006). Indeed, doctorates in engineering were 13.7% of all doctorates awarded in 2004, near the high end of their range since 1966.

Trends from 1990 to 2005 show increasing proportions of students studying most advanced mathematics and science courses, with growth especially rapid in mathematics. Students also increased course completions since 1990 in advanced biology, chemistry, and physics. Despite growth in AP/IB course completions, fewer than 10% of graduates completed any AP/IB course.

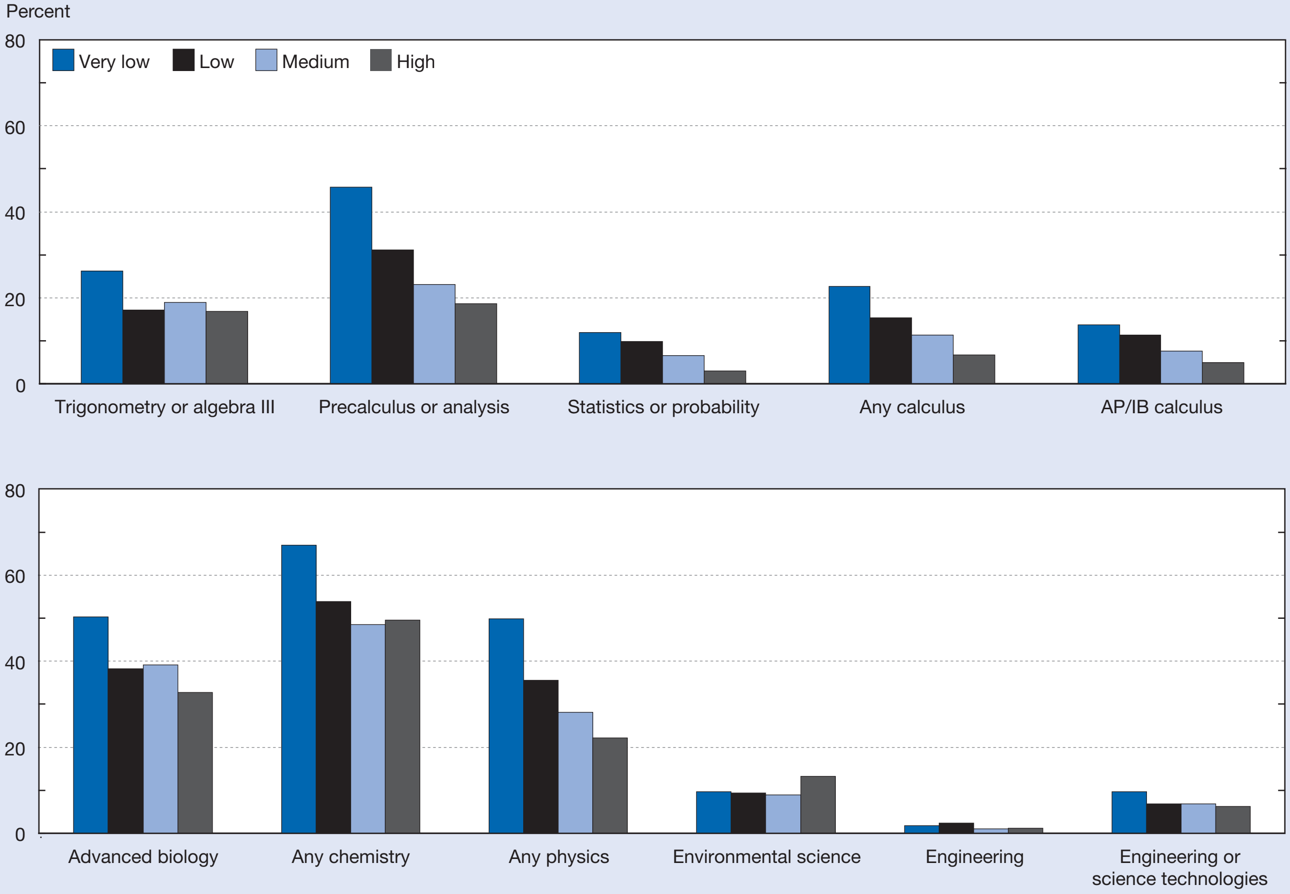
Asian/Pacific Islander students were the most likely of all racial/ethnic groups to earn credits in many mathematics and science subjects, especially in several AP/IB classes. Graduates of private schools and schools with lower poverty rates were more likely than others to study most of these advanced subjects.

Mathematics and Science Teacher Quality

Of the many factors affecting student learning, teacher quality is believed to be one of the most important. Research shows that students learn more from teachers who are skilled, experienced, and know what and how to teach (Darling-Hammond 2000; Darling-Hammond and Youngs 2002; Goldhaber 2002; Hanushek et al. 2005; Rice 2003; Wayne and Youngs 2003). The recent federal NCLB Act has focused a great deal of attention on improving teacher quality in the nation's public schools. It legislates the goal of having a highly qualified teacher in every classroom, and provides a definition of a "highly qualified teacher" (No Child Left Behind Act of 2001).[15]

Figure 1-9

High school graduates completing advanced mathematics and other S&E courses, by school poverty level: 2005



AP = Advanced Placement; IB = International Baccalaureate

NOTE: School poverty level defined as percentage of students eligible for national free/reduced-priced lunch program: very low = ≤5%, low = 6%–25%, medium = 26%–50%, and high = 51%–100%.

SOURCES: National Center for Education Statistics, National Assessment of Educational Progress, 2005 High School Transcript Study; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix tables 1-9 and 1-10.

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This section uses data from SASS to examine indicators of teacher quality, focusing on preservice preparation, degree of congruity between teachers' field of preparation and teaching assignment, and years of teaching experience.[16] The main focus is on mathematics and science teachers in public middle and high schools[17] (see sidebar "Demographic Characteristics of Mathematics and Science Teachers in U.S. Public Schools"). Although this section draws heavily on data from the 2003–04 SASS, comparable data from the 1999–2000 SASS are also used to examine changes occurring over time. When possible, measures are analyzed separately for schools with differing concentrations of minority and low-income students.

Preparation for Teaching

Formal preparation for teaching is typically indicated by highest degree and types of certification. Although having a college degree and certification do not guarantee that a teacher has the deep grasp of subject matter and the repertoire of instructional skills necessary for effective teaching (Public Agenda 2006), they represent two indicators of teacher qualification and are the two basic elements in the NCLB definition of highly qualified teachers. Experts recommend that teachers not only study varied aspects of the profession during preservice education, but also engage in extensive practical training through practice teaching, which is often a requirement for completing an educational degree or state certification, or both (NCTAF 1996; Rice 2003). The following section examines these aspects of preparation that teachers engaged in before starting work in the profession.

Table 1-6
Educational attainment of public school teachers: Academic years 1999–2000 and 2003–04
(Percent distribution)

	Academic year 1999–2000		Academic year 2003–04	
Highest degree earned	All teachers	Mathematics and science	All teachers	Mathematics and science
All teachers	100.0	100.0	100.0	100.0
<Bachelor's	0.7	0.2	1.1	0.3
≥Bachelor's	99.3	99.8	98.9	99.7
Bachelor's	52.0	48.4	50.9	50.1
Master's	42.0	45.8	40.8	43.0
>Master's	5.3	5.6	7.2	6.6

SOURCES: National Center for Education Statistics, Schools and Staffing Survey, 1999–2000 and 2003–04; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

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Highest Degree Attainment

In both 1999 and 2003, virtually all public school teachers, including those who taught mathematics and science, had attained at least a bachelor's degree and nearly half had also earned an advanced degree such as a master's or doctorate (table 1-6). However, mathematics and science teachers holding graduate degrees were not equally distributed across schools. In 2003, for example, mathematics and science teachers in low-poverty schools were more likely than their colleagues in high-poverty schools to have a master's degree or higher (appendix table 1-11).[18] Science teachers with a master's degree or higher were also more prevalent in low-minority schools than in high-minority schools.

Certification Status

In addition to teachers' formal education, certification is an important component of their qualifications. Certification is generally awarded by state education 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 some type of formal test(s) (Kaye 2002). Most teachers complete regular certification programs before beginning to teach. In 2003, 88% of all public school teachers and 84% of mathematics and science teachers held regular or advanced certification (hereinafter called *full certification*) issued by their state (table 1-9). However, fully certified

Demographic Characteristics of Mathematics and Science Teachers in U.S. Public Schools

In 2003, about 3.2 million teachers were employed in U.S. public elementary and secondary schools (table 1-7). About 231,000 were mathematics teachers and 208,000 were science teachers, based on main assignment field (the subject in which they taught the most classes).

The U.S. public school teaching force increased by 7% from 1999 to 2003; the numbers of mathematics and science teachers increased even more, by 11% and 14%, respectively. Most of these increases have occurred in middle schools or in schools with the highest concentrations of minority and poor students. In contrast, and to place these increased staffing levels in perspective, public school enrollment rose by 3%, from 46.9 million in 1999 to 48.5 million in 2003 (NCES 2006c).

In both 1999 and 2003, three of every four public school teachers were female (table 1-8). However, the predominance of female teachers was less pronounced at the high school level. In 2003, for example, 56% of public high school teachers were women. The sex distribution among public school mathematics and science teachers reflects the overall pattern.

Public school teachers were also predominantly white. In both 1999 and 2003, black and Hispanic teachers accounted for 8% and 6%, respectively, and other racial/ethnic groups accounted for less than 3%. The racial and ethnic distributions among middle and high school mathematics and science teachers resemble the overall pattern. Although the share of black and Hispanic teachers among middle and high school mathematics and science teachers appeared to increase between 1999 and 2003, these changes were not statistically significant.

The average age of the teacher workforce increased slightly over this period. In 1999, 29% of public school teachers were at least 50 years old; that percentage rose to 33% in 2003. Similar trends were also observed among middle and high school mathematics and science teachers. These trends suggest that more teachers are approaching retirement age and that recruitment needs may exceed recent levels.

Table 1-7

Public school teachers, by minority enrollment and school poverty level: Academic years 1999–2000 and 2003–04

	All teachers			Mathematics teachers			Science teachers		
School characteristic	1999–2000	2003–04	Change (%)	1999–2000	2003–04	Change (%)	1999–2000	2003–04	Change (%)
All public schools	2,986,000	3,220,000	7.3	206,000	231,000	10.8	180,000	208,000	13.5
Middle schools	517,000	590,000	12.4	65,000	74,000	12.2	59,000	73,000	19.2
Minority enrollment (%)									
0–5	120,000	89,000	–34.8	15,000	10,000	–50.0	13,000	11,000	–18.2
>5–45	239,000	274,000	12.8	30,000	33,000	9.1	28,000	33,000	15.2
>45	157,000	227,000	30.8	20,000	30,000	33.3	17,000	29,000	41.4
School poverty level (%)[a]									
0–10	82,000	67,000	–22.4	12,000	9,000	–33.3	9,000	7,000	–28.6
>10–50	260,000	331,000	21.5	31,000	39,000	20.5	30,000	39,000	23.1
>50	140,000	190,000	26.3	17,000	25,000	32.0	15,000	26,000	42.3
High schools	892,000	888,000	–0.5	114,000	117,000	2.6	103,000	102,000	–1.0
Minority enrollment (%)									
0–5	219,000	159,000	–37.7	26,000	20,000	–30.0	27,000	17,000	–58.8
>5–45	424,000	390,000	–8.7	55,000	51,000	–7.8	49,000	47,000	–4.3
>45	245,000	339,000	27.7	32,000	47,000	31.9	26,000	39,000	33.3
School poverty level (%)[a]									
0–10	233,000	166,000	–40.4	30,000	22,000	–36.4	29,000	21,000	–38.1
>10–50	430,000	520,000	17.3	57,000	70,000	18.6	47,000	59,000	20.3
>50	142,000	165,000	13.9	17,000	22,000	22.7	16,000	18,000	11.1

[a] School poverty level is percentage of students in school qualifying for free/reduced-price lunch. Numbers may not add to total because of rounding.

SOURCES: National Center for Education Statistics, Schools and Staffing Survey, 1999–2000 and 2003–04; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

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Table 1-8

Demographic characteristics of public school teachers: Academic years 1999–2000 and 2003–04

(Percent)

	Sex		Race/ethnicity			Age (years)				
Public school teachers	Male	Female	White, non-Hispanic	Black, non-Hispanic	Hispanic	<30	30–39	40–49	50–59	≥60
Academic year 1999–2000										
All teachers	25.1	74.9	84.3	7.5	5.6	17.0	22.0	31.8	26.1	3.1
Middle school	28.9	71.1	83.8	9.0	5.3	18.6	21.1	33.4	24.7	2.2
Mathematics	29.1	70.9	85.2	9.7	3.2	20.8	20.4	31.7	24.6	2.6
Science	36.6	63.4	85.8	7.0	4.3	24.6	21.9	31.7	19.7	2.2
High school	45.1	54.9	86.1	6.4	5.1	16.1	21.6	30.5	28.6	3.2
Mathematics	47.5	52.5	87.1	6.0	3.8	21.2	24.7	25.5	26.3	2.4
Science	55.2	44.8	87.7	5.7	3.9	17.9	25.9	28.6	24.9	2.6
Academic year 2003–04										
All teachers	25.1	74.9	83.1	7.9	6.2	16.6	24.6	25.8	29.0	4.0
Middle school	31.1	68.9	82.6	10.1	5.1	16.6	25.1	26.9	27.9	3.4
Mathematics	32.4	67.6	82.1	12.5	3.7	19.1	28.5	22.6	27.3	2.6
Science	41.7	58.3	80.6	11.7	6.1	16.2	24.4	27.5	27.4	4.6
High school	43.7	56.3	84.5	7.2	5.5	15.1	24.6	25.3	30.1	5.0
Mathematics	43.5	56.5	83.6	7.1	6.1	16.6	29.1	24.2	26.3	3.9
Science	51.0	49.0	86.3	6.7	4.3	16.1	26.8	26.3	25.5	5.3

NOTES: Racial/ethnic categories Asians/Pacific Islanders, American Indians/Alaska Natives, and “more than one race” not shown because of small sample sizes. More than one race not a response category in 1999, and thus 1999 and 2003 data are not strictly comparable.

SOURCES: National Center for Education Statistics, Schools and Staffing Survey, 1999–2000 and 2003–04; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

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teachers were more common in schools with lower proportions of minority and poor students (appendix table 1-12).

In response to a growing demand for teachers because of increased enrollment and reduced class size, many states have also developed various alternative certification programs allowing individuals to become teachers without first completing a regular certification program (Shen 1997). Depending on the particular requirements completed, these individuals are typically awarded probationary, provisional/temporary, or emergency licenses.[19] In 2003, 11% of all public school teachers and 15% of mathematics and science teachers held one of these kinds of certification (table 1-9).

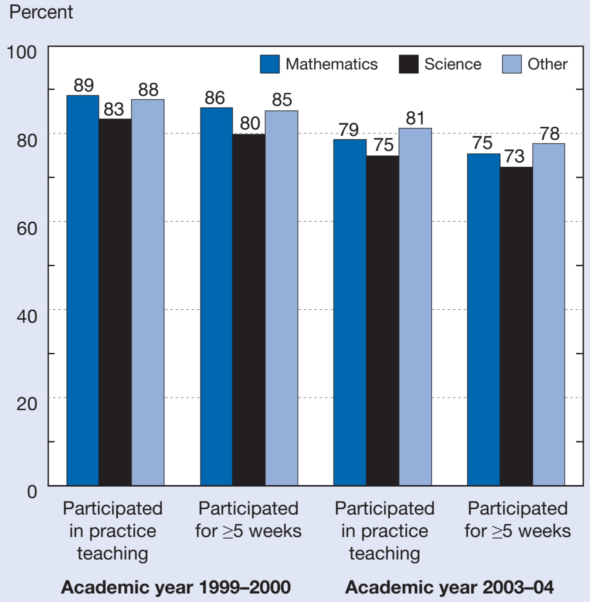
Some states still allow public schools to hire teacher candidates who do not have a license. However, this practice has significantly decreased during recent years; between 1999 and 2003, the percentage of public school mathematics and science teachers who did not have a teaching certificate declined from 10% to 1%.

Practice Teaching

The majority of public middle and high school mathematics and science teachers with less than 5 years of teaching experience (hereinafter called *beginning teachers*) had participated in practice teaching before starting the job; many had practiced for at least 5 weeks (figure 1-10).[20] However, participation in practice teaching has declined in recent years. In 1999, 83%–89% of beginning mathematics and science teachers reported participation in practice teaching for some period of time. These percentages dropped to 75%–79% in 2003. In addition, teachers with practice teaching were not evenly distributed across schools: the percentage of beginning mathematics and science teachers who had any practice teaching was inversely related to school concentrations of minority and poor students (appendix table 1-13).

Figure 1-10

Practice teaching of public middle and high school teachers with less than 5 years of teaching experience: Academic years 1999–2000 and 2003–04



SOURCES: National Center for Education Statistics, Schools and Staffing Survey, 1999–2000 and 2003–04; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

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Self-Assessment of Preparedness

Public middle and high school teachers generally felt well prepared to perform various tasks during their first year of teaching (figure 1-11), particularly teaching the subject

Table 1-9

Type of certification of public school teachers: Academic years 1999–2000 and 2003–04

(Percent distribution)

	Academic year 1999–2000		Academic year 2003–04	
Type of certification	All teachers	Mathematics and science	All teachers	Mathematics and science
All teachers	100.0	100.0	100.0	100.0
Regular or advanced	86.6	81.0	87.6	84.1
Probationary	2.8	3.4	3.8	4.7
Provisionary or alternative	3.2	3.6	4.3	6.3
Temporary	1.1	1.3	2.2	2.8
Emergency	0.6	1.0	0.7	0.7
None	5.8	9.8	1.5	1.3

NOTE: Percents may not add to 100 because of rounding.

SOURCES: National Center for Education Statistics, Schools and Staffing Survey, 1999–2000 and 2003–04; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

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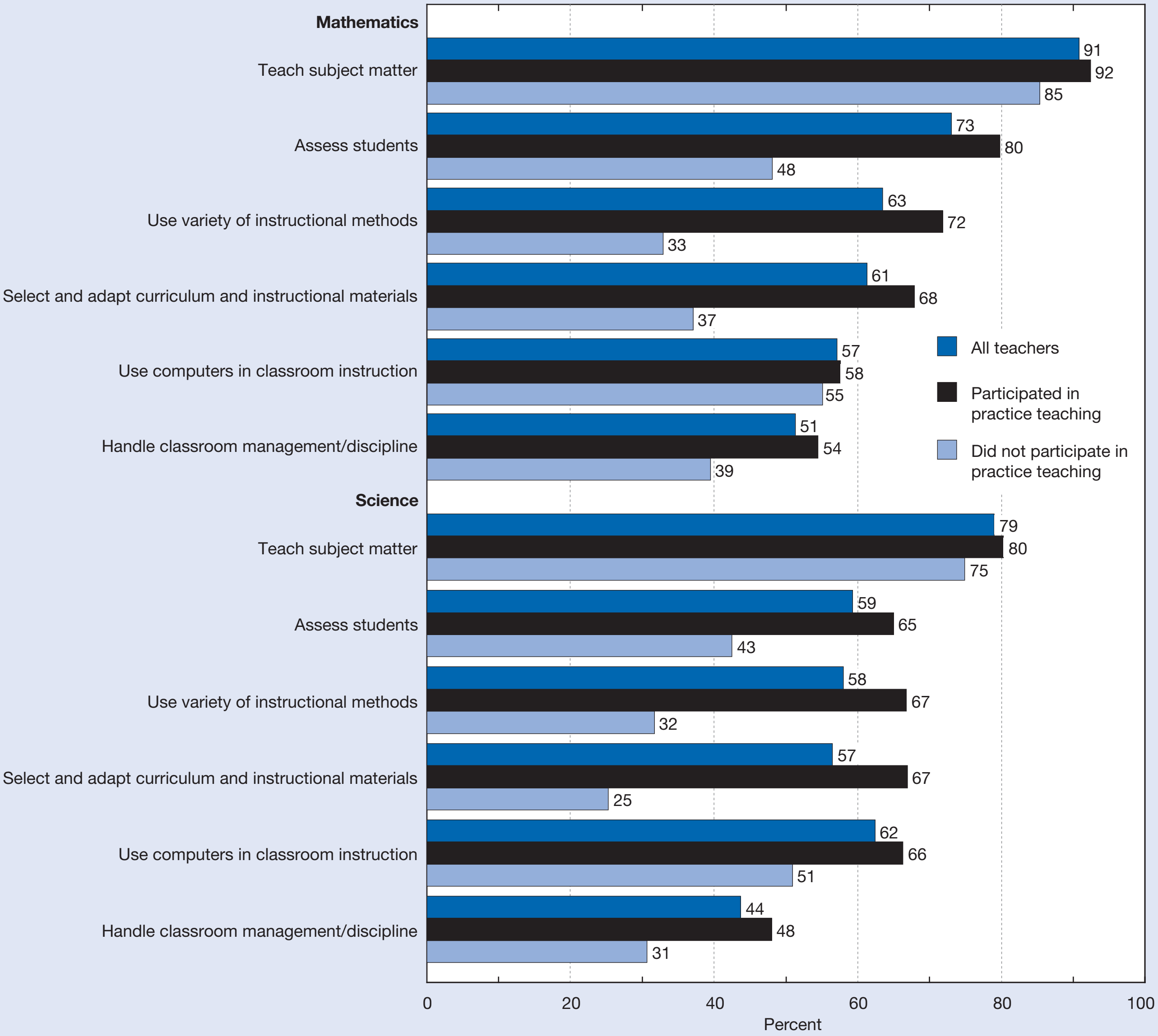
Figure 1-11

Preparedness for first-year teaching of public middle and high school mathematics and science teachers with less than 5 years of experience, by participation in practice teaching: Academic year 2003–04



NOTES: Teachers with <5 years of teaching experience asked about how well they were prepared to perform various tasks during first year of teaching. Response categories included “very well prepared,” “well prepared,” “somewhat prepared,” and “not at all prepared.” Percentages based on teachers who responded “very well prepared” or “well prepared.”

SOURCES: National Center for Education Statistics, Schools and Staffing Survey, 2003–04; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

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matter (79%-91%). Mathematics teachers were more likely than science teachers to report feeling that they had strong preparation for various tasks except for using computers to teach. In general, beginning teachers who taught in schools with lower minority enrollment and poverty rates expressed more confidence about handling their first teaching assignment (appendix table 1-14).

Teacher confidence about preparation for their first teaching job was related to practice teaching. Beginning mathematics and science teachers who participated in practice teaching were more likely than their counterparts without any practice teaching to report feeling well prepared to perform various teaching tasks (figure 1-11).

Match Between Teacher Preparation and Assignment

Over the past decade, no issue related to teacher quality has received more attention than out-of-field teaching in the nation's middle and high schools (Ingersoll 2003; Jerald 2002; Peske and Haycock 2006). This issue is crucial because even well-educated and fully certified teachers may be unqualified, in practical terms, if they are assigned to teach subjects for which they have little formal preparation. To determine how many teachers are teaching their subjects without specific kinds of formal training in those subjects, efforts have focused on the nature of teacher qualifications (postsecondary coursework or state certification in their teaching assignment field) (Ingersoll 1999, 2003; NCTAF 1996). Teachers without qualifications in their teaching assignment fields are described as teaching *out of field.*

The following indicators use SASS data to examine the scope of out-of-field teaching among public middle and high school mathematics and science teachers in academic year 2003. The sidebar "In-Field and Out-of-Field Teaching" provides the detailed definitions used in this section.

Mathematics

In 2003, over half (54%) of mathematics teachers in public middle schools were teaching in field (table 1-10). Five percent were teaching out of field; that is, they taught mathematics with neither a major nor certification in mathematics, related fields, or general education. At the high school level, a substantial majority of mathematics teachers were in field (87%), and about 8% were teaching out of field.

Biological/Life Sciences

More than half (55%) of biology/life science teachers (hereinafter called *biology teachers*) at the middle school level were teaching in field. About 10% of middle school biology teachers were teaching out of field, about twice the proportion of middle school mathematics teachers. The vast majority of high school biology teachers (92%) were teaching in field, and 3% were teaching out of field.

In-Field and Out-of-Field Teaching

Different researchers (and previous editions of *Indicators*) have defined out-of-field teaching in different ways (Ingersoll 1999, 2003; McGrath, Holt, and Seastrom 2005; Seastrom et al. 2002). Estimates of how widespread out-of-field teaching is depend on how strictly the concept is defined. This section uses a four-level indicator of the linkage between preparation for teaching science and mathematics courses and the main teaching assignment reported by teachers in SASS.

In the following definitions *full certification* includes regular, advanced, or probationary certification status. *Major* refers to the field of study for an undergraduate or graduate degree. Unlike related concepts used in the research literature, this definition recognizes general preparation. State certification regulations vary about whether they treat middle-grade teachers more like elementary teachers (thus requiring a general education credential that covers some preparation in core academic subjects) or more like secondary teachers (requiring single-subject credentials). In some states, the most common type of certification for middle-grade teachers is a general elementary certificate.

The four levels of the indicator are as follows (in decreasing strength of linkage between teacher preparation and the teacher's main assignment field).

In-field. In-field teachers have either a major or full certification in their main teaching field, or both. For example, a mathematics teacher is in field if he or she majored in mathematics or is fully certified in mathematics.

Related-field. Related-field teachers have either a major or full certification in a field related to their main teaching field, or both. For example, a related-field mathematics teacher has a major or full certification in computer science, engineering, or physics.

General preparation. General preparation teachers have either a major or full certification in general elementary, middle, or secondary education. For example, a physics teacher has general preparation if he or she has a major or full certification in general elementary, middle, or secondary education.

Out-of-field. Out-of-field teachers have neither a major nor full certification in their main teaching field, a related field, or general elementary, middle, or secondary education. For example, a biology/life science teacher is teaching out-of-field if he or she has neither a major nor certification in biology, a related field (e.g., physics, chemistry, earth science), or general elementary, middle, or secondary education.

This indicator cannot be used as a gauge of teacher competence because indicators of quality teaching include many other characteristics that are difficult and costly to measure, such as commitment to the profession, sense of responsibility for student learning, and ability to motivate students and diagnose and remedy their learning difficulties. Nevertheless, research, policy, and legislation (e.g., NCLB) point to in-field teaching as a desirable national goal, and states, schools, and school systems administrators can look to this indicator as they engage in efforts to improve teaching.

The discussion in this section focuses on the polar categories of in-field and out-of-field teaching. Appendix table 1-15 also provides data on the nation's teachers of mathematics, biology/life science, and physical sciences who fall between these two extremes.

Table 1-10
In-field and out-of-field teaching of public middle and high school mathematics, biology/ life science, and physical science teachers: Academic year 2003–04
(Percent)

Level/field	In-field teaching	Out-of-field teaching
Middle school		
Mathematics	53.5	5.1
Biology/life sciences	54.8	9.5
Physical sciences	32.7	3.1
High school		
Mathematics	87.4	7.5
Biology/life sciences	91.9	3.2
Physical sciences	78.1	1.5

SOURCES: National Center for Education Statistics, Schools and Staffing Survey, 2003–04; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix table 1-15.

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Physical Sciences

Overall, physical science teachers were less qualified on this indicator than mathematics and biology teachers. At the middle school level, 33% of physical science teachers were teaching in field and 3% were teaching out of field. At the high school level, 78% of physical science teachers were teaching in field and 2%, out of field.

Variation Across Schools

In-field and out-of-field teachers were not distributed evenly across schools (appendix table 1-15). In general, mathematics and science teachers in schools with lower concentrations of minority and poor students were more likely to be teaching in field, and those in schools with higher concentrations of minority and poor students were more likely to be teaching out of field. Among high school mathematics teachers, for example, 10% of those in high-minority schools taught mathematics out of field compared with 3% of their counterparts in low-minority schools. Among high school physical science teachers, 86% in low-poverty schools were teaching in field, compared with 77% in high-poverty schools.

Teaching Experience

Although experience does not guarantee quality teaching, empirical evidence indicates that teachers who have at least several years of teaching experience are generally more effective than new teachers in helping students learn (Fetler 1999; Hanushek et al. 2005; Murnane and Phillips 1981; Rivkin, Hanushek, and Kain 2000; Rowan, Correnti, and Miller 2002). The following discussion focuses on new mathematics and science teachers (those with 3 or fewer years of teaching experience) and how they are distributed across schools.

In 2003, new teachers made up 17%–22% of mathematics teachers and 15%–19% of science teachers in public middle and high schools (appendix table 1-16). At the middle school level, the proportion of new teachers was greater among mathematics teachers (22%) than among science teachers or teachers in other fields (15% for both). The difference was not observed at the high school level, however. In general, high-minority and high-poverty schools were more likely than low-minority and low-poverty schools to have new mathematics and science teachers. This was particularly true for mathematics teachers in middle schools: in high-minority and high-poverty middle schools, 28%–33% of mathematics teachers were new teachers, but in low-minority and low-poverty schools, the percentages were 15%–18%.

Summary

Virtually all public school mathematics and science teachers had a bachelor's degree and nearly 9 in 10 held full state certification. The majority of beginning mathematics and science teachers in public middle and high schools had also participated in practice teaching before starting their first teaching job, although the percentage of teachers with practice teaching experience declined from 1999 to 2003. Teachers with preservice practice teaching had greater confidence about their ability to handle their first teaching assignment.

More than three-fourths of mathematics and science teachers in public high schools were teaching in field. However, in-field teaching was less common at the middle school level. Overall, out-of-field teaching ranged from 3% of physical science teachers to 10% of biology teachers in middle schools and from 2% of physical science teachers to 8% of mathematics teachers in high schools. All indicators examined in this section showed a general pattern of unequal access to the most qualified teachers: low-minority and low-poverty schools were more likely than high-minority and high-poverty schools to have teachers with more education, better preparation and qualifications in their field, and more experience.

Professional Development of Mathematics and Science Teachers

Teacher professional development is a major component of current reform policies (Cohen and Hill 2001; Darling-Hammond 2005; Hirsch, Koppich, and Knapp 2001; Little 1993) (see sidebar "State Professional Development Policies for Teachers"). To help all students meet the high educational standards necessary to participate in the global workforce, today's teachers are being called on to provide their students with a high-quality education and to teach in ways they have never taught before. The nature and magnitude of changes demanded by these reform policies require a great deal of learning on the part of teachers. Ongoing professional development provides a vehicle for teachers to gain such learning (NCTAF 1997; NRC 2007). Research has demonstrated that sustained and intensive participation in

State Professional Development Policies for Teachers

For two decades, the U.S. government has made teacher professional development a component of its reform efforts (Little 1993; Porter et al. 2000), and many states have developed and implemented policies designed to promote participation in professional development (CCSSO 2005, 2007; Editorial Projects in Education 2006). A total of 48 states required professional development for teacher license renewal in both 2002 and 2006 (table 1-11). Between 2004 and 2006, the number of states that had standards in place for professional development increased from 35 to 40, as did those that financed professional development programs (37 to 39), provided professional development funds for all districts in the state (27 to 31), and required districts or schools to set aside teacher time for professional development (13 to 15). In 2006, 15 states also required and financed mentoring programs for all novice teachers.

Table 1-11
States with various professional development policies for teachers: 2004 and 2006

Statewide policy	2004	2006
Required professional development for teacher license renewal	48[a]	48
Wrote professional development standards	35	40
Financed professional development	37	39
Financed professional development for all districts in state	27	31
Required and financed mentoring for all novice teachers	16	15
Required districts/schools to set aside time for professional development	13	15

[a]2002 count.

SOURCES: Council of Chief State School Officers, Key State Education Policies on PK-12 Education: 2002 (2002); Key State Education Policies on PK-12 Education: 2006 (2007); Editorial Projects in Education 2005, State of the states, *Education Week: Quality Counts* 24(17); and Quality counts at 10: A decade of standards-based education, *Education Week: Quality Counts 2006* 25(17).

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high-quality professional development can change teacher attitudes, behaviors, and the instructional practices they use in the classroom (Banilower et al. 2005; Garet et al. 2001; Guskey 2003; Hawley and Valli 2001; Porter et al. 2000). Furthermore, student learning increased when their teachers changed in these ways (Cohen and Hill 2000; Desimone et al. 2002; Holland 2005; Wenglinsky 2002).

This section examines several indicators of teacher professional development, including new teacher induction; features of teacher participation in professional development (i.e., content, duration, format, and extent of collaboration); teacher assessments of the usefulness of professional development activities; and their priorities for future activities. These indicators help determine the extent to which effective features of professional development exist at the national level.

New Teacher Induction

Research suggests that teachers with less experience, particularly those in their first year of teaching, are less effective in the classroom (Murnane and Phillips 1981). Without sufficient support and guidance, novice teachers may reduce their commitment to teaching and may leave the profession altogether (Smith and Ingersoll 2004; Smith and Rowley 2005). Teacher induction programs are designed at the school, local, or state level to assist and support beginning teachers in their first few years of teaching (Fulton, Yoon, and Lee 2005).[21] The purpose is to help new teachers improve professional practice, deepen their understanding of teaching, and prevent early attrition (Britton et al. 2003; Smith and Ingersoll 2004). One key component of such programs is that new teachers are paired with mentors or other experienced teachers to receive advice, instruction, and support.

Participation in induction and mentoring programs has been fairly common and has become more so in recent years. In 2003, 68%–72% of beginning mathematics and science teachers in public middle and high schools reported that they had participated in a formal teacher induction program or had worked closely with a mentor teacher during their first year of teaching (appendix table 1-17). However, smaller proportions of these teachers had worked closely with a mentor in the same subject field (50%–52%). Teacher participation in induction and mentoring programs was lower in schools with high concentrations of minority and low-income students.

Ongoing Professional Development

Almost all teachers participate in some form of professional development activities every school year (Choy, Chen, and Bugarin 2006; Scotchmer, McGrath, and Coder 2005). It is important not only to make professional development accessible to teachers, but also to identify features that bring about positive changes in teaching practices and student learning and to build these features into the activities (Elmore 2002; Garet et al. 2001; Guskey 2003; Hawley and Valli 2001; Loucks-Horsley et al. 2003). Recognizing this new need, the education research community began to develop a knowledge base of what constitutes effective professional development programs. Several key features have been identified that are linked to positive change in teacher knowledge and instructional practices, including content focusing on teacher subject-matter knowledge or how students learn the subject content; programs of long and sustained duration (recent research suggests at least 80 hours); program content integrated into teachers' daily work, rather than removed from the context of direct teaching (as in traditional workshops); and emphasis on a team approach and collaboration among teachers (Banilower et al. 2005; Clewell et al. 2004; Cohen and Hill 2000; Desimone et al. 2002; Garet et al. 2001; Porter et al. 2000). The following indicators examine the extent to which public middle and high school mathematics and science teachers participated in professional development that had these characteristics.

Content

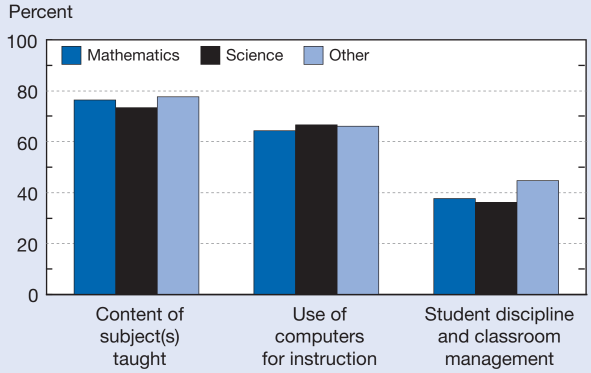
Professional development activities tend to focus on a few topics and teaching skills, frequently on the teacher's main teaching subject. In 2003, more than 70% of mathematics, science, and other subject-area teachers in public middle and high schools reported participation in professional development that focused on the content of the subjects they taught (figure 1-12). Another frequent topic of professional development is using computers for instruction: 64%–67% of teachers reported receiving professional development on this topic. Relatively fewer teachers (38%–45%) participated in professional development related to student discipline and classroom management.

Participation rates varied across schools. Mathematics and science teachers who taught in high-minority and high-poverty schools were more likely than those in low-minority and low-poverty schools to report receiving professional development on subject matter and on student discipline and classroom management (appendix table 1-18).[22]

Duration

Recent research emphasizes intensive participation as a critical feature of effective professional development. Teachers are likely to benefit more from professional development programs that are sustained over an extended period of time and involve a significant number of hours. Some studies recommend at least 60–80 hours to bring about meaningful change in teaching practice (Banilower et al. 2005; Supovitz and Turner 2000; Weiss, Banilower, and Shimkus 2004). However, few teachers participated in professional development programs for this amount of time. In 2003, between 4% and 28% of mathematics and science teachers in public middle and high schools reported attending professional development on various topics for 33 or more hours over the course of a school year (figure 1-13). Most teachers received 9–32 hours of professional development on their subject matter or 8 or fewer hours of professional development on using computers for classroom instruction or on student discipline and classroom management.[23] Thus, the amount of time teachers devoted to professional development may be less than research suggests may be optimal.

Figure 1-12
Professional development of public middle and high school teachers during past 12 months, by topic: Academic year 2003–04



SOURCES: National Center for Education Statistics, Schools and Staffing Survey, 2003–04; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix table 1-18.

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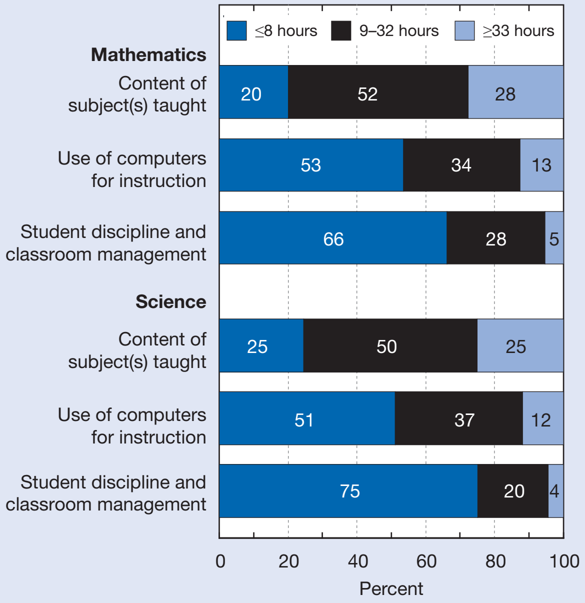
Formats

The *format* of professional development refers to the way in which a professional development activity is delivered. For many years, teacher professional development has been primarily through district- or school-sponsored workshops, conferences, and training sessions (Choy and Chen 1998; Choy, Chen, and Bugarin 2006; Parsad, Lewis, and Farris 2001). In 2003, more than 90% of public middle and high school mathematics, science, and other subject-area teachers participated in professional development through workshops, conferences, and training sessions (figure 1-14). Although

Figure 1-13
Professional development of public middle and high school teachers during past 12 months, by topic and time spent: Academic year 2003–04



SOURCES: National Center for Education Statistics, Schools and Staffing Survey, 2003–04; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

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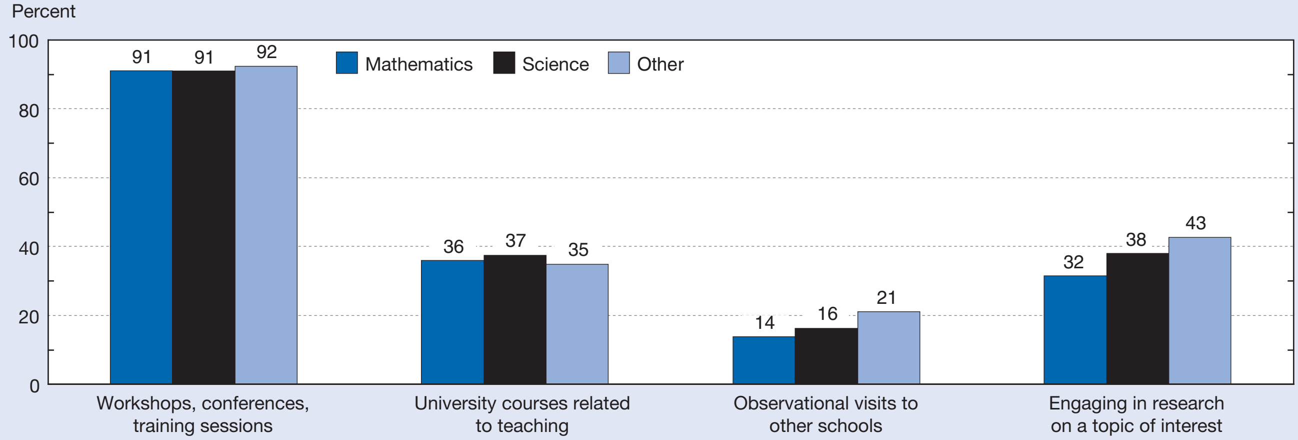
Figure 1-14
Professional development of public middle and high school teachers during past 12 months, by format: Academic year 2003–04



SOURCES: National Center for Education Statistics, Schools and Staffing Survey, 2003–04; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

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some teachers took postsecondary courses, the percentages were much lower (35%-37%). Participation in such activities as visiting other schools or conducting research on a topic of interest was also not common (14%–43%).[24]

Collaborative Participation

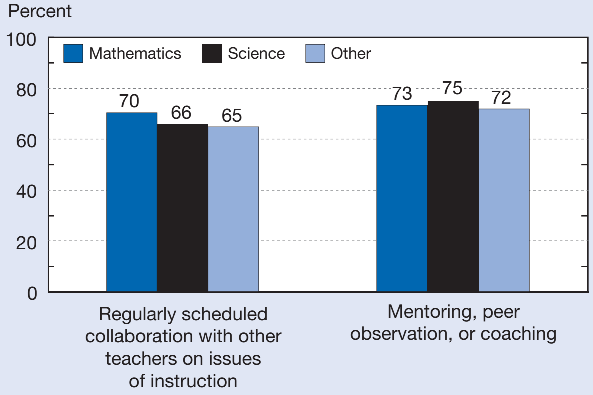
Collaborative participation, which involves professional development designed for groups of teachers from the same school, department, and grade level, fosters cooperation and interaction among teachers (Garet et al. 2001; Desimone et al. 2002). Two constructs were used here to measure this concept, regularly scheduled collaboration with other teachers on issues of instruction and participation in mentoring, peer observation, or coaching. Based on these measures, teacher collaboration was common. In 2003, about two-thirds of public middle and high school mathematics, science, and other subject-area teachers reported that they had collaborated regularly with other teachers on matters of instruction (figure 1-15). More than 70% of these teachers reported that they had participated in peer observation, mentoring, or coaching activities.[25]

Teacher Assessment of Professional Development

Were professional development activities useful to teachers? Teachers' assessments of their professional development activities were generally positive. In 2003, 62%–69% of mathematics, science, and other subject-area teachers in public middle and high schools rated activities on subject content and use of computers for instruction as "useful" or "very useful" (appendix table 1-19). Between 53% and 59% of participants gave similar ratings to the topic of student discipline and classroom management.

Teachers' assessments were strongly related to the amount of time they spent on these activities. For each topic, the more time teachers spent in professional development, the more likely they were to indicate that it was useful or very useful. This relationship held for mathematics, science, and other subject-area teachers.

Figure 1-15
Collaborative professional development activities of public middle and high school teachers: Academic year 2003–04



SOURCES: National Center for Education Statistics, Schools and Staffing Survey, 2003–04; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

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Teacher Priorities for Professional Development

In addition to assessing the usefulness of the programs they attended, teachers identified their priorities for future professional development. Public middle and high school mathematics and science teachers rated their main subject field and the use of technology for instruction as their top interest for future professional development (appendix table 1-20). Teachers in other subject areas had somewhat different priorities. Although the main subject field was also their top pick (24%), many also chose student discipline and classroom management (19%) and teaching students with special needs or limited English proficiency (18%).

Teachers in different types of schools had different priorities. For example, mathematics and science teachers in high-minority and high-poverty schools were more likely to identify student discipline and classroom management as their top priority, whereas their colleagues in low-minority and low-poverty schools were more likely to pick the content of the main subject field.

Summary

Induction and mentoring programs are designed to help new teachers become more effective and stay in teaching. These programs are presently widely implemented in public schools. Teacher participation in professional development was also common. In 2003, for example, more than 70% of public middle and high school mathematics and science teachers reported participation in professional development that focused on the content of the subject matter they taught. However, although recent research has found that intensive participation lasting at least 60–80 hours might be necessary to bring about meaningful change in teaching practice, just 4%–28% of mathematics and science teachers in public middle and high schools attended a professional development program for 33 hours or more over a school year, suggesting that the current amount of time devoted to teacher professional development may not be enough.

The majority of teachers participated in professional development by attending workshops, conferences, and training sessions. Most teachers indicated that the professional development programs in which they participated were useful, especially those that emphasized the content of their subject matter and the use of computers for instruction. Teachers also rated more highly professional development programs that were of longer duration.

Teacher Salaries, Working Conditions, and Job Satisfaction

The challenge of staffing the nation's schools with highly qualified teachers has turned policymaker and researcher attention to the issues of hiring and retention. Reports of difficulty in hiring teachers in elementary and secondary schools began to emerge in the early 1990s and have continued in recent years (Arnold and Choy 1993; BHEF 2007; Broughman and Rollefson 2000; Carroll, Reichardt, and Guarino 2000; Guarino, Santibanez, and Daley 2006; Murphy, DeArmond, and Guin 2003; NCTAF 1996, 2003). Although there have been various explanations for this situation,[26] current research suggests that in recent years hiring difficulty was primarily caused by large numbers of teachers leaving the profession before regular retirement age (Cochran-Smith 2004; Ingersoll 2001, 2004, 2006; Merrow 1999; Wayne 2000) (see sidebar "Attrition From Teaching"). Filling vacancies, seeking qualified candidates, and introducing and mentoring new teachers all involve financial costs (Brenner 2000). The consequences could be even worse if unqualified or partially qualified individuals have to be hired to replace those who leave (NCTAF 2003).

Why do teachers leave their jobs before retirement? What makes them want to stay in the profession? Researchers have addressed these important questions (Guarino, Santibanez, and Daley 2006). Although many factors can influence teachers' decisions about leaving or staying in their jobs, results from past research consistently indicate that teacher working conditions and salary levels are critical in such decisions (Boyd et al. 2005; Dolton and Wilbert 1999; Hanushek, Kain, and Rivkin 2004; Ingersoll 2006; Loeb, Darling-Hammond, and Luczak 2005; Perie and Baker 1997). The research evidence suggests that adequate compensation and safe and supportive school environments serve to attract and retain teachers, whereas low pay and poor working conditions undermine teachers' long-term commitment to their jobs.

This section examines several indicators related to teacher working conditions, including their salaries, perceptions of their work environments, overall job satisfaction, and willingness to continue to teach. To provide a context for such a discussion, the section begins by examining whether there has been an insufficient number of teachers in mathematics and science in recent years. It concludes by looking at how various aspects of teacher work environments are linked to their long-term commitment to teaching as a career and profession.

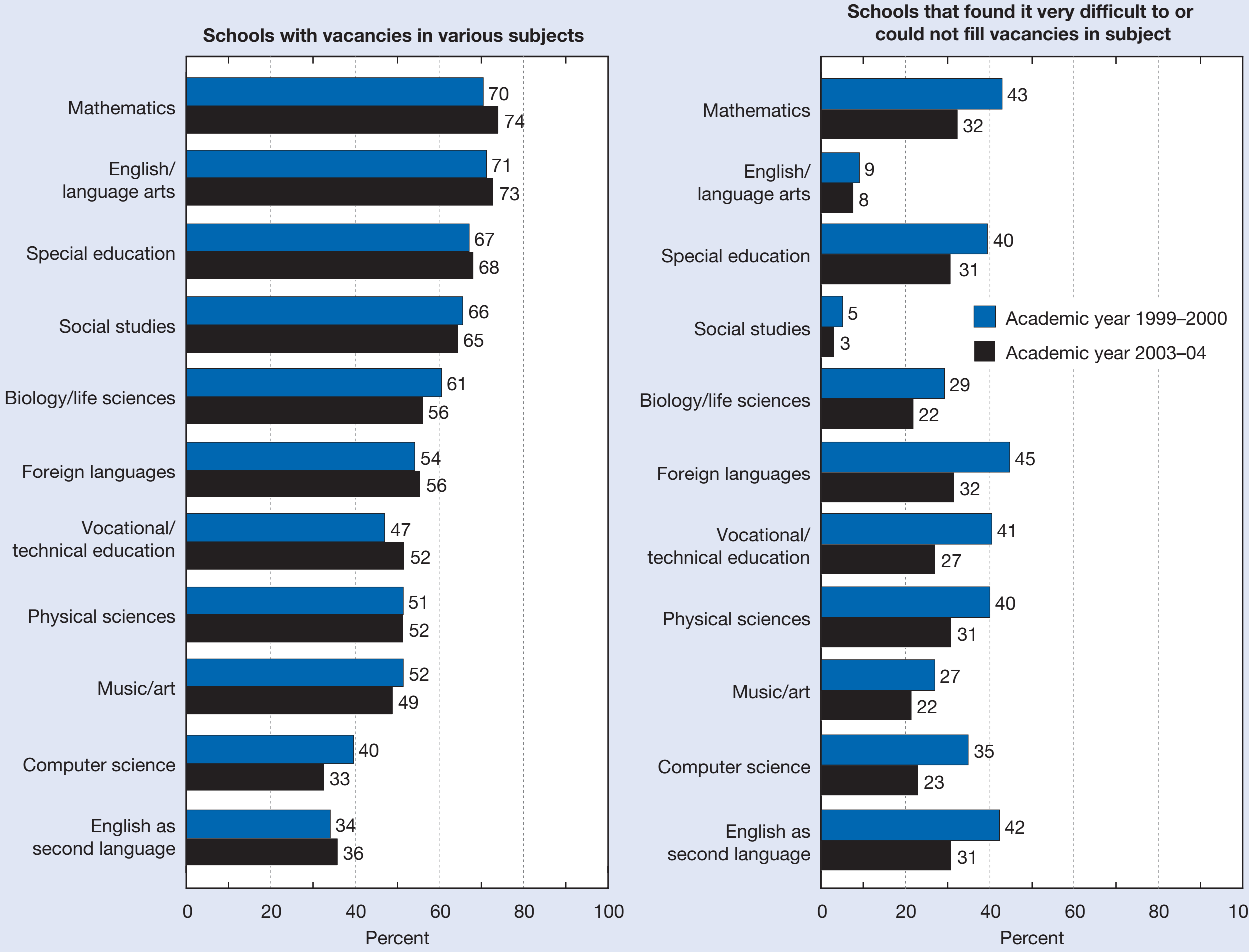
Teaching Vacancies in Mathematics and Science

Researchers have used various methods to determine the extent of any possible teacher shortage,[27] including counting the number of teachers holding alternative or emergency licenses; estimating the net effects of student enrollment, teacher retirement, and teacher attrition; and assessing teaching vacancy rates (Arnold and Choy 1993; Broughman and Rollefson 2000; Carroll, Reichardt, and Guarino 2000; Guarino, Santibanez, and Daley 2006; Henke et al. 1997; Murphy, DeArmond, and Guin 2003). Although none of these methods has proven perfect, researchers found some consistent patterns: teacher shortages existed in specific subject fields, in geographic locations, and in some individual schools. For example, teacher shortages occurred more frequently in certain states where the population grew fast because of immigration and high rates of childbirth (e.g., California, Texas, and Florida); in specific subjects such as mathematics, science, special education, and bilingual education; and in schools located in high-poverty areas (Boe et al. 1998; Howard 2003; Wayne 2000). The following analysis uses school reports of teaching vacancies to evaluate whether there were insufficient numbers of mathematics and science teachers in public secondary schools.

Administrators of schools that participated in SASS were asked whether, in the current school year, their schools had vacancies in various fields (i.e., teaching positions needing to be filled) and how difficult it was to fill these vacant positions. The majority of public secondary schools experienced teaching vacancies in one or more fields (figure 1-16). The vacancy rate decreased somewhat during recent years; still, 80% of public secondary schools reported teaching vacancies in 2003. In both 1999 and 2003, mathematics was one of the fields that had a relatively high vacancy rate. In 2003, for example, 74% of public secondary schools with any teaching vacancy reported at least one vacant position in mathematics. Vacancy rates for biology/life and physical sciences were also high, with 52%-56% reporting at least one vacant position in these fields.

The data in figure 1-16 further reveal that mathematics and physical sciences were among the most difficult fields in which to find teachers in both 1999 and 2003.[28] Although this situation has improved during recent years, close to one-third of public secondary schools with teacher vacancies in mathematics and physical sciences in 2003 either found them very difficult to fill or were unable to do so. Although secondary schools had a high teacher vacancy rate in biology/

Figure 1-16
Teaching vacancies at public secondary schools, by subject: Academic years 1999–2000 and 2003–04



NOTES: Teaching vacancies are teaching positions needing to be filled in current school year. Secondary schools had any of grades 7–12 and none of grades K–6. Schools with any vacancy are base (denominator) in left panel (88% in 1999–2000, 80% in 2003–04); schools with vacancy in subject listed in left panel are base for corresponding subject in right panel.

SOURCES: National Center for Education Statistics (NCES), Schools and Staffing Survey, 1999–2000; and Strizek GA, Pittsonberger JL, Riordan KE, Lyter DM, Orlofsky GF, Characteristics of Schools, Districts, Teachers, Principals, and School Libraries in the United States: 2003–04, NCES 2006-313 (2006).

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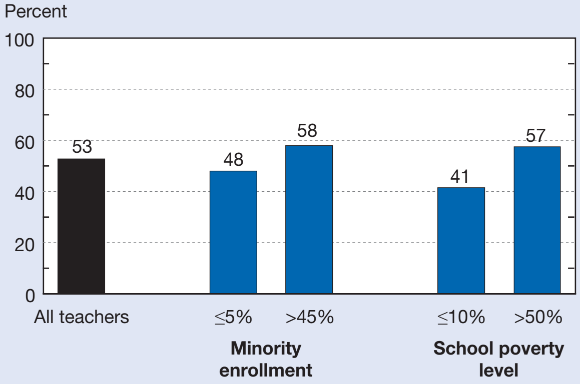
life sciences, teachers in these fields were relatively easier to find than they were in mathematics or physical sciences.

Teacher Salaries

Teachers (particularly mathematics and science teachers) who leave the profession or move to other schools often cite low pay as a main reason for doing so (Bobbitt et al. 1994; Guarino, Santibanez, and Daley 2006; Ingersoll 2006; Leukens, Lyter, and Fox 2004; NSB 2006). Indeed, among professions requiring a minimum of a bachelor's degree, teaching is a relatively low-paying profession. In 2003, the annual median salaries for full-time high school mathematics and science teachers and all full-time elementary school teachers were $43,000 and $41,000, respectively, far below those of professions requiring comparable educational backgrounds (e.g., computer systems analysts, engineers, accountants or financial specialists, and protective service workers) (table 1-12). Moreover, the salary increases for teachers lagged behind those who worked in other professions. Between 1993 and 2003, full-time high school mathematics and science teachers had a real salary gain of 8%, compared with increases of 21%-29% for computer systems analysts, accountants or financial specialists, and engineers. Similar results have been reported elsewhere (AFT 2005; Allegretto, Corcoran, and Mishel 2004). Although the difference in the number of weeks worked between teachers and those in other professions may explain some of the salary gaps, it cannot explain why these gaps grew over the years. If teaching salaries are not competitive with those offered in other professions requiring comparable education and skills, it may be difficult to retain teachers (especially those in mathematics and science) who may find more lucrative opportunities elsewhere.

When asked to rate their satisfaction with their salaries, more than one-half of public middle and high school mathematics and science teachers expressed dissatisfaction (figure 1-17). Those in high-poverty schools were more likely than their colleagues in low-poverty schools to be unhappy with their salaries.

Figure 1-17
Public middle and high school mathematics and science teachers not satisfied with salary, by minority enrollment and school poverty level: Academic year 2003–04



NOTE: School poverty level is percentage of students in school qualifying for free/reduced-price lunch.

SOURCES: National Center for Education Statistics, Schools and Staffing Survey, 2003–04; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

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Table 1-12
Median annual salaries of full-time school teachers and selected other professions: 1993 and 2003
(2003 constant dollars)

Full-time professionals	1993	2003	Change (%)
Teachers			
High school mathematics and science	40,000	43,000	7.5
Elementary school	38,000	41,000	7.9
Selected other professions			
Computer systems analysts	56,000	72,000	28.6
Accountants, auditors, and other financial specialists	50,000	61,000	22.0
Engineers	62,000	75,000	21.0
Protective service workers	46,000	50,000	8.7
Social workers	36,000	40,000	11.1
Retail sales occupations	34,000	40,000	17.6
Clergy and other religious workers	35,000	38,000	8.6

NOTES: 1993 salaries indexed to 2003 salaries using chain-type price index for personal consumption expenditures from Economic Report of the President 2006, table B-7 (column C), http://www.gpoaccess.gov/eop/index.html, accessed 27 December 2006. All respondents had bachelor's or higher degree.

SOURCE: National Science Foundation, Division of Science Resources Statistics, National Survey of College Graduates 1993 and 2003, special tabulations.

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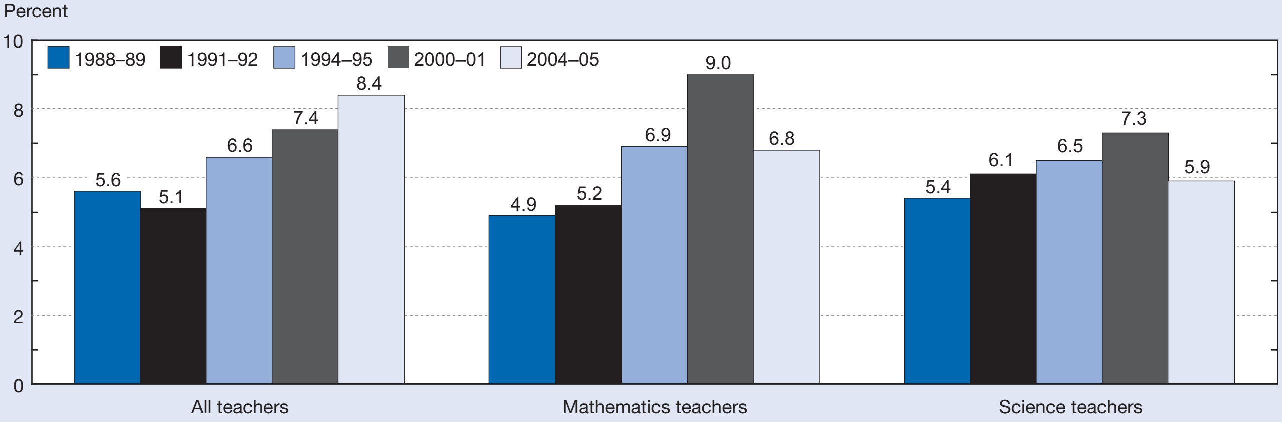
Attrition From Teaching

Concerns about K–12 teacher shortages, teacher quality, and the cost of keeping high-quality instructors in the nation's schools have led policymakers to focus attention on teacher attrition and to identify it as one of the most serious problems occurring today in the teaching profession (NCTAF 2003). A recent national study revealed that 8% of all public K–12 school teachers in the 2003–04 academic year had left the teaching profession by the following year (Marvel et al. 2007). For public school mathematics and science teachers, about 6%–7% had left. Although the attrition rates of all teachers have continued to increase over time, the attrition rates for mathematics and science teachers appeared to level off in recent years (figure 1-18).

Another study (Henke, Cataldi, and Nevill forthcoming) focused on the attrition of a segment of new teachers (recent college graduates who taught any of grades K–12 immediately following receipt of a bachelor's degree) and compared their occupational stability with individuals in other occupations. The results of this study suggest that movement among different occupations is common and that teaching is actually one of the more stable occupations in terms of attrition. As shown in figure 1-19, among recent college graduates working in April 1994, 34% were working in the same occupational category in 2003, and 54% had made a change in occupation. In contrast, of those working as K–12 teachers in 1994, 61% were still doing so in 2003, and only 21% had left teaching for nonteaching jobs. Teachers were more likely to remain in the same occupation than most other professionals, including those with comparable education such as legal professionals and legal support personnel, engineers, scientists, laboratory and research assistants, and computer and technical workers. Although recent college graduates do not represent the teaching workforce as a whole, in this study they indicate the job stability of teachers relative to that of other professionals.

Figure 1-18

One-year attrition rate of public school teachers: Selected academic years, 1988–89 to 2004–05



SOURCES: Whitener SD, Gruber KJ, Lynch H, Tingos K, Perona M, Fondelier S, Characteristics of Stayers, Movers, and Leavers: Results From the Teacher Follow-up Survey: 1994–95, National Center for Education Statistics (NCES), NCES 97-450 (1997); Luekens MT, Lyter DM, Fox EE, Teacher Attrition and Mobility: Results from the Teacher Follow-up Survey, 2000–01, NCES 2004-301 (2004); and Marvel J, Lyter DM, Peltola P, Strizek GA, Morton BA, Teacher Attrition and Mobility: Results from the 2004–05 Teacher Follow-up Survey, NCES 2007-307 (2006).

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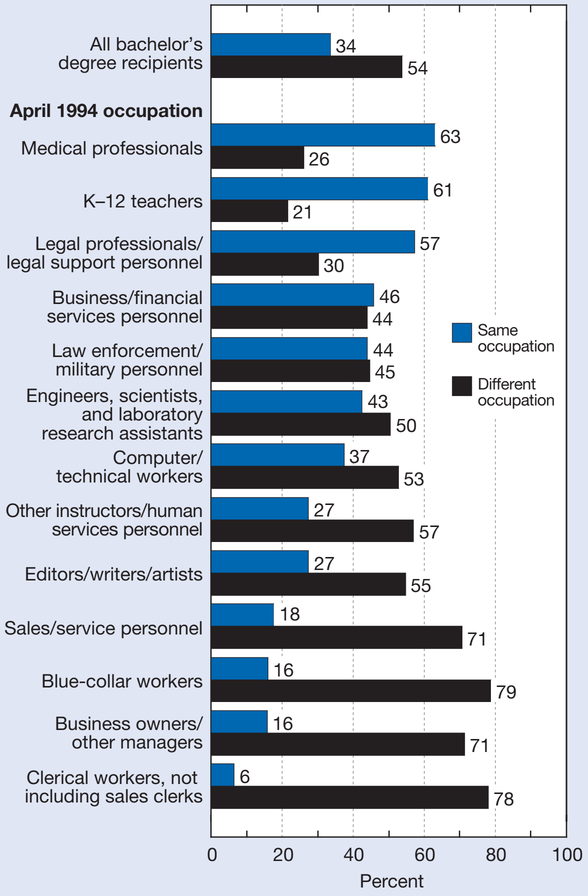
Teacher Perceptions of Working Conditions

Like salaries, working conditions also play a critical role in determining the supply of qualified teachers and in influencing their decisions about remaining in the profession. Research shows that safe environments, strong administrative leadership, collegial cooperation, high parental involvement, and sufficient learning resources can improve teacher effectiveness, enhance their commitment to school, and promote their job satisfaction (Darling-Hammond 2003; Guarino, Santibanez, and Daley 2006; McGrath and Princiotta 2005). Characteristics of a school's student body are also important in increasing teacher satisfaction and keeping them in the profession. Students who go to school ready to learn, obey school rules, show respect for their teachers, and exhibit good learning behaviors not only can contribute to a positive school climate, but also can increase teacher enthusiasm, effectiveness, and commitment (Hanushek, Kain, and Rivkin 2004; Kelly 2004; Stockard and Lehman 2004).

SASS asked teachers whether they agreed with a number of statements about their school environments and working conditions. A majority of public middle and high school mathematics and science teachers expressed positive views of their school administrators' leadership and support, cooperation among colleagues, and availability of instructional

Figure 1-19
1992–93 bachelor's degree recipients working in April 1994 in same or different occupation in 2003



NOTE: Those unemployed in 2003 or who had left labor force omitted from figure.

SOURCE: Henke R, Cataldi E, Nevill S, Occupation Characteristics and Changes in Labor Force Status and Occupation Category: Comparing K–12 Teachers and College Graduates in Other Occupation Categories, National Center for Education Statistics (NCES), NCES 2007-170 (forthcoming).

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resources (figure 1-20). Although teachers overall held generally positive perceptions of their school environments, these perceptions tended to be less prevalent in schools with more minority and poor students than in schools with fewer such students. This was particularly the case for teacher perceptions of parental support: 42%–44% of mathematics and science teachers in high-minority and high-poverty schools said that they had received a great deal of support from parents, compared with 67%–71% of their counterparts in low-minority and low-poverty schools.

In addition to school environments, teachers were asked to indicate whether particular student attitudes and behaviors were serious problems in their schools. The problem that public middle and high school mathematics and science teachers most often reported as serious concerned students coming to school unprepared to learn: 37% of the teachers viewed this issue as a serious problem in their schools (figure 1-21). They also frequently cited student apathy, student absenteeism, and student tardiness as serious problems. Teachers who taught in schools with high concentrations of minority and low-income students cited various student problems (especially that students came unprepared to learn) as serious more frequently than did those who taught in schools with low concentrations of such students.

Job Satisfaction and Commitment to Teaching

Although teachers are paid less than those in many comparable professions and sometimes have to work in environments that are less than ideal, the large majority of them are happy about being teachers. When asked whether they were satisfied with being a teacher at their school, 90% of public middle and high school teachers gave a positive answer (table 1-13). Responses from mathematics and science teachers were similar.

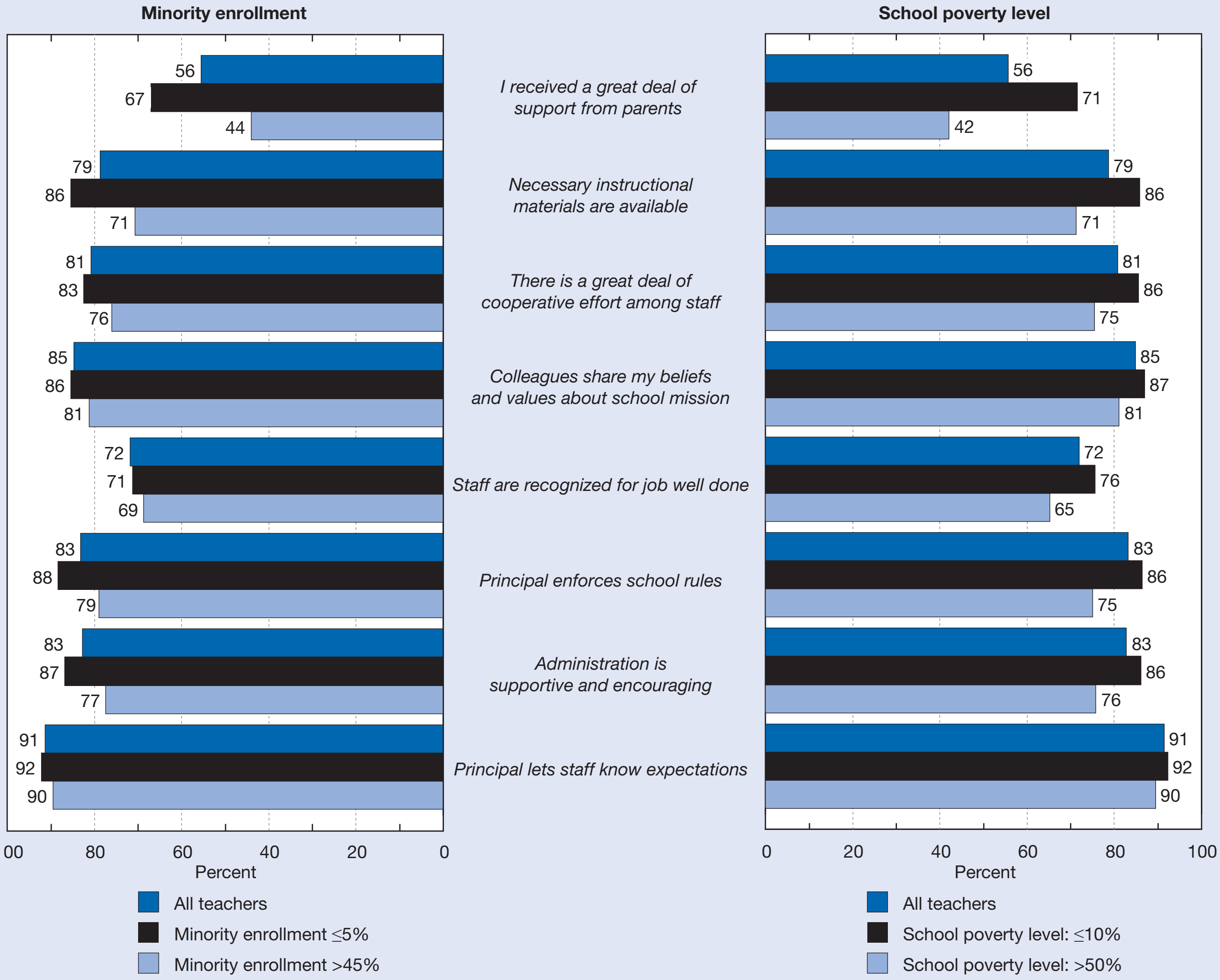
When asked how long they planned to remain in teaching, many teachers responded that they planned to remain as long as they were able (42%) or until they were eligible for retirement (34%). Just 3% had definite plans to leave teaching as soon as possible. When asked whether they would become teachers again if they could start over, 66% indicated that they certainly or probably would, and only 5% responded they certainly would not. Responses from mathematics and science teachers to these questions resembled the overall patterns, although less science teachers (32%) than mathematics and other teachers (42% and 40%, respectively) said they would certainly go into teaching again.

Working conditions were strongly associated with teacher commitment to teaching. Regardless of what they taught, teachers who worked in a positive school environment tended to be more likely to consider teaching as a long-term career and to believe they would choose the profession again (appendix table 1-21). For example, among public middle and high school mathematics teachers who thought that their school administrators were supportive and encouraging, 48% said that they planned to continue teaching as long as they could, and 49% said that they would certainly become a teacher again if they could start over, compared with 22% and 20%, respectively, of those who did not share this perception about their school administrators.

Summary

College graduates who entered teaching were more likely to stay in that occupation than graduates who entered most other professions requiring comparable education, including legal professionals and legal support personnel, engineers, scientists, laboratory and research assistants, and computer

Figure 1-20
Perceptions of working conditions of public middle and high school mathematics and science teachers, by minority enrollment and school poverty level: Academic year 2003–04



NOTES: Teachers asked to indicate their agreement with various statements about their school conditions. Response categories included “strongly agree,” “somewhat agree,” “somewhat disagree,” and “strongly disagree.” Percentages based on teachers responding “strongly agree” or “somewhat agree” to various statements. School poverty level is percentage of students in school qualifying for free/reduced-price lunch.

SOURCES: National Center for Education Statistics, Schools and Staffing Survey, 2003–04; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

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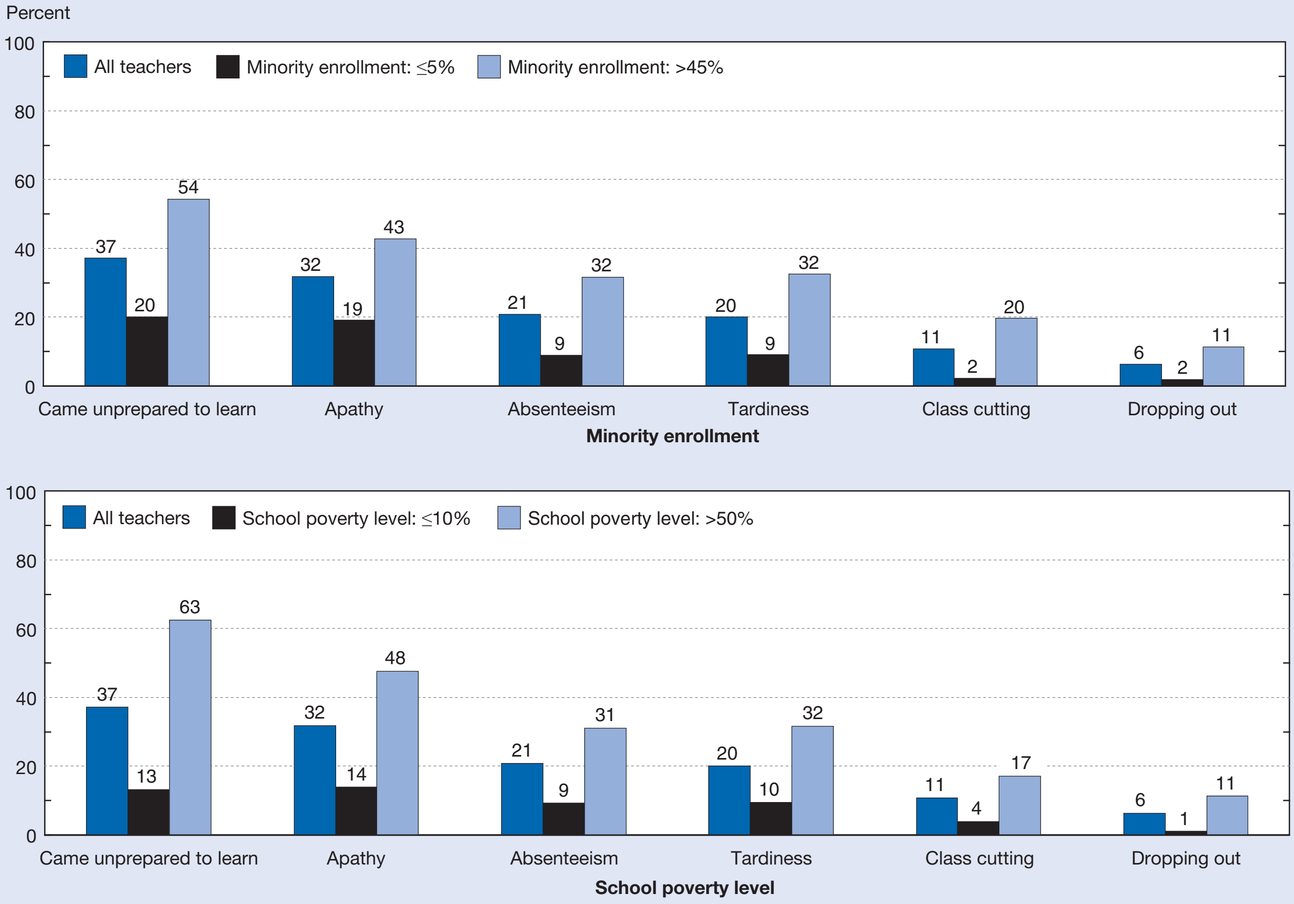
and technical workers. Between academic years 2003 and 2004, about 6%–7% of mathematics and science teachers in public schools left teaching, compared with 8% of all teachers. Regardless, public secondary schools continued to experience various degrees of difficulty in hiring mathematics and science teachers in recent years.

Teacher salaries lagged behind those of many comparable professionals. These gaps have widened substantially in recent years, and about half of public middle and high school mathematics and science teachers were not satisfied with their pay. Although public school teachers generally had favorable perceptions of their working conditions, those in schools with high concentrations of minority or poor students viewed their work environments as less satisfactory. The findings that working conditions and pay were associated with teacher long-term commitment to teaching signify that high-minority and high-poverty schools may face greater challenges than others in recruiting and retaining qualified teachers.

Transition to Higher Education

More and more high school students expect to attend college at some point, and many do so immediately after finishing high school. In 2003–04, about 7 in 10 high school seniors expected to attain at least a bachelor’s degree (NCES 2006c), and in fall 2004, approximately 1.8 million high

Figure 1-21
Serious student problems reported by public middle and high school mathematics and science teachers, by minority enrollment and school poverty level: Academic year 2003–04



NOTES: Teachers asked to indicate the seriousness of various student problems in their schools. Response categories include “serious problem,” “moderate problem,” “minor problem,” and “not a problem.” Percentages based on teachers viewing various student problems as “serious.” School poverty level is percentage of students in school qualifying for free/reduced-price lunch.

SOURCES: National Center for Education Statistics, Schools and Staffing Survey, 2003–04; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

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school graduates (two-thirds of this population) enrolled in a 2- or 4-year institution directly after high school (NCES 2006d). However, despite heightened educational expectations and rising college enrollment rates, students from disadvantaged socioeconomic backgrounds attend college at substantially lower rates than other students, and many of them discontinue their education before graduating from high school (Berkner and Chavez 1997; Laird et al. 2007).

This section presents several indicators related to student transitions from high school to college, including high school graduation rates in the United States and in other countries and long-term trends in immediate college enrollment rates among U.S. high school graduates. These indicators provide a broad picture of how effective the nation is in providing education at the secondary level and making higher education accessible to high school students.[29]

Completion of High School

Who is counted as having completed high school in the United States? In a broad sense, a high school completer is anyone who has met the requirements of high school completion and received a regular diploma or earned an equivalent credential such as a GED certificate. Based on this definition, an NCES report (Laird et al. 2007) estimated that in 2005, 88% of those 18–24 years old not enrolled in high school had received a high school diploma or equivalency credential (figure 1-22). Between 1975 and 2005, completion rates increased in all racial/ethnic groups. The rate for blacks increased faster than that for whites, narrowing the gaps between the two groups. However, although the Hispanic completion rate increased overall between 1975 and 2005, the gap between Hispanics and whites remained wide.

Table 1-13
Professional satisfaction and commitment of public middle and high school teachers: Academic year 2003–04
(Percent)

Professional satisfaction and commitment	All teachers	Mathematics	Science	Other teachers
I am satisfied with being a teacher	89.6	89.6	87.2	89.9
How long do you plan to remain in teaching?				
As long as I am able	41.8	41.8	39.7	42.1
Until I am eligible for retirement	33.9	32.4	33.8	34.1
Continue unless something better comes along	9.0	9.2	11.0	8.7
Definitely plan to leave as soon as I can	3.0	3.3	3.7	2.9
Undecided at this time	12.3	13.2	11.8	12.2
If you could start over again, would you become a teacher?				
Certainly	39.3	41.5	32.0	40.1
Probably	26.4	24.4	28.5	26.4
Even chances	17.6	15.6	21.6	17.3
Probably not	12.0	12.1	13.2	11.8
Certainly not	4.6	6.3	4.7	4.3

SOURCES: National Center for Education Statistics, Schools and Staffing Survey, 2003–04; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

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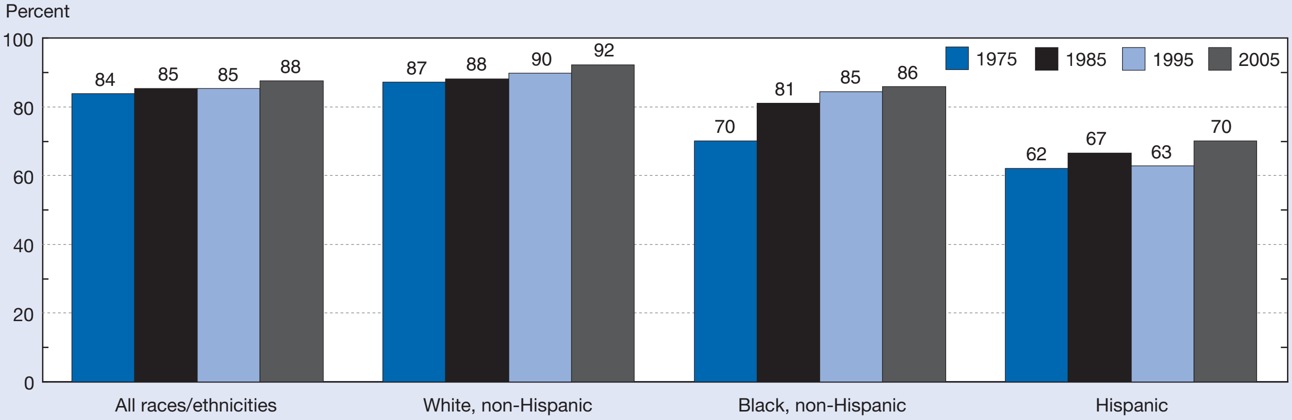
Figure 1-22
High school completion rates of 18–24-year-olds, by race/ethnicity: Selected years, 1975–2005



NOTES: High school completion rates measure percentage of 18–24-year-olds not enrolled in high school and holding a high school diploma or equivalent credential such as a General Equivalency Diploma (GED) certificate. Those still enrolled in high school excluded from analysis.

SOURCE: Laird J, DeBell M, Kienzl G, Chapman C, Dropout Rates in the United States: 2005, National Center for Education Statistics (NCES), NCES 2007-059 (2007).

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Largely in response to the federal NCLB Act,[30] researchers and educators have been trying to create a more rigorous definition of high school graduates. To do so, they have been focusing on on-time graduation rates and counting only students with regular diplomas as graduates (Seastrom et al. 2006a; Swanson 2003; WestEd 2004). To examine on-time graduation rates, researchers used the percentage of the incoming freshman class that graduates with a regular diploma 4 years later as a measure (Seastrom et al. 2006b).[31] Based on this measure, it was estimated that 74% of public high school students who entered ninth grade in academic year 1999 graduated with a regular diploma 4 years later in academic year 2003 (table 1-14). On-time graduation rates changed little from 2000 to 2004, staying in the range of 72%–74%. (See sidebar "International Comparisons of High School Completion.")

Enrollment in Postsecondary Education

On completing high school, young adults make critical choices about the next stage of their lives. Today, a majority of high school graduates choose to go to college immediately after high school (NCES 2007d). In 2005, 69% of

Table 1-14

On-time graduation rates of public high school students: Academic years 2000–01 to 2003–04

(Percent)

Academic year	On-time graduation rate
2000–01	71.7
2001–02	72.6
2002–03	73.9
2003–04	74.3

SOURCES: Seastrom M, Chapman C, Stillwell R, McGrath D, Peltola P, Dinkes R, Xu Z, User's Guide to Computing High School Graduation Rates, National Center for Education Statistics (NCES), NCES 2006-604 and 2006-605 (2006a); Seastrom M, Hoffman L, Chapman C, Stillwell R, The Averaged Freshman Graduation Rate for Public High Schools from the Common Core of Data: School Years 2002–03 and 2003–04, NCES 2006-606rev (2006b).

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students ages 16–24 enrolled in a 2- or 4-year postsecondary institution in the fall immediately after high school graduation, compared with 51% in 1975 (figure 1-23). From 1975 to 2005, the immediate enrollment rate increased faster for females than for males. Much of the growth in the overall rate for females was because of increases between 1981 and 1997 in the rate of females attending 4-year institutions. During this period, the rate at which females enrolled at 4-year institutions increased faster than it did for their male counterparts, and faster than for either males or females at 2-year institutions.

Although the growth in immediate college enrollment over the past three decades looks impressive, wide gaps by student socioeconomic background persisted. In each year between 1975 and 2005, low-income students lagged considerably behind their high-income peers in college enrollment (appendix table 1-22). Wide gaps also existed among racial/ethnic groups, with black and Hispanic students trailing far behind their white peers. Enrollment rates differed by parent education, as well, although students whose parents had only a high school education increased their enrollments considerably.

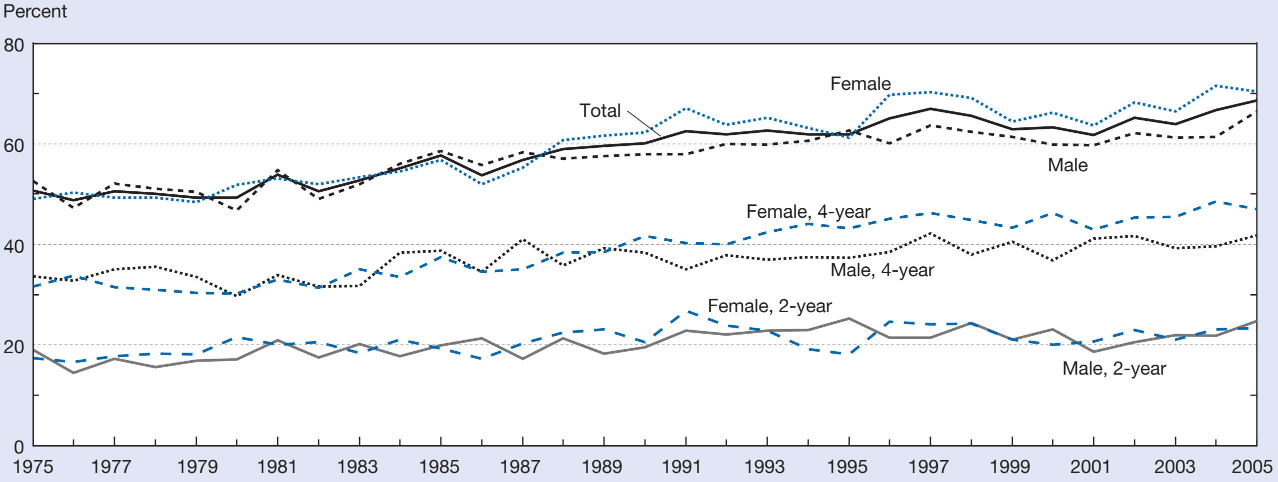
The type of institution was also related to student racial/ethnic and family background. Berkner and Chavez (1997) found that the proportion of 1992 high school graduates who enrolled in 4-year colleges and universities increased with family income and the level of their parents' education. Four-year college enrollment rates were also higher among white and Asian/Pacific Islander students than among black and Hispanic students. On the other hand, Hispanic students and those from low-income and less-educated families were more likely to attend 2-year institutions after high school graduation. Persistent inequality on many indicators of postsecondary education (e.g., gaining access and attaining a degree) is discussed extensively in chapter 2.

Summary

Over the past three decades, high school completion rates have been increasing gradually and the white-black gaps in completion rates have been narrowing. However, on-time graduation rates, which measure the rates at which high school freshmen graduate with a regular diploma 4 years later, remained in the range of 72%-74% in the early 2000s. Although more and more students choose to enroll in college right after high school, students from disadvantaged socioeconomic backgrounds continue to attend college at substantially lower rates than their more advantaged classmates.

Figure 1-23

High school graduates enrolled in college in October after completing high school, by sex and type of institution: 1975–2005



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

SOURCE: National Center for Education Statistics (NCES), The Condition of Education 2007, NCES 2007-064 (2007).

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International Comparisons of High School Completion

How does the United States compare with other nations in terms of the rates at which young people graduate from high school? A 2006 report from the Organisation for Economic Co-Operation and Development (OECD) found that the United States is falling behind other industrialized nations on this indicator (OECD 2006). In 2004, the high school graduation rate was 75% in the United States, which was lower than the overall average rate of 81% for the 22 OECD countries with available data (figure 1-24). The United States ranked 17th in the overall high school graduation rate among OECD countries, behind such top-ranked countries as Norway, Germany, South Korea, Ireland, Japan, and Denmark.*

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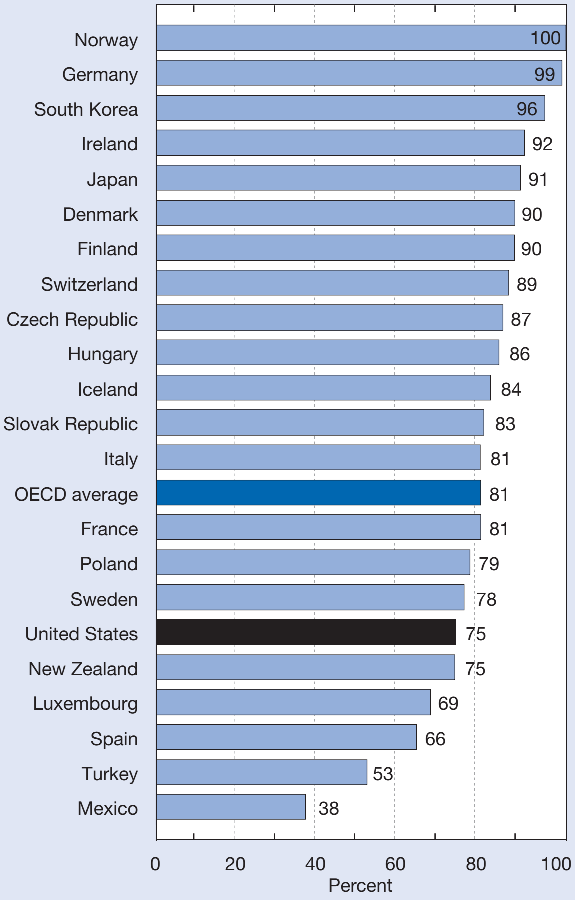
* One reason for the lower U.S. rate is that the U.S. high school student population may be more inclusive than in some OECD countries. In other words, some OECD countries may have more students dropping out before entering high school and therefore have a more selective high school student population than does the United States.

Figure 1-24
High school graduation rates, by OECD country: 2004



OECD = Organisation for Economic Co-operation and Development

NOTES: High school graduation rate is percentage of population at typical upper secondary graduation age (e.g., 18 years old in United States) completing upper secondary education programs. OECD average based on all OECD countries with available data.

SOURCE: OECD, Education at a Glance: OECD Indicators 2006 (2006).

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Conclusion

When they start kindergarten, students in the United States already exhibit differing mathematics knowledge and skills, and most of the achievement gaps between groups either remain or grow over the years students spend in school. Mathematics and science performance gaps widened between racial/ethnic groups, between students from financially disadvantaged and advantaged families, and between students whose mothers differ in educational attainment.

However, trends between 1990 and 2005 indicate rising test scores, particularly in mathematics in grades 4 and 8 (measured with cross-sectional data). The rise in scores occurred across the board: for both sexes, across racial/ethnic groups, and for students in all ranges of performance. Notably, some mathematics achievement discrepancies narrowed; for example, the difference between white and black fourth grade student scores decreased. Average science scores on fourth grade tests also increased since 1996 (particularly those in lower and middle score ranges), but science achievement in grades 8 and 12 has been resistant to improvement.

As educators and policymakers strive to improve student learning, they continue to make changes in schooling resources and school environments. Coursetaking and content standards, teacher qualifications, and continuing professional development for teachers are among the primary elements featured in efforts to promote student achievement.

Coursetaking and Content Standards

States have been increasing academic course requirements for high school graduation since the 1980s. By 2006, most states required 3 years of both mathematics and science courses, and nearly all required at least 2 years. Coursework standards have expanded in the past decade or so to require specific courses (such as algebra) and to enhance the rigor of course content.

Coursetaking Trends

Trends from 1990 to 2005 show higher proportions of students completing advanced mathematics and science courses with growth especially strong in mathematics. Students also increased course completions in advanced biology, chemistry, and physics. Even so, completion rates were relatively low in 2005 for most of these advanced course categories. For the AP/IB courses, rates doubled for some and increased substantially for others; still, the most common AP/IB course, calculus, was completed by less than 10% of 2005 graduates.

Teacher Preparation and Qualifications

Most public school teachers have a bachelor's degree and are fully certified. Majorities of beginning mathematics and science teachers in public middle and high schools also participated in practice teaching before starting their first teaching job and were confident of their ability to handle its challenges. However, practice teaching declined in recent years by about 8–10 percentage points, even though participation contributes to new teachers' confidence. In high schools, large majorities of mathematics and science teachers were teaching in field; that is, they had a postsecondary major or certification in that field. However, in middle schools, about one-half of mathematics and biology science teachers and two-thirds of physical science teachers lacked these in-field qualifications. Across all mathematics and science fields, a pattern of unequal access to the most highly qualified teachers (including those with more than a few years of teaching experience) was the rule, favoring low-minority and low-poverty schools.

Participation in Professional Development

Most beginning teachers participated in induction programs or worked closely with a mentor teacher during their first year of teaching. Participation in professional development was also widespread, most often on a teacher's subject matter or on using computers for instruction. The most common formats were workshops, conferences, and training sessions. Overall, the amount of time that most teachers devoted to professional development did not reach the levels recommended by researchers.

Teacher Supply, Salaries, Working Conditions, and Job Satisfaction

Attrition from teaching is typically lower than from other professions, and attrition rates for mathematics and science teachers have mostly leveled off in recent years. Nevertheless, public secondary schools continued to experience some difficulty filling teacher vacancies in mathematics and physical sciences, and to a lesser degree, in biology/life sciences. Overall, a majority of public school teachers were satisfied with their jobs and planned to remain in teaching as long as they could. Science and mathematics teacher pay still falls behind that of many professionals with comparable education, even more so in recent years. Although dissatisfaction with pay is on the rise, public school teachers had mostly favorable perceptions of their working conditions.

High School Graduation Rates and Enrollment in Postsecondary Education

Since 1975, high school completion rates have increased slightly. In 2005, among 18–24-year-olds not enrolled in high school, nearly 90% held either a high school diploma or an equivalency credential. However, the on-time graduation rate changed little from 2000 to 2004, staying in the range of 72%–74%. Increasingly students are entering postsecondary education directly after high school. Between 1975 and 2005, the percentage of students ages 16–24 enrolling in a 2- or 4-year institution in the fall following high school graduation rose from 51% to 69%.

Notes

1. Differences between two estimates were tested using the Student's t statistic to minimize the chances of concluding that a difference exists based on the sample when no true difference exists in the population from which the sample was drawn. Setting the significance level at 0.05 indicates that a reported difference would occur by chance no more than once in 20 samples when there was no actual difference between the population means.

2. In the 2004 followup for the ECLS kindergarten class of fall 1998, 86% of cohort members were in fifth grade, 14% were in a lower grade, and less than 1% were in a higher grade. For the sake of simplicity, students in the ECLS followups are referred to by the expected grade; that is, they are referred to as first graders in the spring 2000 assessment, as third graders in the spring 2003 assessment, and as fifth graders in the spring 2004 assessment.

3. The poverty status variable in ECLS is based on information provided by the parent. The variable is derived from household income and total number of household members (Princiotta, Flanagan, and Germino Hausken 2006). Federal poverty thresholds are used to define households below the poverty level. For example, if a household contained two members, and the household income was lower than $12,015, the student was considered to be living below the poverty threshold.

4. Socioeconomic status was based on five equally weighted components: father's education, mother's education, family income, father's occupational prestige score, and mother's occupational prestige score.

5. 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.

6. These recent trends are based on data from the national NAEP program. The current national mathematics assessment for grades 4 and 8 was first administered in 1990 and was given again in 1992, 1996, 2000, 2003, and 2005. In 2003, only fourth and eighth grade students were assessed. The current grade 12 mathematics assessment has only been administered once: in 2005. Trend analyses for grade

12 mathematics are therefore not available. The current national science assessment was first administered in 1996 and was given again in 2000 and 2005.

7. Although the NAEP program collects information about eligibility for the free or reduced-price lunch program for grade 12 students, it does not report these data. Because other reasons for not applying for school lunch programs (including food preferences, ability to buy lunch outside school, and wanting to avoid embarrassment) generally increase with student age, program eligibility becomes an increasingly unreliable indicator of poverty at higher grade levels. For example, approximately 35%–45% of fourth grade and 30%–40% of eighth grade public school students have been eligible in recent years for the subsidized lunch program. In contrast, only about 15%–25% of 12th grade public school students have been eligible (determined using the online NAEP Data Explorer tool at http://www.nces.ed.gov/nationsreportcard/naepdata/). The relatively low percentage of grade 12 students noted as eligible for the program raises concerns that it is not a reliable indicator of low family income for these students.

8. Insufficient sample size in 1990 for Asian/Pacific Islanders and American Indians/Alaska Natives precluded calculation of reliable estimates for this group. Increases in average scores for Asian/Pacific Islanders in grades 4 and 8 were observed between 2003 and 2005. Scores increased for grade 4 American Indians/Alaska Natives between 2003 and 2005, but not for grade 8 American Indians/Alaska Natives.

9. Many states developed initial standards for at least some subjects starting after about 1980, while others revised existing standards and/or curricular guidelines; in some states both of these activities occurred.

10. Although effects were somewhat different for men and women, Trusty's analysis also adjusted for variables such as previous test scores, previous course completions, and confidence about their mathematics and science skills. These factors sometimes interact in both directions, with strong performance in early grades often leading to greater self-confidence and interest in the subjects, which in turn lead to greater coursetaking, which may increase performance, and so on. Studies may not measure other relevant characteristics like students' motivation and career aspirations.

11. The fairly flat pattern for trigonometry/algebra III does not necessarily mean that fewer students studied these topics; some schools may have reconfigured courses so that rather than providing a full semester of trigonometry, for example, they may include that material in a precalculus or other course.

12. Except for biology, AP/IB science course data are available only for 2000 and 2005.

13. In some course categories, the difference between Asian/Pacific Islander and white graduates was not significant, whereas in others, differences between Asians/Pacific Islanders and one or more of the other groups proved to be not significant. These findings are likely due in part to large standard errors associated with smaller population groups.

14. Poverty rate is defined as the percentage of students in the school who were eligible for the national subsidized lunch program. For reasons explained above, school lunch program eligibility can be an unreliable indicator of individual families' poverty, particularly for high school students. It is used here as a rough proxy for poverty at the school level because it is the only available measure, but the caveat stands.

15. 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.

16. Teacher quality can include many characteristics that are not discussed here, such as teachers' commitment to the profession; sense of responsibility for student learning; and 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.

17. Research on how elementary school teachers are prepared to teach mathematics and science is emerging but limited (National Research Council 2007). Based on an extensive literature review on science education, the National Research Council (2007) concludes that K–8 teachers had limited training in science education and insufficient knowledge of science. However, some evidence suggests that K–5 teachers are confident about their ability to teach their subjects including mathematics and science (Weiss et al. 2003). Much more research is needed to increase understanding about elementary teacher preparation for teaching mathematics and science.

18. To simplify the discussion, schools in which 10% or fewer of the students were eligible for the federal free and reduced-price lunch program are called low-poverty schools; and schools in which more than 50% of the students were eligible are called high-poverty schools. Similarly, low-minority schools are those in which 5% or fewer of the students were members of a minority, and high-minority schools are those in which more than 45% of the students were members of a minority.

19. In general, probationary certification is awarded to those who have completed all the requirements except for a

probationary teaching period. Provisional or temporary certification is awarded to those who still have requirements to meet. Emergency certification is issued to those with insufficient teacher preparation who must complete a regular certification program in order to continue teaching (Henke et al. 1997).

20. Practice teaching (also called student teaching) offers prospective teachers hands-on classroom experience that allows them to transform the knowledge learned from coursework into teaching exercises in the classroom. Currently, 39 states require public school teachers to complete a minimum of 5 weeks of practice teaching, through either traditional teacher education programs or licensure requirements (Editorial Projects in Education 2006).

21. It should be noted that induction programs have great variability in terms of program goals, content, duration, and format. This variability cannot be addressed by using the SASS data.

22. Similar results have been reported elsewhere (Choy, Chen, and Bugarin 2006; Scotchmer, McGrath, and Coder 2005). This finding suggests that schools and districts, and perhaps teachers themselves, were attempting to address the needs of teachers in high-minority and high-poverty schools.

23. The amount of time teachers devoted to professional development was generally not associated with schools' minority enrollment and poverty levels.

24. Teacher participation in various formats of professional development was generally not significantly associated with schools' minority enrollment and poverty levels.

25. Teacher participation in these activities was generally not significantly related to schools' minority enrollment and poverty levels.

26. For example, these explanations include the retirement of an aging teaching force, increased student enrollments, reforms such as the reduction of class sizes, high rates of attrition, and lack of qualified candidates willing to enter the profession (Broughman and Rollefson 2000; Howard 2003; Hussar 1999).

27. Teacher shortages occur in a labor market when demand is greater than supply. This can be the result of either increases in demand or decreases in supply or of both simultaneously (Guarino, Santibanez, and Daley 2006).

28. Teaching vacancies in foreign languages, English as a second language, and special education were also difficult to fill in secondary schools, according to SASS data.

29. The 2004 and 2006 editions of *Science and Engineering Indicators* included an indicator of college remediation. However, this indicator cannot be updated for this edition because there were no new data available at the time of preparation for this chapter.

30. NCLB requires that states include graduation rates in determining adequate yearly progress and calls for measurement of on-time graduation that explicitly excludes GEDs and other types of nonregular diplomas from the counts of graduates.

31. Researchers examined several proxy measures of on-time graduation rates (Seastrom et al. 2006a). Although none of them is as accurate as the on-time graduation rate computed from a cohort of students using student record data, one of the methods, called Averaged Freshman Graduation Rates (AFGR), most closely approximates the true cohort rate and is used here. AFGR measures the percentage of an incoming freshman class that graduates with a regular diploma 4 years later. The incoming freshman class size is estimated by averaging the enrollment of 8th graders 5 years earlier, enrollment of 9th graders 4 years earlier, and enrollment of 10th graders 3 years earlier. This averaging is intended to adjust for higher grade retention rates in the 9th grade.

Glossary

Student Learning in Mathematics and Science

Eligibility for National School Lunch Program: Students' eligibility for this program, which provides free or reduced-price lunches, is a commonly used indicator for family poverty. Eligibility information is part of the administrative data kept by schools and is based on parent-reported family income and family size.

Longitudinal studies: Researchers follow the same group of students over a period of years, such as from kindergarten through fifth grade. These studies can show achievement gains in a particular subject from grade to grade.

Repeating cross-sectional studies: This type of research focuses on how a specific group of students performs in a particular year, then looks at the performance of a similar group of students at a later point in time. An example would be comparing fourth graders in 1990 to fourth graders in 2005.

Scale score: Scale scores place students on a continuous achievement scale based on their overall performance on the assessment. Each assessment program develops its own scales. For example, NAEP used a scale of 0–500 for the mathematics assessment and a scale of 0–300 for the science assessment, and the ECLS mathematics scale ranged from 0 to 153.

Standards and Student Coursetaking

Advanced Placement: Courses that teach college-level material and skills to high school students who can earn college credits by demonstrating advanced proficiency on a final course exam. The curricula and exams for AP courses, available for a wide range of academic subjects, are developed by the College Board.

Core subjects: Fundamental academic subjects that students spend the most time on and are the focus of coursetaking requirements and achievement tests: mathematics, science, English/language arts, and social studies. Computer science and foreign language are sometimes included in the category.

International Baccalaureate: An internationally recognized pre-university academic subject course designed for high school students.

Poverty rate: A school's poverty rate is defined as the percentage of students eligible for subsidized lunches through the National School Lunch Program. It is considered a less accurate measure of family poverty at higher grade levels.

Mathematics and Science Teacher Quality

High schools: Schools that have at least one grade higher than 8 and no grade in K–6.

In-field and out-of-field teachers: This report defines in-field teachers as those who had either a college major or full certification (i.e., regular, advanced, or probationary certification) in their main teaching assignment field or both and out-of-field teachers as those who had neither a college major nor full certification in their main teaching assignment field, a related field, or general education.

Main teaching assignment field: The field in which teachers teach the most classes in school.

Major: A field of study in which an individual has taken substantial academic coursework at the postsecondary level, implying that the individual has substantial knowledge of the academic discipline or subject area.

Middle schools: Schools that have any of grades 5–8, and no grade lower than 5 and no grade higher than 8.

Practice teaching: Programs designed to offer prospective teachers hands-on classroom practice. Practice teaching is often a requirement for completing an educational degree or state certification, or both.

Secondary schools: Schools that have any of grades 7–12 and no grade in K–6.

Teaching certification: A license or certificate awarded to teachers by the state to teach in a public school. The SASS surveys include five types of certification: 1) regular or standard state certification or advanced professional certificate; 2) probationary certificate issued to persons who satisfy all requirements except the completion of a probationary period; 3) provisional certificate issued to persons who are still participating in what the state calls an "alternative certification program;" 4) temporary certificate issued to persons who need some additional college coursework, student teaching, and/or passage of a test before regular certification can be obtained; and 5) emergency certificate issued to persons with insufficient teacher preparation who must complete a regular certification program in order to continue teaching.

Professional Development of Mathematics and Science Teachers

Professional development: In-service training activities designed to help teachers improve their subject-matter knowledge, acquire new teaching skills, and stay informed about changing policies and practices.

Teacher induction: Programs designed at the school, local, or state level for beginning teachers in their first few years of teaching. The purpose of the programs is to help new teachers improve professional practice, deepen their understanding of teaching, and prevent early attrition. One key component of such programs is that new teachers are paired with mentors or other experienced teachers to receive advice, instruction, and support.

Teacher Salaries, Working Conditions, and Job Satisfaction

Teacher attrition: Teachers leaving the teaching profession for another occupation.

Teaching vacancy: Open teaching positions needing to be filled.

Transition to Higher Education

Postsecondary education: The provision of formal instructional programs with a curriculum designed primarily for students who have completed the requirements for a high school diploma or its equivalent. This includes programs with an academic, vocational, and continuing professional education purpose, and excludes vocational and adult basic education programs.

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Highlights

Financing Higher Education

Tuition increases at colleges and universities in the United States have grown rapidly for the past two decades, although the rate of increase slowed in the past few years.

- ♦ Compared with the previous year, average tuition and fees rose 6.3% for academic year 2006–07 for in-state students in public 4-year colleges, 5.9% for students in private 4-year colleges, and 4.1% for students in public 2-year colleges.
- ♦ As state spending on higher education rose from FY 2005 to FY 2007, the rate of tuition increase at public 4-year colleges slowed.

Levels of debt for both undergraduate and graduate education are high.

- ♦ Among 2003–04 bachelor's degree recipients in all fields who took out loans, the median level of debt was $19,300.
- ♦ At the time of doctorate conferral, about half of 2005 S&E doctorate recipients reported having debt from either their undergraduate or graduate education: 27% reported undergraduate debt and 33% reported graduate debt.
- ♦ High levels of educational debt were most associated with graduate education: 10% of S&E doctorate recipients had more than $50,000 of graduate debt but only 1% had similar amounts of undergraduate debt.

In 2005, about 21% of full-time S&E graduate students received more than half of their financial support for graduate education from the federal government.

- ♦ Most (69%) S&E graduate students primarily funded by the federal government are funded under grants to universities for academic research.
- ♦ Fellowships and traineeships fund 22% of federally funded full-time S&E graduate students.
- ♦ Federal support for graduate education reaches relatively more students in the physical sciences; earth, atmospheric, and ocean sciences; agricultural sciences; biological sciences; and engineering. Relatively few students receive federal support in mathematics, computer sciences, social sciences, psychology, and medical/other life sciences.

Higher Education Faculty

The types of assignments and methods used to grade students vary by discipline.

- ♦ Most (83%) instructional faculty use lecture/discussion as the primary instructional method for undergraduate classes.
- ♦ More than half of natural sciences and engineering faculty require their undergraduate students to participate in group projects (compared with 48% of social and behavioral sciences faculty), and more than 60% require lab assignments (compared with 24% of social and behavioral sciences faculty).
- ♦ The use of term papers increased in all disciplines between 1992 and 2003. Social and behavioral sciences faculty are more likely than faculty in other S&E fields to require written work of their students: 85% of social and behavioral sciences faculty require term papers of their undergraduate students compared with 76% of agricultural/biological/health sciences faculty and 57% of physical/mathematics/computer sciences/engineering faculty.

Higher Education Enrollments

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

- ♦ Enrollment rose from 12.7 million in 1986 to 16.9 million in 2004.
- ♦ The number of individuals ages 20–24 in the U.S. population is projected to rise through 2050 although the demographic composition will shift.
- ♦ Increased enrollment in higher education is projected to come mainly from minority groups, particularly Asians and Hispanics.

S&E graduate enrollment in the United States continued to rise, reaching a new peak of 583,200 in fall 2005.

- ♦ Following a long period of growth, graduate enrollment in S&E declined in the latter half of the 1990s then increased steadily since 1999.
- ♦ In fall 2005, graduate enrollment increased in most S&E fields except computer sciences and engineering.
- ♦ Graduate enrollment in computer sciences and engineering decreased in the past 2 years because of declining foreign student enrollment.

Total enrollment of foreign S&E graduate students dropped in fall 2005 for the second year in a row, but first-time full-time enrollment increased in 2005 after 3 years of decline.

- ♦ S&E graduate students on temporary visas increased from 20% to 25% of all S&E graduate students from 1985 to 2005.
- ♦ The number of first-time full-time S&E graduate students with temporary visas declined 18% from 2001 through 2004 but increased 4% in fall 2005.

Higher Education Degrees

The number of S&E bachelor's and master's degrees awarded annually continued to rise, reaching record highs in 2005.

- The numbers of S&E bachelor's and master's degrees awarded reached new peaks of 466,000 and 120,000, respectively, in 2005.
- Most S&E fields (except computer sciences) experienced increases in the number of degrees awarded in 2005.
- In computer sciences, the number of bachelor's degrees increased sharply from 1998 to 2004 but decreased in 2005.

Women earned more than half of all bachelor's degrees and S&E bachelor's degrees in 2005 but major variations persist among fields.

- Women earned more than half of bachelor's degrees in psychology (78%), agricultural sciences (51%), biological sciences (62%), chemistry (52%), and social sciences (54%).
- Men earned the majority of bachelor's degrees awarded in engineering (80%), computer sciences (78%), and physics (79%).

Blacks, Hispanics, and American Indians/Alaska Natives choose S&E fields at the same rate as whites.

- Among bachelor's degree recipients, about one-third of the 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.

Students in the United States on temporary visas earned only a small share (4%) of S&E bachelor's degrees in 2005.

- The number of S&E bachelor's degrees awarded to students on temporary visas increased over the past two decades from 14,100 in 1985 to 18,400 in 2005.
- In 2005, these students earned 8% of bachelor's degrees awarded in computer sciences and 7% in engineering.

Master's degrees in S&E fields increased from 70,600 in 1985 to 120,000 in 2005.

- Increases in master's degrees occurred in most major S&E fields.
- Master's degrees in engineering and physical sciences decreased from 1995 to 2002 but increased in recent years, and master's degrees in computer sciences generally increased through 2004 but dropped in 2005.

The number and percentage of master's degrees awarded to women in all major S&E fields (with the exception of computer sciences) have increased since 1985.

- Since 1985, the number of S&E master's degrees earned by women more than doubled, rising from 22,300 in 1985 to 53,000 in 2005.
- In computer sciences, the number of master's degrees awarded to women increased through 2004 but dropped in 2005, and the percentage of degrees awarded to women dropped from 34% in 2001 to 29% in 2005.
- The number of master's degrees earned by men grew more slowly from 48,200 in 1985 to 67,000 in 2005, with most of the growth occurring between 2002 and 2004.

The number of S&E master's degrees awarded increased for all racial/ethnic groups from 1985 to 2005.

- 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 2005, an increase from 5% in 1985. Blacks and Hispanics also registered gains during this period (from 3% to 6% for blacks and from 2% to 4% for Hispanics). American Indians/Alaska Natives earned 0.4% of S&E master's degrees in 1985 and 2005.
- The percentage of S&E master's degrees earned by white students fell from 68% in 1985 to 47% in 2005. Meanwhile, the percentage of degrees earned by minorities and temporary residents increased, and the number of S&E master's degrees earned by white students dropped from 1996 to 2002 before increasing again.

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.

- During the past two decades, the share of S&E master's degrees earned by temporary residents rose from 19% to 28%.
- S&E master's degrees awarded to students on temporary visas rose from approximately 12,500 in 1985 to about 33,500 in 2005 and increased in most S&E fields during that period.

The number of S&E doctorates awarded by U.S. academic institutions reached a new peak of almost 30,000 in 2005.

- The largest growth in the number of doctorate awards was in engineering and the biological and agricultural sciences.
- Virtually all of the growth reflected higher numbers of S&E doctorates earned by temporary visa holders.

Students on temporary visas earned more than a third (36%) of all S&E doctorates awarded in the United States in 2005.

- The number of S&E doctorates earned by temporary residents rose to a new peak of 10,800 in 2005.
- Temporary residents earned half or more of all U.S. doctorates in engineering, mathematics, computer sciences, physics, and economics in 2005.

Most foreign recipients of U.S. S&E doctorates plan to stay in the United States after graduation.

- Among 2002–05 graduates, 74% of foreign S&E doctorate recipients with known plans reported they planned to stay in the United States and 49% had accepted firm offers of employment.
- The percentage of students who had firm plans to remain in the United States dropped after 2001, then increased in 2005.
- More than 90% of 2002–05 U.S. S&E doctoral recipients from China and 88% of those from India reported plans to stay in the United States, and 60% and 63%, respectively, reported accepting firm offers for employment or postdoctoral research in the United States. The percentages of U.S. S&E doctorate recipients from China and India with definite plans to stay in the United States dropped from 1998–2001 to 2002–05. The decreases were almost entirely among doctorate recipients in computer sciences and engineering.

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

- Temporary visa holders accounted for 55% of S&E postdocs in academic institutions in fall 2005.
- More than two-thirds of S&E postdocs in academic institutions are in the biological, medical, and other life sciences fields.

Global S&E Education

Educational attainment of the U.S. population has long been among the highest in the world, but other countries are catching up.

- The United States continues to have the highest percentage of the population ages 25–64 with a bachelor's degree or higher. However, among the population ages 25–34, the United States (30%) lags behind Norway (37%), Israel (34%), the Netherlands (32%), and South Korea (31%) in the percentage with at least a bachelor's degree.
- The United States ranks 4th (behind Russia, Israel, and Canada) in the population ages 25–64 with any postsecondary degree (including 2-year and 4-year or higher degrees), and it ranks 10th (behind Russia, Canada, Japan, Israel, South Korea, Sweden, Belgium, Ireland, and Norway) in the population ages 25–34 with any postsecondary degree.

Global competition for foreign students increased in the past two decades.

- The U.S. share of foreign students declined in recent years, although the United States remains the predominant destination for foreign students (accounting for 22% of internationally mobile students in 2004).
- The United Kingdom, Germany, and France also attract large numbers of foreign students, accounting for 11%, 10%, and 9%, respectively, of internationally mobile students in 2004.

Introduction

Chapter Overview

The importance of higher education in S&E 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.[1]

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 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 and Hispanics becoming an increasing share of the population. Recent enrollment and degree trends, to some extent, reflect 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. Increases in foreign students contributed to most of the growth in overall S&E graduate enrollments in recent years. After September 11, 2001, the number of foreign students coming to the United States for graduate education dropped for several years, but these numbers increased in 2005 (although they have not yet regained earlier levels).

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 expanded educational access to their own population, and attracting larger numbers of foreign students. The effects of these trends on foreign student enrollment in U.S. institutions remain to be seen.

Chapter Organization

This chapter describes characteristics of the U.S. higher education system as well as trends in higher education worldwide. It begins with characteristics of U.S. higher education institutions providing S&E education, including trends in tuition and fees, financial support, and debt levels. Trends in student involvement in higher education, including freshmen interest and enrollment in S&E fields, degree completions, and postdoctoral study are discussed along with trends by sex, race/ethnicity, and citizenship. 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 S&E students. Additional state data on tuition charges, enrollment, and degrees granted are available in chapter 8, State Indicators.

The U.S. Higher Education System

Higher education in S&E has been receiving increasing attention as an important component contributing to the nation's maintenance of a strong economic position in the world (NSB 2003). A number of recent reports (AACU 2007; BEST 2004; COSEPUP 2006; NAE 2005; NSB 2004a; Project Kaleidoscope 2006) called for increasing the quantity, quality, and diversity of the students studying and graduating in S&E fields.

Institutions Providing S&E Education

The U.S. higher education system consists of a large number of academic institutions and a wide variety of institution types that provide broad access, advance the frontiers of knowledge, and strive to meet students' changing needs through new forms of teaching and learning (U.S. Department of Education 2006). Among the approximately 4,300 postsecondary degree-granting institutions in the United States in the 2005–06 academic year, 71% offered bachelor's or higher degrees and 29% offered associate's degrees as the highest degree awarded (NCES 2007). In 2005, these institutions awarded more than 2 million bachelor's or higher degrees (about 614,000 in S&E) plus about 641,000 associate's degrees (46,000 in S&E).

Research Institutions

Research institutions, although few in number, are the leading producers of S&E bachelor's, master's, and doctoral degrees. In 2005, research institutions (i.e., doctorate-granting institutions with very high research activity) awarded 69% of S&E doctoral degrees, 42% of master's degrees, and 36% of bachelor's degrees in S&E fields. (See sidebar "Carnegie Classification of Academic Institutions.") Master's colleges and universities awarded another 28% of S&E bachelor's degrees and 24% of S&E master's degrees in 2005. Baccalaureate colleges were the source of relatively few S&E bachelor's degrees (13%) (appendix table 2-1).

Community Colleges

Community colleges figure broadly in answering the nation's need for well-prepared technicians, and as the initial (and sometimes only) college experience for many students who are the first in their family to seek education beyond high school (Adelman 2005) or who have limited funds or ability to leave a given geographic area for a college education. *Community colleges* (also known as *associate's colleges* and *2-year institutions*) are the largest segment of the higher education enterprise in the United States. In 2004, they enrolled 6.3 million students, about 60% of whom were enrolled part time.

Carnegie Classification of Academic Institutions

The 2005 version of the Carnegie Foundation for the Advancement of Teaching's basic classification scheme for colleges and universities is more complex than previous versions and includes subcategories, new names, and new criteria for categories. Academic institutions are categorized primarily on the basis of highest degree conferred, level of degree production, and research activity. In this report, several categories have been aggregated for statistical purposes. The following are characteristics of those groups:

Doctorate-granting universities include institutions that award at least 20 doctoral degrees per year. They include three subgroups based on level of research activity: very high research activity, high research activity, and doctoral/research universities.

Master's colleges and universities include institutions that award at least 50 master's degrees and fewer than 20 doctoral degrees per year.

Baccalaureate colleges include institutions in which baccalaureate degrees represent at least 10% of all undergraduate degrees and that award fewer than 50 master's degrees or 20 doctoral degrees per year.

Associate's colleges include institutions in which all degrees are at the associate's level or bachelor's degrees account for less than 10% of all undergraduate degrees.

Special focus institutions are those in which at least 75% of degrees are concentrated in a single field or a set of related fields.

Tribal colleges are colleges and universities that are members of the American Indian Higher Education Consortium.

Although community colleges are not major sources of S&E degrees, they provide S&E coursework that is affordable, remedial, and potentially transferable, and they play a role in developing public scientific literacy. They also serve as a bridge for students who go on to major in S&E fields at 4-year institutions. Almost 29% of students who began at a community college in the 1995–96 academic year had transferred to 4-year institutions as of 2001 (Berkner, He, and Cataldi 2003).

Several efforts are underway to improve community college students' transition to 4-year institutions. Four-year institutions and private foundations are directing a portion of their entering student scholarship funds and recruitment efforts to community college student transfers. The impetus for these efforts is a desire to meet students' need for financial assistance coupled with the perception that community college transfers generally do well on transferring (Fischer 2007a; Suggs 2005; Blanton 2007). A recent study of Latino(a)s' pathway to graduate school reinforces that view (de los Santos and de los Santos 2005). (See sidebar "Community Colleges and Latinos.") Another factor in the ability of transfer students to obtain a bachelor's degree within 4–6 years of transfer is the number of transfer credits accepted by the 4-year colleges to which they transfer (Doyle 2006). Many states have adopted articulation policies (i.e., policies among institutions to accept the transfer credits) to encourage transfer of students from 2-year to 4-year colleges (NCES 2005a).

Community college courses play a large role in mathematics preparation of undergraduates. In fall 2005, 1.7 million students were enrolled in mathematics and statistics courses at public 2-year colleges (an increase of 26% from fall 2000); this includes 42,000 high school students who took dual-enrollment math courses on a high school campus and received course credit at both the high school and the community college. Two-year colleges taught about 47% of all undergraduates enrolled in courses in the nation's mathematics departments and programs. Although enrollment in elementary statistics courses in 4-year colleges and universities grew by 9% from fall 2000 to fall 2005, community college enrollment in those courses grew by 58% (Kirkman et al. 2007).

In addition to their traditional roles, community colleges are beginning to offer a limited number of 4-year degrees (AASCU 2004), to examine closely their role in teacher preparation, and to develop some dual-credit programs with neighboring high schools. With the exception of those related to teacher preparation, the 4-year degrees offered at

Community Colleges and Latinos

Latinos share many risk factors associated with educational attainment with community college students in general. Community college students are more likely than 4-year college students to be from households with low incomes, to be from groups currently underrepresented in S&E fields, to be the first in their family to attend college, to have dependents to support, to be older than the average college student, to exhibit lower achievement in high school, and to delay attendance at college rather than go directly from high school to college (Bailey 2004).

Latino students, as well as black and American Indian/Alaska Native students, are more likely than white or Asian students to attend community colleges. More than half (53%) of Latino undergraduates in 2004 were enrolled in community colleges compared with 41% of white students (NSF/SRS 2007a). At Arizona State University, which has a large Latino population, 67% of all students and 73% of the Latino bachelor's degree recipients in 2002–03 attended one or more of the local community colleges (Maricopa Community Colleges) before obtaining their degree (de los Santos and de los Santos 2005).

community colleges generally are in high-demand fields and are issued as bachelor of applied science degrees. (See, for example, the approximately 30 such programs offered in Florida's community college system [Fischer 2007b].)

Community colleges provide the science and mathematics coursework for many elementary and secondary science and mathematics teachers. They increasingly offer coursework for K–8 teachers and provide programs in which preservice education students can complete their entire mathematics courses or licensure requirements. Thirty percent of community colleges reported that they offer mathematics programs for preservice elementary school teachers and 19% reported preservice middle school licensure-oriented programs. In fall 2000, teacher certification programs were almost entirely limited to 4-year colleges and universities; however, by fall 2005, several community colleges offered courses and programs that would lead directly to certification of primarily K–8 teachers (Kirkman et al. 2007).

Community colleges also offer dual enrollment (high school and community college) courses in mathematics, including college algebra, precalculus, calculus, and statistics. Fifty percent of community colleges report having such courses. Most of them are taught on the high school campus by high school teachers, and usually the college and high school mathematics departments come to mutual agreement about factors such as syllabuses and textbooks (Kirkman et al. 2007).

U.S. Higher Education Faculty

S&E faculty constituted about half of the approximately 1.1 million instructional faculty in U.S. institutions in fall 2003. Most S&E faculty have doctoral or first professional degrees, and the number and percentage of S&E faculty with doctoral or first professional degrees is increasing. About 305,000 doctoral S&E faculty (about 60% of all S&E faculty) taught in U.S. universities in 2003, up from 249,000 in 1992 (appendix table 2-2). The largest fraction of doctoral S&E faculty (43%) taught agricultural, biological, or health sciences; another third (34%) taught physical sciences,[2] mathematics, computer sciences, or engineering; and 23% taught social and behavioral sciences. This section deals with the teaching aspects of S&E faculty. Additional information about faculty employment can be found in chapter 3 (Science and Engineering Labor Force), and information about trends in academic employment of doctoral faculty and faculty research can be found in chapter 5 (Academic Research and Development).

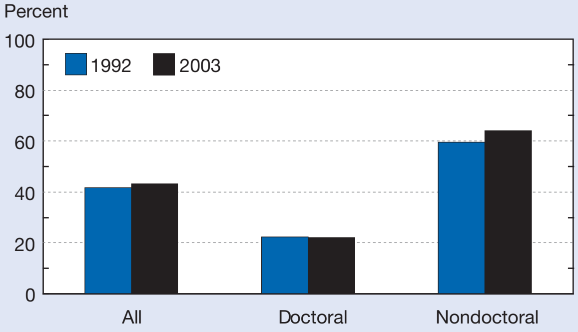
About 40% of S&E faculty have a master's or bachelor's degree as their highest degree. The number of S&E faculty with master's or bachelor's degrees who taught in U.S. colleges or universities rose from 174,000 in 1992 to 202,000 in 2003. Almost half are physical, mathematical, computer sciences, and engineering faculty (mainly computer sciences and mathematics faculty). In contrast to S&E faculty, about 60% of the approximately 586,000 non-S&E faculty in 2003 had master's or bachelor's degrees (appendix table 2-2).

Part-time faculty are an increasing portion of all instructional faculty in the United States. The overall increase in part-time faculty from 1992 to 2003 was almost entirely accounted for by an increase in the percentage of nondoctoral faculty (from 60% in 1992 to 64% in 2003) (figure 2-1). Among doctoral faculty, there was no increase in the percentage of faculty employed part time between 1992 and 2003. Most doctoral S&E faculty (about 80%) are employed full time (appendix table 2-2). In contrast, the majority of faculty with bachelor's and master's degrees (both S&E and non-S&E) are employed part time.

The types of institutions in which doctoral and nondoctoral S&E faculty teach differ. Close to half (47%) of full-time doctoral S&E faculty (and more than half of full-time doctoral life sciences faculty) teach in research institutions (appendix table 2-3).[3] In contrast, 11% of full-time nondoctoral S&E faculty teach in research institutions. Most nondoctoral S&E faculty and almost half of part-time S&E faculty teach in public 2-year institutions (table 2-1).

Most (62%) full-time S&E faculty taught only undergraduates in 2003, while 25% taught only graduate students, and the remainder taught both undergraduate and graduate students (appendix table 2-4). In 2003, about two-thirds of physical sciences/mathematics/computer sciences/engineering and social/behavioral sciences faculty taught only undergraduate students. A far higher percentage of agricultural/biological/health sciences faculty (42%) than of other S&E faculty (13%) taught only graduate students. Full-time nondoctoral S&E faculty taught undergraduates almost exclusively. Among full-time doctoral S&E faculty, almost one-third taught only graduate students, slightly more than half (51%) taught only undergraduate students, and the remainder taught both undergraduate and graduate students. From 1992 to 2003, the percentage of doctoral faculty who taught only undergraduates declined and the percentage who taught only graduate or first professional students (e.g., law or medical students) increased, particularly among full-time doctoral agricultural/biological/health sciences faculty.

Figure 2-1
Higher education faculty employed part time, by highest degree: Fall 1992 and fall 2003



SOURCE: National Center for Education Statistics, National Survey of Postsecondary Faculty, 1993 and 2004, special tabulations (2006).

Science and Engineering Indicators 2008

Table 2-1
Higher education faculty, by teaching field, highest degree, employment status, and institution type: Fall 2003
(Percent)

Faculty characteristics	Number	Research institutions	Other institutions	Public 2-year institutions
S&E	505,300	29.3	42.1	28.7
Full time	322,500	38.1	44.3	17.6
Part time	182,700	13.6	38.2	48.3
Doctorate/first professional degree	304,600	43.3	48.3	8.5
Other high degree	200,700	8.0	32.6	59.4
Non-S&E	587,800	16.7	53.1	30.2
Full time	297,300	23.4	56.9	19.7
Part time	290,500	9.9	49.1	41.0
Doctorate/first professional degree	236,100	26.5	63.0	10.5
Other high degree	351,700	10.2	46.4	43.5

NOTES: Institution type based on 1994 Carnegie classification. See National Science Board, *Science and Engineering Indicators 2006* (NSB 06-01A) for characteristics of these institution types.

SOURCE: National Center for Education Statistics, 2004 National Survey of Postsecondary Faculty, special tabulations (2006).

Science and Engineering Indicators 2008

Undergraduate S&E faculty increasingly rely on teaching assistants (TAs) to help with their courses. More than one-third of full-time undergraduate S&E faculty used TAs in 2003, up from 26% in 1992 (appendix table 2-5). The use of TAs is higher for doctoral faculty than for nondoctoral faculty, and is especially prevalent among doctoral faculty in the aggregate physical sciences/mathematics/computer sciences/engineering fields (54%). Only 16% of full-time nondoctoral S&E faculty and 18% of full-time non-S&E faculty use TAs in their undergraduate classes. Among all undergraduate faculty, primary instruction methods differ by discipline. (See sidebar "Primary Instruction Methods of Undergraduate Faculty.")

Trends in Undergraduate Education

The recent Spellings Commission report called for higher education in the United States to improve access for all students, reform the financial aid system, provide better assessments of learning outcomes, improve the quality of instruction, meet changing employer needs, and improve accountability (U.S. Department of Education 2006). Several other recent reports (BEST 2004; COSEPUP 2006; NAE 2005; Project Kaleidoscope 2006) called for reforms to undergraduate S&E education, including increasing opportunities for students to engage in original research, developing a more global perspective, broadening the diversity of S&E majors, and encouraging interdisciplinary approaches. These reports also called for improvement in teaching through incorporation of new technologies and findings from education research and assessment, and broadening education to include non-science-based skills. In recent years, new approaches to undergraduate education have been developed in a wide variety of disciplines and types of institutions. (See sidebar "Interdisciplinary Degree Programs" for ways in which some of these changes are being manifested in new programs. See sidebar "Nontechnical Skills Employers Expect of New Entrants to the Workforce" for information about what employers expect undergraduate education to provide.)

A number of recent developments, including research (both general and discipline specific) on S&E undergraduate education, published outcomes from initiatives begun earlier to improve the delivery of S&E education (AAAS 2004; Boylan 2006; Clewell et al. 2006; Lattuca, Terenzini,

Primary Instruction Methods of Undergraduate Faculty

Most (83%) instructional faculty use lecture/discussion as the primary instructional method for undergraduate classes (Chen 2002). The types of assignments and methods used to grade students vary by discipline. More than half of faculty in the natural sciences* and engineering require their undergraduate students to participate in group projects (compared with 48% of social and behavioral sciences faculty) and more than 60% require lab assignments (compared with 24% of social and behavioral sciences faculty) (appendix table 2-6).

Social and behavioral sciences faculty are more likely than faculty in other S&E fields to require written work of their students: 85% of social and behavioral sciences faculty require term papers of their undergraduate students compared with 76% of agricultural/biological/health sciences faculty and 57% of physical/mathematical/computer sciences/engineering faculty. The use of term papers increased in all disciplines between 1992 and 2003.

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* Natural sciences include agricultural, biological, health, physical, earth, atmospheric, and ocean sciences; mathematics; and computer sciences.

Interdisciplinary Degree Programs

In response to the increasing interdependence of S&E disciplines, programs and courses within higher education increasingly reflect interdisciplinary approaches. In one notable interdisciplinary field, neuroscience, the number of doctorates awarded increased from 308 in 1995 to 689 in 2005 (NORC 2006). New interdisciplinary approaches are exemplified in the multidisciplinary doctorate program being adapted at the University of California at Santa Barbara, the Economics and Environmental Science PhD Training Program (www.ees.ucsb.edu/). Students earn a doctorate in either economics or in one of the natural sciences. Students in both fields are required to fulfill requirements in their own discipline as well as interdisciplinary courses. They design and conduct thesis research projects that span the two disciplines and include faculty from both departments as advisors.

At the undergraduate level, some interdisciplinary approaches include efforts to design courses and programs around an inherently interdisciplinary discipline (such as bioinformatics or nanotechnology) as a means of developing students' abilities with allied disciplines. Others involve developing programs whose implementation is enhanced by knowledge, habits of mind, and work approaches from many disciplines. As an example of the first, a broad spectrum of physics and biology faculty in New Mexico are developing a collaborative educational network. This network uses an interdisciplinary approach to produce materials about nanoscience appropriate for use in undergraduate courses in both biology and physics as a means of introducing nanoscience into two diverse disciplines. Biology faculty are developing a knowledge base in physics and physics faculty are developing a knowledge base in biology through joint attendance at workshops and development of course materials. As an example of the second, tissue engineering is being introduced to biology and engineering students in a joint biology/mechanical engineering course at the University of South Carolina–Columbia. Senior-level students are designing bioreactors in their laboratory course and then using the experience to design experiments in courses at their own and other institutions.

and Volkwein 2006; Lopatto 2004; NAE 2005), a growing body of literature of efforts to change undergraduate education, the emergence of the National Science Digital Library (http://nsdl.org/), increasing availability of assessment and evaluation tools, and new technologies available to undergraduate students, help to inform undergraduate education reform efforts.

Several efforts to improve engineering education have been introduced by professional societies, the National Academy of Engineering, and ABET (the accrediting body for postsecondary degree-granting programs in engineering) (Lattuca, Terenzini, and Volkwein 2006; NAE 2005). In 1996, ABET adopted a new set of standards for engineering programs called Engineering Criteria 2000 (EC2000). These new standards focused on assessing learning outcomes and broadening the set of skills required to include communication, working in teams, and ethics. Another project, Engineer of 2020, is an effort by the National Academy of Engineering to look at the future of engineering, including skills that may be needed in coming years. The project envisions that graduates in 2020 will need such traits as strong analytical skills, creativity, ingenuity, professionalism, and leadership (NAE 2005).

Nontechnical Skills Employers Expect of New Entrants to the Workforce

Employers believe that in order for the United States to compete in a global economy, the entering workforce should possess certain skills beyond expertise in their major field (AACU 2005; Bollag 2005; Conference Board 2006; NACE 2005; SCANS 1991). Some of the most important of these skills include good written and oral communication, critical thinking, the ability to work in teams, good interpersonal skills, and professionalism/work ethic.

The Conference Board (2006) recently found that too few college graduates excel in these areas. The majority of employers reported that 2- and 4-year college graduates were "adequate" in terms of general preparation for entry-level jobs. However, only 10% reported that 2-year graduates and 24% reported that 4-year graduates were "excellent." In addition, more than one-fourth of employers reported that 4-year college graduates and almost half reported that 2-year college graduates were deficient in written communication. When asked about future skill needs, employers reported that the following basic knowledge and applied skills are expected to increase in importance: knowledge of foreign languages, making appropriate choices concerning health and wellness, and creativity/innovation.

Beyond attitudinal surveys, there is little current quantitative evidence of the effectiveness of postsecondary education, whether for specific knowledge and skills related to a field of study or for workplace readiness (Swyer, Millet, and Payne 2006; U.S. Department of Education 2006). However, efforts are under way to provide such evidence.

In mathematics, special interest groups focusing on educational issues at the undergraduate level have been formed at the Mathematical Association of America. In biology, several new or upgraded education journals have been introduced in recent years, for example, *CBE Life Sciences Education, Microbiology Education, Biochemistry and Molecular Biology Education,* and Education Forum section in *Science*. Across fields, science departments are beginning to build science education positions into their departmental structure, hiring people with a strong research degree within the discipline and interest and expertise in educational research (Bush et al. 2006; NAS 2006). These types of positions have a relatively long history in mathematics and physics but are only beginning to be widely introduced in disciplines such as biology, chemistry, or earth sciences.

In the federal government, the Academic Competitiveness Council recently focused attention on the effectiveness of federal agency programs in science, technology, engineering, and mathematics (STEM) education (U.S. Department of Education 2007). Nine federal agencies administer 43 programs aimed at improving STEM undergraduate education, including increasing numbers and retention in STEM fields, increasing diversity, and improving content and pedagogy. The council advocated more rigorous evaluation of these programs, particularly of long-term student outcomes.

Financing Higher Education

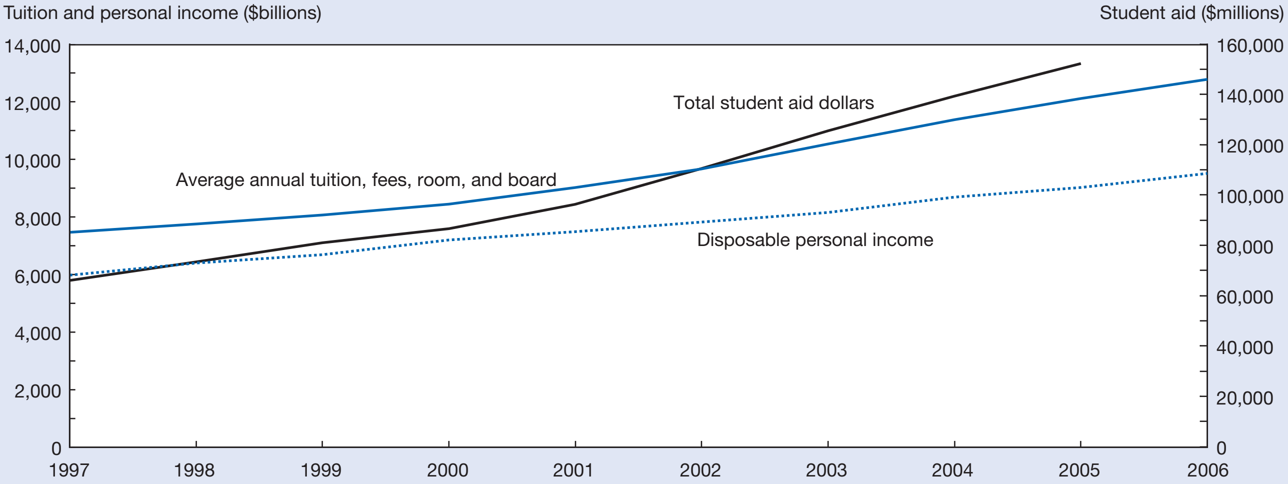
Rising costs of higher education and increases in student debt over the past two decades raised questions about affordability and access in U.S. higher education institutions (NSB 2003). Public institutions account for about 40% of all degree-granting higher education institutions in the United States and enroll almost 80% of all undergraduates. In the past, these institutions were funded primarily through state expenditures. In recent years, the percentage of funding coming from state expenditures has declined, state per-student spending has declined, and tuition has increased. This section examines trends in tuition levels (including net price to students by family income), need-based and merit-based financial aid, financial support for undergraduate and graduate education, and student debt.

Tuition

Tuition and fee increases at colleges and universities in the United States have grown rapidly for the past two decades, rising well above increases in disposable income. However, student aid increased even faster than tuition (figure 2-2). Tuition and fee increases reached double-digit rates in 2003–04, although the rate of increase slowed in the past few years (table 2-2). In the 2006–07 academic year, average tuition and fees, compared with the previous year, rose 6.3% for in-state students at public 4-year colleges, 5.9% for students in private 4-year colleges, and 4.1% for students at public 2-year colleges (College Board 2006a).

As state spending rose from FY 2005 to FY 2007, the rate of increase of tuition and fees at public 4-year colleges slowed. Fluctuations in state spending, however, do not completely explain variations in tuition and fees. Other contributors to tuition and fee increases include rising prices of goods and services purchased by colleges and universities as measured by the Higher Education Price Index, which have risen faster in recent years than the Consumer Price Index (CPI). From academic years 2000–01 to 2005–06, the prices paid by colleges and universities for utilities, salaries, fringe benefits, and supplies and materials rose faster than the CPI (College Board 2006a).

Figure 2-2
Average annual tuition, fees, room, and board for public 4-year institutions, total student aid dollars, and disposable personal income: 1997–2006



SOURCES: College Board, Trends in College Pricing 2006; and Bureau of Economic Analysis, National Income and Product Accounts Table 2.1, http://www.bea.gov/national/nipaweb/SelectTable.asp?Selected=N, accessed 13 April 2007.

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Table 2-2
Average annual published tuition and fee charges: 1996–97 to 2006–07

	Private 4-year		Public 4-year		Public 2-year		Private 4-year		Public 4-year		Public 2-year	
Academic year	Charges (current US$)	Annual change (%)	Charges (current US$)	Annual change (%)	Charges (current US$)	Annual change (%)	Charges (2006 constant US$)	Annual change (%)	Charges (2006 constant US$)	Annual change (%)	Charges (2006 constant US$)	Annual change (%)
1996–97	12,994	na	2,975	na	1,465	na	16,843	na	3,856	na	1,899	na
1997–98	13,785	6.1	3,111	4.6	1,567	7.0	17,480	3.8	3,945	2.3	1,987	4.6
1998–99	14,709	6.7	3,247	4.4	1,554	-0.8	18,355	5.0	4,052	2.7	1,939	-2.4
1999–2000	15,518	5.5	3,362	3.5	1,649	6.1	18,935	3.2	4,102	1.2	2,012	3.8
2000–01	16,072	3.6	3,508	4.3	1,642	-0.4	18,965	0.2	4,139	0.9	1,938	-3.7
2001–02	17,377	8.1	3,766	7.4	1,608	-2.1	19,962	5.3	4,326	4.5	1,847	-4.7
2002–03	18,060	3.9	4,098	8.8	1,674	4.1	20,379	2.1	4,624	6.9	1,889	2.3
2003–04	18,950	4.9	4,645	13.3	1,909	14.0	20,931	2.7	5,131	11.0	2,109	11.6
2004–05	20,045	5.8	5,126	10.4	2,079	8.9	21,568	3.0	5,516	7.5	2,237	6.1
2005–06	20,980	4.7	5,492	7.1	2,182	5.0	21,781	1.0	5,702	3.4	2,265	1.3
2006–07	22,218	5.9	5,836	6.3	2,272	4.1	22,218	2.0	5,836	2.4	2,272	0.3

na = not applicable

NOTE: Enrollment data weighted.

SOURCE: College Board, Trends in College Pricing 2006.

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Students typically do not pay the full tuition and fee charges, which averaged $5,836 for in-state students at public 4-year colleges, $22,218 for students at private 4-year colleges, and $2,272 for students at public 2-year colleges during the 2006–07 academic year (table 2-2). The net price of an undergraduate college education is defined as the published price minus the average grant aid and tax benefits that students receive. Student aid (grant aid and tax benefits) averaged $3,100 at public 4-year institutions, $9,000 at private 4-year institutions, and $2,200 at public 2-year institutions in 2006–07.

In 2006–07, the net price was about $2,700 at public 4-year institutions, $13,200 at private 4-year institutions, and under $100 at public 2-year colleges (College Board 2006a).[4] The net price at public 4-year institutions (in inflation-adjusted dollars) fell between 1997–98 and 2002–03 but rose through 2006–07, while the net price at private 4-year institutions rose between 1997–98 and 2006–07. The net price of college for low-income students did not increase over the past decade. For middle-income students, the net price of college also remained stable after accounting for grants and loans (with the bulk of aid in the form of loans). Thus, middle-income students 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 both increased (American Council on Education 2005).

Graduate tuition varies more than undergraduate tuition. Graduate tuition is typically per credit, which varies by academic institution and often varies within an institution depending on the school, department, or degree program, and sometimes the stage of the program (e.g., first-year, dissertation). Furthermore, the number of credits required for graduation and thus the total tuition varies by the length of the program (e.g., 1-year master's, 2-year master's, doctoral). On average, the cost of attendance was $24,000 for full-time graduate students in public institutions and $35,800 for those in private institutions for the 2003–04 academic year (Redd 2006).

The number of students who pay tuition also varies by enrollment status, institution, discipline, and type of funding. In some disciplines, most full-time students receive financial assistance in the form of fellowships, teaching assistantships, or research assistantships, and many may receive tuition waivers. However, school-to-school differences exist even within disciplines, and master's level students are generally treated differently from doctoral candidates. In other disciplines, students are largely self-supported and do not receive tuition waivers. (See sidebar, "Cost of Higher Education Internationally.")

Undergraduate and Graduate Student Financial Support Patterns

Financial Support for Undergraduate Education. As tuition increased in the 1990s, students increasingly relied on financial aid (especially loans) to finance their education. Financial aid for undergraduate students is mainly in the form of grants, student loans (federal or private), and work study. A financial aid package may contain one or more of these kinds of support. In the 2003–04 academic year, about one-third of all undergraduate students received no financial aid, about half received grants, and about one-third took out loans (NCES 2005a). A higher percentage of undergraduates in private, nonprofit 4-year institutions (83%) than of those in public 4-year

Cost of Higher Education Internationally

Unlike the United States, many countries historically did not charge tuition for higher education. In the past decade, however, most instituted some form of cost sharing, either tuition or fees (Preston 2006). Imposition of tuition and fees has been a response to a growing need for additional revenue, growth in enrollment, and competing demands on public funding. For example, tuition was first instituted in China in 1997, in Great Britain in 1998, in Austria in 2001, and in some German states in 2006 (Johnstone 2003; Kehm 2006). In the Scandinavian countries, tuition remains free but students are charged for room and board. In some countries in East Asia and Latin America, public institutions remain free but because enrollment is limited, expansion of higher education has been primarily through private institutions that charge tuition and fees. In most countries where tuition is charged, students are offered some form of low-cost loans for higher education (Johnstone 2003).

The initiation of tuition and fees and increases in tuition in some countries have raised concerns about affordability. For example, in China in 2000, the government set annual tuition at about 5,000 yuan (about U.S. $600), which is considered high given the average urban per capita income of 10,493 yuan (U.S. $1,313) and the average farmer's income of 3,256 yuan (U.S. $407) (OBHE 2003; Shinan 2006). In Canada, average undergraduate tuition increased at an average of 7% annually since 1990–91, almost 4 times the average rate of inflation (Statistics Canada 2006). Canadian public colleges are seen by some as less affordable than those in the United States because even though tuition is lower, U.S. public colleges provide far more money in the form of grants than do Canadian colleges (Birchard 2006; Usher and Steele 2006). Direct comparisons of affordability across countries are difficult because tuition, financial assistance, and policies for providing public subsidies vary widely among countries and even within some countries depending on citizenship (OECD 2006). Table 2-3 shows average amounts of tuition by country. Countries with higher tuition fees do not necessarily provide greater amounts of financial support to students, and countries with low tuition may have substantial proportions of students receiving scholarships and grants (OECD 2006).

Table 2-3

Estimated average annual tuition fees of tertiary-type A educational institutions for full-time students, by type of institution: Academic year 2004

(U.S. dollars)

Country	Public institutions	Private institutions
OECD countries		
Australia	5,289	13,420
Austria	853	800
Belgium (Flemish)[a]	540	536
Belgium (French)[a]	658	751
Canada	3,267	NA
Czech Republic	None	3,449
Denmark	None	NA
Finland	None	None
France	156–462	500–8,000
Germany	NA	NA
Greece	NA	NA
Hungary	351	991
Iceland	None	3,000 (2,100–4,400)
Ireland	NA	NA
Italy	983	3,992
Japan	3,747	5,795 (4,769–25,486)
Korea	3,623 (1,955–7,743)	6,953 (2,143–9,771)
Luxembourg	na	na
Mexico	NA	NA
Netherlands	na	1,565
New Zealand[b]	2,538	3,075
Norway	None	4,000–6,500
Poland	NA	NA
Portugal	868	3,803
Slovak Republic	None	NA
Spain	801 (668–935)	NA
Sweden	None	None
Switzerland	566–1,132	NA
Turkey	274	9,303–11,961
United Kingdom	na	1,794
United States	4,587	17,777
Partner countries		
Chile	3,845	3,822
Israel	2,300	2,442

NA = not available; na = not applicable; OECD = Organisation for Economic Co-operation and Development

[a] Tuition fees same in public and private institutions, but distribution of students differs between public and private institutions, explaining why weighted average not same.

[b] Tertiary-type A includes advanced research programs.

NOTES: Academic year 2004 refers to 2003–04 school year. U.S. dollars converted using purchasing power parities (PPPs). PPPs are currency conversion rates that both convert to common currency and equalize purchasing power of different currencies and eliminate differences in price levels between countries in process of conversion. Amounts of tuition fees and associated proportions of students should be interpreted with caution because result from weighted average of main tertiary-type A programs and do not cover all educational institutions. However, figures reported can be considered good proxies and show difference among countries in tuition fees charged by main educational institutions for majority of students.

SOURCE: OECD, Education at a Glance: OECD Indicators 2006 (2006), http://www.oecd.org/edu/eag2006. See Annex 3 for notes, accessed 13 April 2007.

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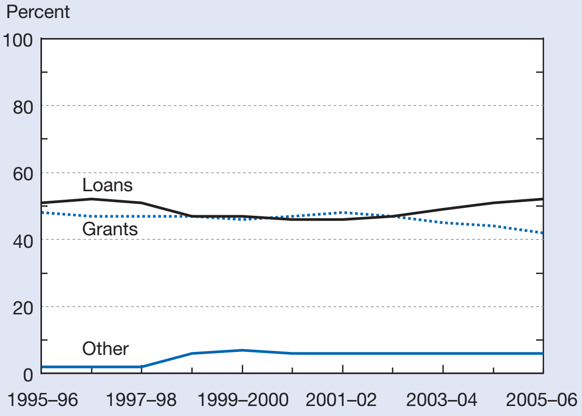
(69%) or public 2-year institutions (47%) received some type of financial aid, either grants (73% compared with 52% and 40%, respectively) or loans (56% compared with 45% and 12%, respectively). The percentage of full-time undergraduates who had federal loans increased from 31% in 1992–93 to 48% in 2003–04 (NCES 2006), and the average amount of loans increased. In recent years, students have increasingly relied on private loans, which typically have much higher interest rates. At the same time, the percentage of students who are supported by grants alone or in combination with other mechanisms decreased (College Board 2006b) (figure 2-3).

Financial aid packages are often awarded on the basis of either need or academic merit, although some forms of aid combine both criteria. Need-based financial aid, which was the norm through the 1980s, aims to increase access for students who otherwise could not afford to attend college. In recent years, an increasing number of financial aid programs and increasing dollar amounts focused on academic merit in an effort to attract top students. Merit-based aid (i.e., aid for which recipients are selected on the basis of test scores, performance, class rank, grade point average, or other achievement) makes up an increasing percentage of state grants, rising from 9% in 1984–85 to 27% in 2004–05. The number of federal Pell Grant (which are based on financial need) recipients increased over time, but the average amount of aid per recipient decreased in recent years in both current and inflation-adjusted dollars (College Board 2006b).

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.

Figure 2-3
Grants and loans as percentage of undergraduate student aid: 1991–92 to 2005–06



NOTES: Estimated 2004–05 data; preliminary 2005–06 data.

SOURCE: College Board, Trends in Student Aid: 2006, Trends in Higher Education Series (2006).

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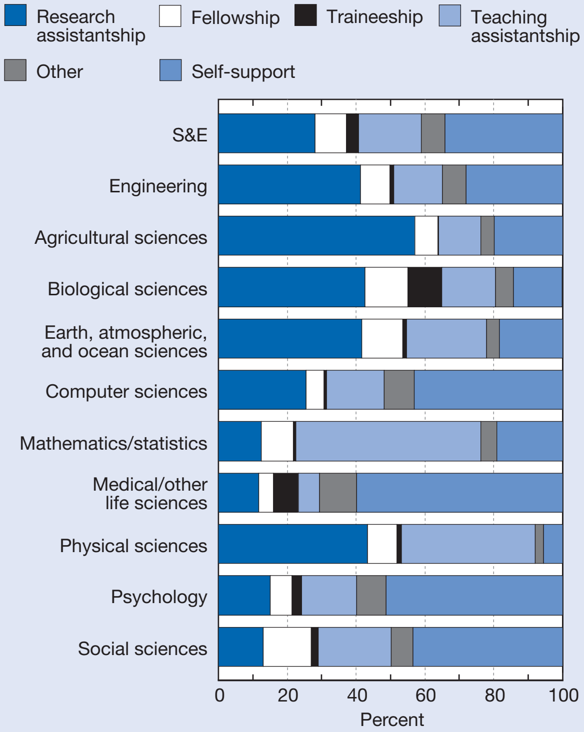
Support mechanisms include research assistantships (RAs), teaching assistantships (TAs), fellowships, and traineeships. Sources of funding include federal agency support, nonfederal support, and self-support. Nonfederal support includes state funds, particularly in the large public university systems; these funds are affected by the condition of overall state budgets. 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 any given academic year.

Other than self-support, RAs are the most prevalent primary mechanism of financial support for S&E graduate students. The percentage of full-time S&E graduate students supported primarily by RAs increased in the late 1980s, rising from 24% in 1985 to roughly 27%–29% from 1988 through 2005. Although the number of full-time S&E graduate students relying primarily on fellowships and TAs rose over the past two decades, an increase in overall graduate enrollment meant that the percentage of students supported by these mechanisms stayed flat or declined. In 2005, 18% of full-time S&E graduate students were primarily supported through TAs and 13% were primarily supported through either traineeships or fellowships (appendix table 2-7).

Primary mechanisms of support differ widely by S&E field of study (appendix table 2-8). For example, in 2005, full-time students in physical sciences were financially supported mainly through RAs (43%) and TAs (39%) (figure 2-4). RAs also were important in agricultural sciences (57%); biological sciences (43%); earth, atmospheric, and ocean 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 (47%) or receive TAs (19%), and students in medical/other life sciences are mainly self-supporting (60%).

The federal government served as the primary source of financial support for about 21% of full-time S&E graduate students in 2005 (appendix table 2-9). 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 2005, the federal government funded 67% of S&E graduate students on traineeships, 51% of those with RAs, and 23% of those with fellowships. Federal financial support for graduate education reaches relatively more students in the physical sciences; earth, atmospheric, and ocean sciences; agricultural sciences; biological sciences; and engineering. Relatively fewer students in mathematics, computer sciences, social sciences, psychology, and medical/other life sciences receive federal support (figure 2-5). Appendix table 2-9 provides detailed information by field and mechanism. (See "Expenditures by Field and Funding Source" in chapter 5 for information on federal academic R&D funding by discipline.)

Figure 2-4
Full-time S&E graduate students, by field and mechanism of primary support: 2005



NOTE: Self-support includes any loans (including federal) and support from personal or family financial contributions.

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 2-8.

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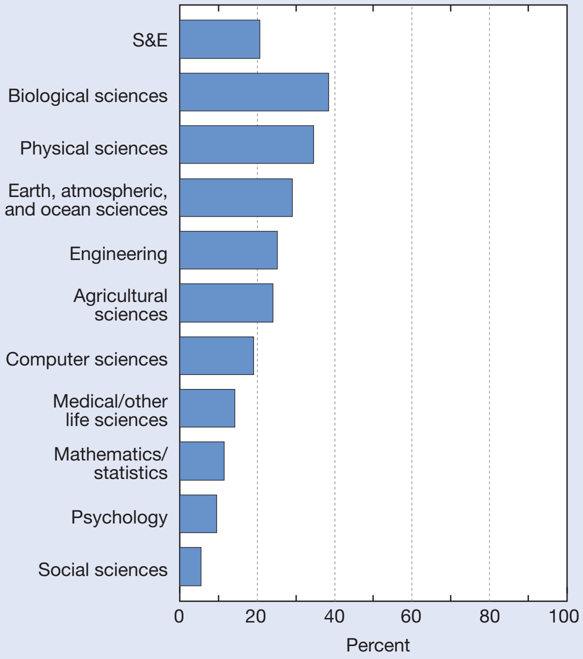
Most federal financial support for graduate education is in the form of research assistantships funded through grants to universities for academic research. Research assistantships are the primary mechanism of support for 69% of federally supported full-time S&E graduate students, up from 62% two decades earlier. Fellowships and traineeships are the means of funding 22% of the federally funded full-time S&E graduate students, and federally funded fellowships and traineeships fund 4% of all full-time S&E graduate students. The share of federally supported S&E graduate students receiving traineeships declined from 18% in 1985 to 12% in 2005. For students supported through nonfederal sources in 2005, TAs were the most prominent mechanism (40%), followed by RAs (31%) (appendix table 2-7).

The National Institutes of Health (NIH) and the National Science Foundation (NSF) support most of the full-time S&E graduate students whose primary support comes from the federal government. In 2005, they supported about 26,800 and 20,400 students, respectively. Trends in federal agency support of graduate students show considerable increases from 1985 to 2005 in the proportion of students funded (NIH, from 23% to 32%; NSF, from 21% to 24%). Support from the U.S. Department of Defense declined during the 1990s (from 15% to 11% of federally supported graduate students), offsetting to some extent the increasing percentage that received NSF support (appendix table 2-10).

Figure 2-5
Full-time S&E graduate students with primary support from federal government, by field: 2005



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 2-9.

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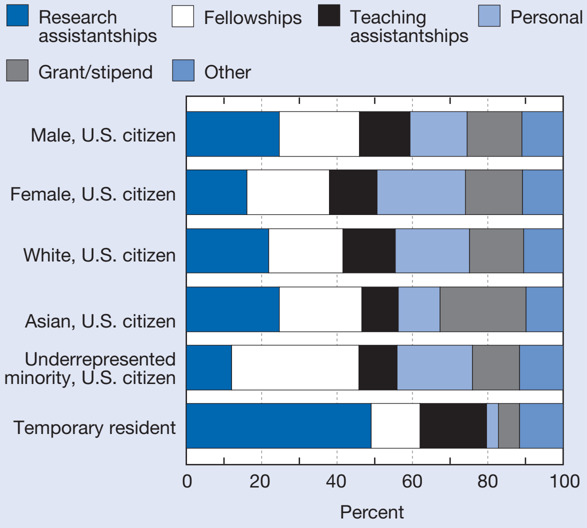
For doctoral degree students, notable differences exist in primary support mechanisms by sex, race/ethnicity, and citizenship (figure 2-6). In 2005, male U.S. citizens were more likely to have been supported by RAs (25%) and female U.S. citizens were more likely to have supported themselves from personal sources of funds (23%). Among U.S. citizens, whites and Asians/Pacific Islanders were more likely than other racial/ethnic groups to have had primary support from RAs (22% and 25%, respectively), and underrepresented minorities depended more on fellowships (34%). The primary source of support for doctoral degree students with temporary visas was an RA (49%) (appendix table 2-11).

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 of both sexes 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 self-support is prevalent. Differences in type of support by sex, race/ethnicity, or citizenship remain, however,

Figure 2-6
Primary mechanisms of support for S&E doctorate recipients, by citizenship, sex, and race/ethnicity: 2005



NOTES: Personal sources include personal savings, other personal earnings in graduate school, other family earnings or savings, and loans. Other includes employer reimbursement or assistance, foreign support, traineeships, other assistantships, and other and unknown sources. S&E includes health fields (i.e., medical and other life sciences). U.S. citizen total includes unknown sex. Underrepresented minority includes blacks, Hispanics, American Indians/Alaska Natives, Native Hawaiians/other Pacific Islanders, and multiple races/ethnicities.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Earned Doctorates, special tabulations (2007).

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even accounting for doctorate field (NSF/SRS 2000). These differences in type of support have potential consequences for levels of debt and long-term career success (Nettles and Millett 2006).

Undergraduate and Graduate Debt

Undergraduate debt. Undergraduate major has relatively little effect on undergraduate debt (NSF/SRS 2006a); however, levels of debt vary by type of institution and state. Levels of undergraduate debt for students from public colleges and universities are almost as high as those for students from private colleges and universities. The median level of debt for 2003–04 bachelor's degree recipients who took out loans was $19,300 overall; $19,500 for those who graduated from private nonprofit institutions and $15,500 for those who graduated from public colleges and universities (College Board 2006b).

Levels of debt vary widely by state. Average debt for 2005 graduates of public 4-year colleges and universities ranged from $23,198 in Iowa to $11,067 in Utah (Burd 2006; Project on Student Debt 2006). Average debt for graduates of private nonprofit colleges and universities ranges from $32,504 in Arizona to $13,309 in Utah. Levels of debt are not necessarily higher in states where the cost of living is high, and are not necessarily higher in schools in which tuition is high. Some low-tuition schools with large numbers of low-income students report high levels of average student debt. See "Higher Education" in chapter 8 (State Indicators) for additional state indicators dealing with higher education.

Debt Levels of S&E Doctorate Recipients. At the time of doctoral degree conferral, about half of S&E doctorate recipients have debt related to either their undergraduate or graduate education. About a fourth have some undergraduate debt and about a third owe money directly related to graduate education. In 2005, 27% of S&E doctorate recipients reported having undergraduate debt and 33% reported having graduate debt. For some, debt levels were high, especially for graduate debt: 1% reported more than $50,000 of undergraduate debt and 10% reported more than $50,000 of graduate debt (appendix table 2-12).

Levels of debt vary widely by doctorate fields. High levels of graduate debt were most common among doctorate recipients in psychology, social sciences, and medical/other health sciences. Psychology doctorate recipients were most likely to report having graduate debt and also high levels of debt.[5] In 2005, 26% of psychology doctoral degree recipients compared with 10% of all S&E doctoral degree recipients reported graduate debt of more than $50,000. Doctorate recipients in engineering; biological sciences; computer sciences; earth, atmospheric, and ocean sciences; mathematics; and physical sciences were least likely to report graduate debt. Although men and women differed little in level of debt, blacks and Hispanics had higher levels of graduate debt than whites, even accounting for differences in field of doctorate (NORC 2006).

Debt levels in non-S&E graduate/professional fields. Average student loan debt was higher for students graduating with law degrees, medical degrees, and other health degrees than it was for those with doctoral degrees in 2003–04. Law graduates from public institutions averaged $51,200, medical doctors averaged $78,400, and other health graduates averaged $66,000 in cumulative student loan debt, compared with $39,000 for doctoral degree recipients. Debt for those with degrees from private institutions was even higher (Redd 2006).

Debt burden. Graduates with relatively high post-college earnings may find it easier to pay off education-related debt than those with lower earnings, given similar amounts of debt and similar interest rates. Because starting salaries in the humanities and social sciences are relatively low and debt is relatively high, debt burden (loan payments as a percent of salary) of master's and doctoral graduates in the humanities and social sciences is higher than in other fields (although debt burden of law students is also high). Debt burden is lower in the natural sciences, life sciences, and engineering (Redd 2006).

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. 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 12.7 million students in 1986 to 16.9 million in 2004 (appendix table 2-13), despite declines in the college-age population in the mid-1990s. 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 2004. Research universities (doctorate-granting universities with very high research activity) and master's-granting universities together accounted for another 37% of all students enrolled (6.2 million) (appendix table 2-13). (See sidebar "Carnegie Classification of Academic Institutions" for definitions of the types of academic institutions.)

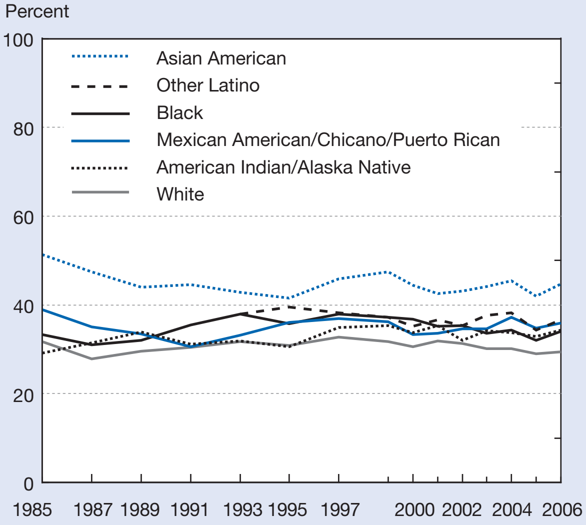
Enrollment in higher education is projected to increase in coming years because of increases in the college-age population (NCES 2005b). These projections are based primarily on population projections but also incorporate information about household income (a measure of ability to pay) and age-specific unemployment rates (a measure of opportunity costs).[6] According to Census Bureau projections, the number of college-age (ages 20–24) individuals is expected to grow from 20.8 million in 2005 to 26.3 million by 2050 (appendix table 2-14). Increased enrollment in higher education is projected to come mainly from minority groups, particularly Asians and Hispanics. From 2000 to 2050, the Asian and Hispanic college-age populations are projected to more than double, while the black and white non-Hispanic college-age populations are projected to rise by 48% and 0.5%, respectively (appendix table 2-14).

Undergraduate Enrollment in S&E

Freshmen Intentions to Major in S&E

Since 1972, the annual Survey of the American Freshman, National Norms, which is administered by the Higher Education Research Institute at the University of California at Los Angeles, asked freshmen at a large number of universities and colleges about their intended majors. The data provided a broadly accurate picture of degree fields several years later.[7] For at least the past two decades, about one-third of all freshmen planned to study S&E. In 2006, about one-third of white, black, Hispanic, and American Indian freshmen and 45% of Asian freshmen reported that they intended to major in S&E (figure 2-7). The proportions planning to major in S&E were higher for men in every racial/ethnic group (appendix table 2-15). For most racial/ethnic groups, about 10%–16% planned to major in social/behavioral sciences, about 6%–8% in engineering, about 8%–10% in biological/agricultural sciences, 1%–2% in computer sciences, 2%–3% in physical sciences,[8] and 1% in mathematics or statistics. Higher proportions of Asian freshmen than of those from other racial/ethnic groups planned to major in biological/agricultural sciences (17%) and engineering (12%). The percentages of all freshmen intending to major in engineering or computer sciences dropped in recent years, while the percentage intending to major in biological/agricultural sciences increased.

Figure 2-7
Freshmen intending S&E major, by race/ethnicity: Selected years, 1985–2006



SOURCE: Higher Education Research Institute, University of California at Los Angeles, Survey of the American Freshman: National Norms, special tabulations (2007).

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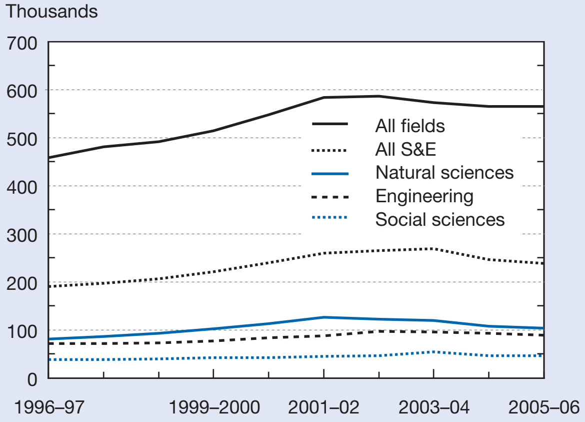
The demographic composition of students planning S&E majors has become more diverse over time. Women constituted 39% of freshmen planning S&E majors in 1985, but this proportion rose to 47% in 2006. White students declined from 84% in 1985 to 72% in 2006. On the other hand, the proportion of Asian students increased from 4% to 12%, Hispanic students from 2% to 9%, and American Indian students from 1% to 2% (appendix table 2-16). Black students increased from 10% to 11% of freshmen intending to major in S&E.

Foreign Undergraduate Enrollment

The total number of foreign students (undergraduate, graduate, and other) enrolled in U.S. academic institutions held steady in 2005–06 after 2 consecutive years of decline. The number of foreign students in S&E fields dropped in 2005–06 for the second year in a row (figure 2-8). Enrollment of new foreign students increased 5%, suggesting that total foreign enrollment is likely to increase in coming years. The number of foreign undergraduates decreased 1%, the fourth con-

Figure 2-8
Foreign students, by field of study: 1996–97 to 2005–06



NOTES: Foreign students include both undergraduate and graduate students. Natural sciences include physical, biological, earth, atmospheric, ocean, agricultural, and computer sciences and mathematics. Social sciences include psychology.

SOURCE: Institute of International Education, Open Doors (various years).

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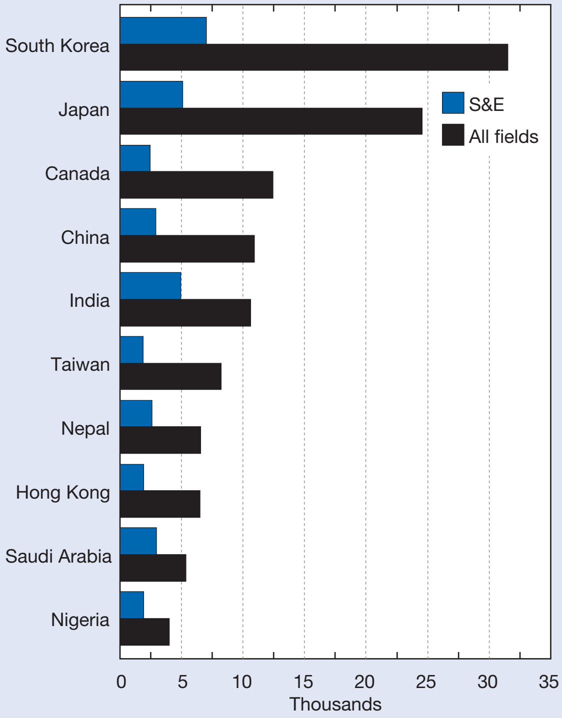
secutive decline after record increases during the 1990s (IIE 2006). Decreases in foreign enrollments from 2001 through 2005 have been attributed to increased opportunity for higher education in the home country, competition from other countries for foreign students, rising U.S. tuition, and difficulties in obtaining U.S. visas (IIE 2005). Recently, adjustments to visa requirements made it easier for students to obtain visas, and their number increased. Declines in particular fields may also be due to declining job opportunities in those fields. Among all foreign students (undergraduate and graduate), the number of those studying the physical sciences dropped 4%, mathematics 5%, engineering 5%, and computer sciences 12% in 2005–06 compared with the preceding year. Other S&E fields experienced increases in foreign students; for example, agricultural sciences and biological and biomedical sciences each increased 5% and psychology increased 3% (IIE 2006).

South Korea (31,500), Japan (24,500), Canada (12,400), China (10,900), and India (10,600) accounted for the largest numbers of foreign undergraduates in the United States in April 2007 and were among the top countries sending foreign undergraduates in S&E fields (figure 2-9; appendix table 2-17). Saudi Arabia and Nepal, which accounted for fewer total undergraduates in the United States, were also among the top countries sending foreign undergraduates in S&E fields.

Enrollment by Field

For the most part, undergraduate enrollment data are not available by field; however, annual data on engineering enrollment are available from the Engineering Workforce Commission, and the Conference Board of Mathematical Sciences compiles data on enrollment in mathematics and statistics every 5 years.

Figure 2-9
Foreign undergraduate student enrollment in U.S. universities, by field (S&E and all fields) for top 10 places of origin: April 2007



SOURCE: Bureau of Citizenship and Immigration Services, Student and Exchange Visitor Information System database, special tabulations (2007). See appendix table 2-17.

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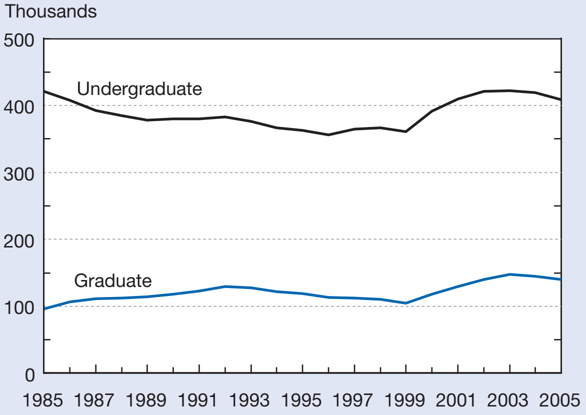
Engineering. Undergraduate engineering enrollment declined through most of the 1980s and 1990s, rose from 2000 through 2003, and declined slightly in recent years. Undergraduate engineering enrollment declined from 420,900 students in 1985 to about 361,400 students by 1999 before rebounding to about 422,000 in 2003. By 2005, it declined to 409,300 (figure 2-10; appendix table 2-18). The declines in undergraduate engineering enrollment in recent years were evident for both men and women and for most racial/ethnic groups (NSF/SRS 2007a). Graduate engineering enrollment rose since the late 1990s, reaching a new peak of 147,900 in 2003, then declined to 139,800 in 2005 (figure 2-10; appendix table 2-19).

Mathematics and Statistics. Undergraduate enrollment in mathematics and statistics departments declined slightly between fall 2000 and fall 2005 in 4-year colleges and universities, and increased 26% in public 2-year colleges. More than half of student enrollment in mathematics courses in 2-year colleges is in precollege (or remedial) mathematics (Kirkman et al. 2007). The number of students taking precollege level courses (remedial courses) in mathematics at 4-year colleges and universities dropped from 261,000 in fall 1990 to 201,000 in fall 2005. During the same period,

Figure 2-10
U.S. engineering enrollment, by level: 1985–2005



NOTE: Enrollment data include full- and part-time students.

SOURCE: Engineering Workforce Commission, Engineering & Technology Enrollments, Fall 2005, American Association of Engineering Societies (2006). See appendix table 2-19.

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the number of students taking precollege level mathematics courses at 2-year colleges increased from 724,000 to 965,000 (table 2-4). The decline at 4-year institutions may reflect the policies of some states to move state-supported remedial education to 2-year institutions. Efforts are currently under way in at least 26 states to improve communication between high schools and colleges and to better align high school graduation standards to skills required for college entry (Cohen et al. 2006).

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 trends in graduate S&E enrollment, including trends in first-time enrollment of foreign students after September 11, 2001.

Enrollment by Field

S&E graduate enrollment in the United States reached a new peak of 583,200 in fall 2005. Following a long period of growth that began in the 1970s, graduate enrollment in S&E declined in the latter half of the 1990s but increased steadily since 1999 (appendix table 2-20). Growth occurred through 2005 in most major S&E fields, with two notable exceptions. In computer sciences, enrollment increased through 2002, and in engineering, through 2003. Enrollment in both areas then declined through 2005, with the decline attributable to foreign student enrollment. The number of full-time students enrolled for the first time in S&E graduate departments offers a good indicator of developing trends. The number of first-time full-time S&E graduate students also reached a new peak (110,400) in 2005. It declined in the mid-1990s in all major S&E fields but increased in most science fields through 2005 (appendix table 2-21). Growth was greatest in biological sciences, medical/other life sciences, and social and behavioral sciences. First-time full-time graduate enrollment declined in recent years in engineering; computer sciences; mathematics; earth, atmospheric, and ocean sciences; and agricultural sciences.

First-time full-time graduate enrollment, particularly in engineering and computer sciences, often follows trends in employment opportunities. When employment opportunities are plentiful, recent graduates often forego graduate school, but when employment opportunities are scarce, further training in graduate school may be perceived as a better option. Figure 2-11 shows trends in unemployment rates and first-time full-time graduate enrollment in engineering and computer sciences. Enrollment in S&E fields that offer fewer employment opportunities at the bachelor's level (e.g., biological sciences) does not follow this trend.

Enrollment by Sex and Race/Ethnicity

The recent increase in S&E graduate enrollment overall occurred across all major U.S. citizen and permanent resident demographic groups: women, minorities, and white men. The number of women enrolling in graduate science programs increased for the past two decades except for a

Table 2-4
Enrollment in mathematics courses, by type of school and course level: Fall 1990, 1995, 2000, and 2005
(Thousands)

Type of school/course level	1990	1995	2000	2005
4-year colleges and universities				
All mathematics courses	1,619	1,469	1,614	1,607
Precollege mathematics courses	261	222	219	201
Public 2-year college mathematics programs				
All mathematics courses	1,241	1,384	1,273	1,580
Precollege mathematics courses	724	800	763	965

NOTE: Includes distance learning.

SOURCE: Kirkman E, Lutzer KJ, Maxwell JW, Rodi SB, CBMS [Conference Board for Mathematical Sciences] 2005: Statistical Abstract of Undergraduate Programs in the Mathematical Sciences in the United States, Fall 2005 CBMS Survey, American Mathematical Society (2007), http://www.ams.org/cbms/, accessed 3 April 2007.

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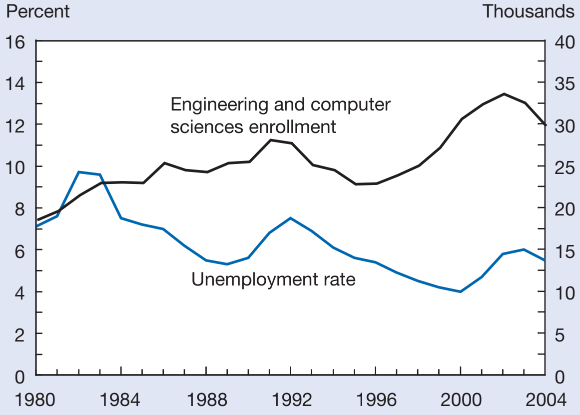
Figure 2-11
First-time full-time graduate enrollment in engineering and computer sciences and unemployment rate of all workers: 1980–2004



SOURCES: National Science Foundation, Division of Science Resources Statistics, Survey of Graduate Students and Postdoctorates in Science and Engineering, WebCASPAR database, http://webcaspar.nsf.gov. Unemployment rates from Bureau of Labor Statistics, Current Population Survey, Table 1. Employment status of the civilian noninstitutional population, 1940 to date, ftp://ftp.bls.gov/pub/special.requests/lf/aat1.txt, accessed 3 April 2007. See appendix table 2-21.

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decline in computer sciences enrollment since 2002. In contrast, the number of male S&E graduate students declined from 1993 through the end of that decade before increasing in recent years (appendix table 2-20).

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 1985 and 49% in 2005, although large variations among fields persist. In 2005, women constituted the majority of graduate enrollment in psychology (76%), medical/other life sciences (78%), biological sciences (56%), and social sciences (54%). They constituted considerable proportions of graduate students in mathematics (37%), chemistry (40%), and earth, atmospheric, and ocean sciences (46%). However, their percentage in computer sciences (25%) remains unchanged since 1985 and their percentages in engineering (22%) and physics (20%) remain low (appendix table 2-20).

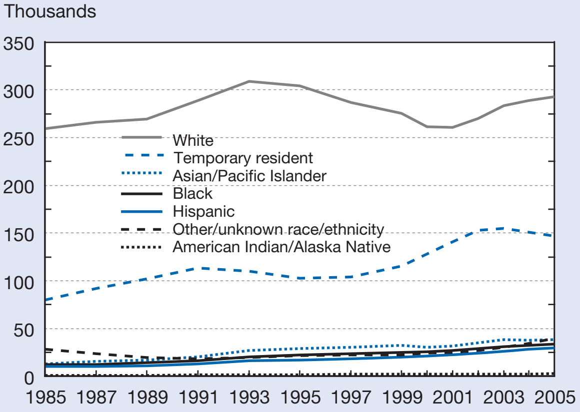
The proportion of underrepresented minority (black, Hispanic, and American Indian/Alaska Native) students in graduate S&E programs increased from about 6% in 1985 to about 11% in 2005.[9] Increases occurred in all major science fields and in engineering during that period (appendix table 2-22). In 2005, blacks, Hispanics, and American Indians/Alaska Natives as a group made up 6%–7% of graduate enrollment in many S&E fields (engineering; mathematics; physical sciences; earth, atmospheric, and ocean sciences; and computer sciences), 8%–9% of graduate enrollment in agricultural and biological sciences, 14% in medical/other life 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 and then increased through 2005, while the numbers of black, Hispanic, and American Indian/Alaska Native students increased steadily from 1985 through 2005 (figure 2-12). The long-term rise in the numbers of black, Hispanic, and American Indian/Alaska Native graduate students occurred in most S&E fields with the exceptions of engineering and mathematics. In those two fields, enrollment reached a plateau in the 1990s before rising again from 2000 through 2005. In computer sciences, enrollment of blacks and American Indians/Alaska Natives peaked in the early 2000s as it did for all other racial/ethnic groups, then declined (although Hispanic enrollment in computer sciences continued to rise). The number of Asian/Pacific Islander S&E graduate students increased every year since 1985 with the exception of 2000 and 2004. As was the case for all racial/ethnic groups, Asian enrollment in graduate engineering programs dropped in the mid-1990s, increased through 2003, then declined again. Asians/Pacific Islanders accounted for about 7% of S&E graduate enrollment in 2005 (appendix table 2-22).

Foreign Student Enrollment

Foreign graduate student enrollment in S&E grew from 79,900 in 1985 to 154,900 in 2003 before declining through 2005. Despite the decline, the number of foreign S&E graduate students in 2005 (146,700) was higher than in 2001. Foreign students increased from 20% to 25% of all S&E graduate students from 1985 to 2005 (appendix table 2-22). The concentration of foreign enrollment was highest in engineering (45%), computer sciences (43%), physical sciences (40%), and mathematics (37%).

Figure 2-12
S&E graduate enrollment, by citizenship and race/ethnicity: Selected years, 1985–2005



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.

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First-time full-time enrollment of foreign S&E graduate students increased 4% in fall 2005, the first increase since September 11, 2001, although numbers remain below those of 2001 (appendix table 2-23). The number of first-time full-time foreign students declined 18% from 2001 through 2004. Declines were concentrated mainly in engineering (down 26%) and computer sciences (down 36%); these fields are heavily favored by foreign students. First-time full-time foreign enrollment increased 5% in biological sciences and 1% in medical/other life sciences from 2001 through 2004. Foreign students' share of first-time full-time S&E graduate enrollment dropped from 35% in fall 2000 to 27% in fall 2005, with most of the decrease in computer sciences (from 71% to 56%) and engineering (61% to 51%) (appendix table 2-23).

According to data collected by the Institute of International Education, the overall number of foreign graduate students in all fields decreased 2% from academic year 2004–05 to 2005–06, with all of the decrease occurring among master's degree students. The proportion of foreign master's degree students decreased 5% and that of foreign doctoral students increased 6%. India, China, South Korea, Taiwan, and Canada are the top places of origin for foreign graduate students. More than half of all foreign graduate students are studying S&E. More recent data from the Bureau of Citizenship and Immigration Services show an increase in foreign graduate students from April 2006 to April 2007, with foreign enrollment in S&E fields growing 8% (appendix table 2-24). Most of the growth was in computer sciences (up 14%) and engineering (up 10%). In April 2007, India accounted for 66,500 foreign graduate students with 70% in S&E fields. China accounted for 48,300 foreign graduate students with 67% in S&E. In contrast, less than half of graduate students from South Korea, Taiwan, and Canada were studying S&E fields. Business accounts for large numbers of graduate students from South Korea and Taiwan, and education accounts for large numbers of graduate students from Canada.

Persistence, Retention, and Attainment in Higher Education and in S&E

Many students who start out in undergraduate or graduate programs drop out before completing a degree. This section examines differences between S&E and non-S&E students in persistence and completion of higher education.

Undergraduate Retention

S&E students persist and complete undergraduate programs at about the same rate as non-S&E students. Six years after enrollment in a 4-year college or university in 1995–96, about 60% of both S&E and non-S&E students had completed a bachelor's degree. Another 13%–17% were still enrolled and may eventually have earned a bachelor's degree, and about 20% had not completed any degree and were no longer enrolled (table 2-5).

Undergraduate field switching out of S&E is about equally matched by entry into S&E fields as a whole. Among postsecondary students who began at 4-year colleges or universities in 1995–96, 26% reported an S&E major, 44% reported a non-S&E major, and 31% were missing data on major or had not declared a major. Of those for whom data on major are available and reported, 37% reported an S&E major. Six years later, among those who had attained a bachelor's degree, 39% were S&E majors. Although about 30% of agricultural/biological sciences majors, 20% of engineering/computer sciences/mathematics/physical sciences majors, and 30% of social sciences majors eventually switched to non-S&E majors before earning a bachelor's degree, 43% of those with initially missing or undeclared majors and 14% of those with initial non-S&E majors switched into S&E fields before earning their bachelor's degrees (table 2-6).

Within S&E fields, undergraduate attrition out of agricultural/biological sciences and physical/mathematics/computer sciences/engineering fields is greater than transfers into those fields, and transfers into social/behavioral sciences are greater

Table 2-5
Persistence and outcome of postsecondary students beginning 4-year colleges or universities in 1995: 2001
(Percent)

		Cumulative persistence outcome 2001				
Major in 1995	Number	Bachelor's	Associate's or certificate	Still enrolled	No longer enrolled	Missing
All majors	1,369,400	58.0	6.6	14.4	20.8	0.3
Agricultural/biological sciences	115,300	60.8	4.0	16.7	18.2	0.3
Physical/math/computer sciences/engineering	153,600	59.4	7.3	14.1	19.2	0.1
Social and behavioral sciences	82,600	62.4	3.4	14.7	19.1	0.5
Non-S&E	599,000	57.7	7.6	13.2	21.2	0.2
Missing/undeclared	418,900	56.3	6.1	15.5	21.7	0.4

NOTE: Physical sciences include earth, atmospheric, and ocean sciences.

SOURCE: National Center for Education Statistics, 2001 Beginning Postsecondary Students Longitudinal Study, special tabulations (2007).

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Table 2-6
Field switching among postsecondary students beginning 4-year colleges and universities in 1995: 2001
(Percent)

		Major when last enrolled in 2001				
Major in 1995	Number	Agricultural/ biological sciences	Physical/math/ computer sciences/ engineering	Social and behavioral sciences	Non-S&E	Missing/ undeclared
All majors	1,369,400	9.9	13.1	15.9	61.1	0.1
Agricultural/biological sciences	115,300	48.9	9.1	11.5	30.5	0.0
Physical/math/computer sciences/engineering	153,600	5.6	71.4	3.5	19.6	0.0
Social and behavioral sciences	82,600	3.0	3.2	64.1	29.6	0.0
Non-S&E	599,000	3.4	2.7	8.1	85.9	0.0
Missing/undeclared	418,900	11.0	9.4	22.7	56.7	0.2

NOTE: Physical sciences include earth, atmospheric, and ocean sciences.

SOURCE: National Center for Education Statistics, 2001 Beginning Postsecondary Students Longitudinal Study, special tabulations (2007).

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than attrition. Among postsecondary students who began at 4-year colleges or universities in 1995–96 and for whom data on major are available and reported, 12% reported an agricultural/biological sciences major, 16% reported a physical sciences/mathematics/computer sciences/engineering major, and 9% reported a social/behavioral sciences major. Six years later, among those who had attained a bachelor's degree, 10% were agricultural/biological sciences majors, 13% were physical sciences/mathematics/computer sciences/engineering majors, and 16% were social/behavioral sciences majors. (See sidebar "Effects of Research Experiences on Interest, Retention, and Success.")

Graduate Retention

S&E bachelor's degree recipients are more likely to enroll in and complete graduate training than bachelor's degree recipients in most other fields. Fifty-seven percent of 1992–93 bachelor's degree recipients in natural sciences and mathematics and 50% of those with bachelor's degrees in social and behavioral sciences enrolled in graduate school by 2003, compared with 25%–43% of graduates in most other fields (including 39% of engineering graduates). Education graduates also had a high percentage enrolling in graduate school (50%). Forty percent of natural sciences and mathematics bachelor's degree recipients completed an advanced degree program within 10 years, compared with 17%–31% of graduates in other fields, and 9% had completed a doctoral degree compared with up to 3% of graduates in other fields (table 2-7). Not all of those who completed an advanced degree completed it in an S&E field. The majority of S&E bachelor's degree recipients who earn additional degrees earn them in non-S&E fields (e.g., business, law, or medicine). About one-fourth earn additional degrees in the same S&E field, and the remainder earn them in other S&E fields (NSF/SRS 2006b).

Graduate completion rates are roughly comparable to undergraduate completion rates. Among students enrolled in doctoral programs in the early 1990s, about 60% completed doctorates within 10 years. Completion rates vary by discipline, with 64% of engineering students, 62% of life sciences students, and 55% of physical and social sciences students completing doctorates within 10 years (CGS 2005). Timing of graduate attrition varies by discipline. Early attrition from doctoral programs is more common in engineering, physical sciences, and mathematics, and later attrition is more common in humanities and social sciences.

U.S. Higher Education Degree Awards

The number of degrees awarded by U.S. academic institutions has been increasing over the past two decades both in S&E and non-S&E fields. For information on the labor market conditions for recent S&E graduates, see "Labor Market Conditions for Recent S&E Graduates" in chapter 3 (Science and Engineering 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.[10] Associate's degrees in S&E or engineering technology accounted for about 12% of all associate's degrees in 2005.

S&E associate's degrees from all types of academic institutions rose from 26,500 in 1985 to 45,700 in 2005. The increase in the late 1990s and the early 2000s is mainly attributable to computer sciences, which represented 61% of all S&E associate's degrees by 2005. In contrast, the number of associate's degrees awarded in engineering mainly

Effects of Research Experiences on Interest, Retention, and Success

Opportunities for students to engage in early experiences as a working scientist or engineer have been in existence for some time. However, formal studies of the outcomes of such opportunities were not undertaken until fairly recently. There is now a growing body of literature that examines the results of such efforts and analyzes them for their effect on at least one of the following outcomes: student attitudes toward science, student research skills, student confidence in his or her ability to become a scientist or engineer, and retention of students within the field, including entry into graduate school or graduation with a doctorate. In general, each study found increases in students' understanding of the scientific process, the way in which research is done, and, to varying degrees, their commitment to majoring in science or engineering, to entering a science or engineering career, and to enrolling in a science or engineering graduate program.

These research experiences are often either hands-on research opportunities (participation in an active research laboratory or a didactic laboratory course specifically devoted to working on ongoing research projects) or literature-based research opportunities (participation in a class designed around seminar-type discussion of ongoing research topics or analysis of papers from the primary literature). In engineering, these experiences generally include a freshman design course and/or a sophomore or junior internship.

A recent comparison of results from nine studies of undergraduate hands-on research experiences (Boylan 2006) reveals some overall consistencies in findings but also some interesting variations. Students who participated in an undergraduate research experience reported, in general, a greater interest in STEM research, greater understanding of the research process and the strategies and tools that scientists use to solve problems, and a broader sense of career options in the field (particularly true of the life sciences when students switched from purely medical to broader career goals). The size of the effect on changes in career or graduate education goals are, to some extent, less consistent. One study (Hunter, Laursen, and Seymour 2007) focused on a small set of institutions and found that participating students with high grade point averages were already committed to a career in S&E and so the research experience, although affirming, did not seem to have a large effect on subsequent entry into a graduate program. Other studies (Barlow and Villarejo 2004; Clewell et al. 2006; Price 2005; Russell, Hancock, and McCullough 2007; Summers and Hrabowski 2006) found that students with a broader range of abilities as well as underrepresented minority students were more likely to stay in or switch to an S&E major and to pursue S&E graduate education.

Table 2-7

1992–93 bachelor's degree recipients, by graduate enrollment status, highest degree attained, and baccalaureate degree major: 2003

(Percent)

	Enrollment in graduate program				Highest degree attained				
						Advanced degree			
Baccalaureate degree major	All ever enrolled	Completed	Currently enrolled	Left without completing	Bachelor's degree[a]	All	Master's degree	First professional degree	Doctoral degree
All majors	40.1	24.8	5.9	9.4	74.4	25.6	19.7	4.0	1.9
Business and management	25.4	16.6	3.2	5.6	83.3	16.7	14.7	1.8	0.2
Education	50.3	28.3	8.1	13.9	71.1	28.9	26.3	1.5	1.1
Engineering	39.2	24.5	5.4	9.3	74.2	25.9	22.2	0.9	2.7
Health	36.5	22.0	6.5	8.0	77.9	22.1	19.4	2.1	0.6
Public affairs/social services	36.3	20.6	6.2	9.5	79.4	20.6	18.2	1.8	0.6
Humanities	42.6	25.5	7.1	10.1	73.0	27.1	21.5	4.3	1.2
Social and behavioral sciences	49.8	30.3	8.7	10.8	68.6	31.4	21.8	7.2	2.3
Natural sciences and mathematics	56.7	38.6	6.4	11.7	60.3	39.7	18.7	12.0	9.0
Other	34.4	21.7	4.2	8.6	77.6	22.4	18.0	3.4	1.0

[a] Includes postbaccalaureate certificates.

SOURCE: National Center for Education Statistics (NCES), Where Are They Now? A Description of 1992–93 Bachelor's Degree Recipients 10 Years Later, NCES 2007-159 (2006).

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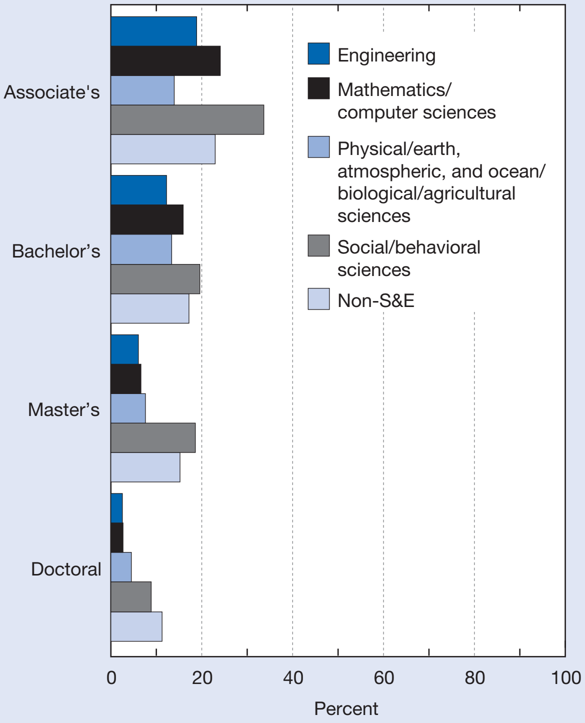
decreased. Degrees earned in engineering technology (not included in S&E degree totals because of their practice-focused nature) declined from 53,700 in 1985 to 28,800 in 2005 (appendix table 2-25).

Women earned 40% of S&E associate's degrees in 2005, down from 45% in 1985 and less than their percentage of S&E bachelor's degrees (50%). As is the case with men, the largest number of S&E associate's degrees earned by women are in computer sciences (appendix tables 2-25).

Trends in the number of associate's degrees earned by students' race/ethnicity are shown in appendix table 2-26.[11] Students from underrepresented groups earn a considerably higher proportion of associate's degrees than they do of bachelor's or more advanced degrees (figure 2-13). In 2005, they earned more than one-third of all associate's degrees in social and behavioral sciences and almost one-quarter of all associate's degrees in mathematics and computer sciences. The percentage of computer sciences associate's degrees earned by these students almost doubled since 1985.

Figure 2-13
Underrepresented minority share of S&E degrees, by degree level and field: 2005



NOTE: Underrepresented minority includes black, Hispanic, and American Indian/Alaska Native.

SOURCES: 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 2-26, 2-28, 2-30, and 2-32.

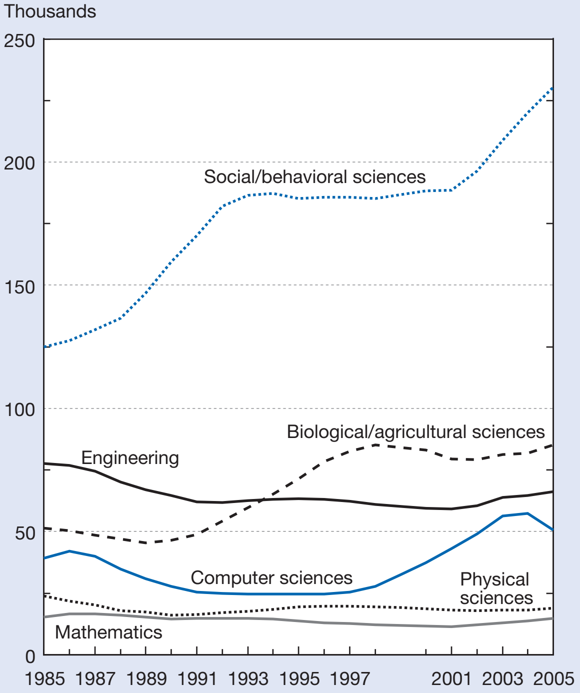
Science and Engineering Indicators 2008

S&E Bachelor's Degrees

The baccalaureate is the most prevalent degree in S&E, accounting for 70% of all S&E degrees awarded. S&E bachelor's degrees 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 332,300 in 1985 to 466,000 in 2005 (appendix table 2-27).

Trends in the number of S&E bachelor's degrees vary widely among fields (figure 2-14). The number of bachelor's degrees earned in engineering, which peaked in 1985, dropped through most of the 1990s before increasing again through 2005. In computer sciences, the number of bachelor's degrees increased sharply from 1998 to 2004 but fell in 2005. Except for slight dips in the late 1980s and from 1999 to 2002, bachelor's degrees in biological/agricultural sciences have been increasing, reaching a new peak in 2005. The number of social and behavioral sciences degrees awarded rose in the late 1980s and again in the 2000s, reaching a new peak in 2005 (appendix table 2-27).

Figure 2-14
S&E bachelor's degrees, by field: 1985–2005



NOTES: Physical sciences include earth, atmospheric, and ocean sciences. Data not available for 1999.

SOURCES: 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.

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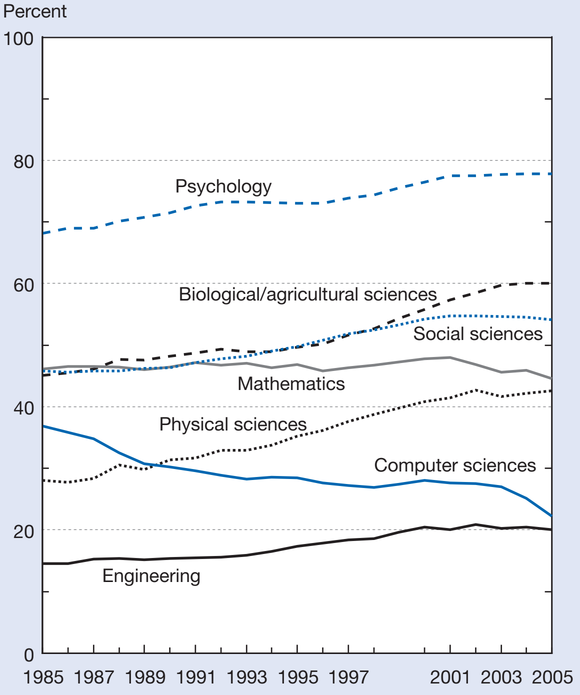
S&E Bachelor's Degrees by Sex

Women outnumbered men in undergraduate education since 1982 and earned 58% of all bachelor's degrees in 2005; they earned about 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 physics (80%, 78%, and 79%, respectively). Women earned more than half of bachelor's degrees in psychology (78%), agricultural sciences (51%), biological sciences (62%), chemistry (52%), and social sciences (54%) (appendix table 2-27). 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. From 1985 through 2005, the proportion of computer sciences bachelor's degrees awarded to women dropped from 37% to 22% (figure 2-15). Among fields with notable increases in the proportion of bachelor's degrees awarded to women are earth, atmospheric, and ocean sciences (from 25% to 42%); agricultural sciences (from 35% to 51%); and chemistry (from 36% to 52%).

The number of S&E bachelor's degrees awarded to women as well as the total number of bachelor's degrees in all fields rose from 1985 through 2005, with a brief drop in numbers of engineering and natural sciences degrees in the late 1980s and early 1990s and another decline in 2005. In contrast, the number of S&E bachelor's degrees awarded to men as well as the total number of bachelor's degrees in all fields reached a plateau in the 1990s but increased from 2002 through 2005. The flat numbers of S&E bachelor's degrees awarded to men in the 1990s masked several divergent trends. The number of engineering, physical sciences, and social and behavioral sciences degrees awarded to men dropped in the 1990s, while the number of bachelor's degrees in agricultural and biological sciences generally increased in the 1990s.[12]

Figure 2-15
Female share of S&E bachelor's degrees, by field: 1985–2005



NOTES: Physical sciences include earth, atmospheric, and ocean sciences. Data not available for 1999.

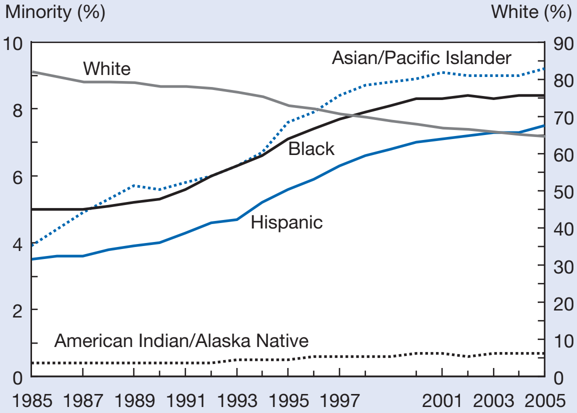
SOURCES: National Center for Education Statistics, Integrated Postsecondary Education Data System, Completions Survey; and National Science Foundation, Division of Science Resources Statistics, WebCASPAR database, http://webcaspar.nsf.gov. See appendix table 2-27.

Science and Engineering Indicators 2008

S&E Bachelor's Degrees by Race/Ethnicity

The racial/ethnic composition of those earning S&E bachelor's degrees changed over the past two decades, reflecting both population change and increasing college attendance by members of minority groups.[13] Between 1985 and 2005, the proportion of S&E degrees awarded to white students declined from 82% to 65%. The proportion awarded to Asians/Pacific Islanders increased from 4% to 9%, to black students from 5% to 8%, to Hispanic students from 4% to 8%, and to American Indian/Alaska Native students from 0.4% to 0.7% (figure 2-16). The number of S&E bachelor's degrees earned by white students decreased in the 1990s as their numbers in the college-age population dropped, but rose again through 2005. The number of S&E bachelor's degrees earned by students of unknown race/ethnicity also increased. See sidebar "Increase in Student Nonreporting of Race/Ethnicity."

Figure 2-16
Minority share of S&E bachelor's degrees, by race/ethnicity: 1985–2005



NOTE: Data not available for 1986, 1988, and 1999.

SOURCES: 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 2008

Increase in Student Nonreporting of Race/Ethnicity

For several years, the number and percentage of students not reporting race/ethnicity on their college applications and thus the number and percentage of students of unknown race/ethnicity in federal surveys of higher education enrollment and degrees have increased. In 2005, about 25,700 S&E bachelor's degree recipients (almost 6% of the total) were of unknown race/ethnicity, up from about 3,700 (1% of the total) in 1985 (appendix table 2-28). At some colleges and universities, the percentage of students who decline to report race/ethnicity is as high as 25% (JBHE 2005). How the unknown category is treated in data reporting can affect estimates of the composition of the student body and trends in minority enrollment or degree attainment. Inclusion of these students in counts of "minority" students or omitting these students from totals or calculations of percentages inflates the number and fraction of minority students.

Level of selectivity of the school is a factor, with the most selective colleges and universities having a higher percentage of students not reporting race than is the case for colleges and universities in the United States overall (JBHE 2005). Most students of unknown race/ethnicity are white and another substantial number are thought to be multiple race (Linneman and Chatman 1996; Smith et al. 2005). The reluctance of white students to report race/ethnicity on college admissions forms may reflect a belief that their race/ethnicity would negatively affect admissions decisions. Thus, timing of collection of race/ethnicity data seems to be a factor in the number of students who do or do not report (Smith et al. 2005). Schools that collect race/ethnicity data after students matriculate generally have lower percentages of students not reporting race/ethnicity.

Despite considerable progress for underrepresented minority groups between 1985 and 2005 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 25–29 with a bachelor's or higher degree rose from 12% in 1985 to 18% in 2005, whereas the percentage of Hispanics ages 25–29 with a bachelor's or higher degree was 11% in 1985 and 2005 (NCES 2006). For whites ages 25–29, this percentage rose from 24% in 1985 to 34% in 2005. 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 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 American Indian/Alaska Native S&E baccalaureate recipients share a similar distribution across broad S&E fields. In 2005, between 9% and 12% 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 biological sciences, computer sciences, and engineering (appendix table 2-28).

For all racial/ethnic groups (except white), the total number of bachelor's degrees, the number of S&E bachelor's degrees, and the number of bachelor's degrees in most S&E fields (except computer sciences) generally increased over the past two decades. After steep increases since the late 1990s, students in each racial/ethnic group earned sharply fewer bachelor's degrees in computer sciences in 2005. For white students, the total number of bachelor's degrees, the number of S&E bachelor's degrees, and the number of bachelor's degrees in most S&E fields, generally dropped between 1993 and 2001 and increased since then. The number of computer science bachelor's degrees earned by white students dropped in 2004 and 2005 (appendix table 2-28).

Bachelor's Degrees by Citizenship

Over the past two decades, students on temporary visas in the United States consistently 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 2005 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 1985 to 18,400 in 2005. Trends in the number of degrees by field generally followed the pattern noted above for all racial/ethnic groups except whites (appendix table 2-28).

S&E Master's Degrees

Master's degrees are often the terminal degree for students in some fields, for example, engineering and geology. In other fields, master's degrees are a step toward a doctoral degree, and in yet others, master's degrees are awarded when students fail to advance to the doctoral level. A relatively new development, professional master's degrees, often stress interdisciplinary training and preparation for work in emerging fields (NSB 2006).

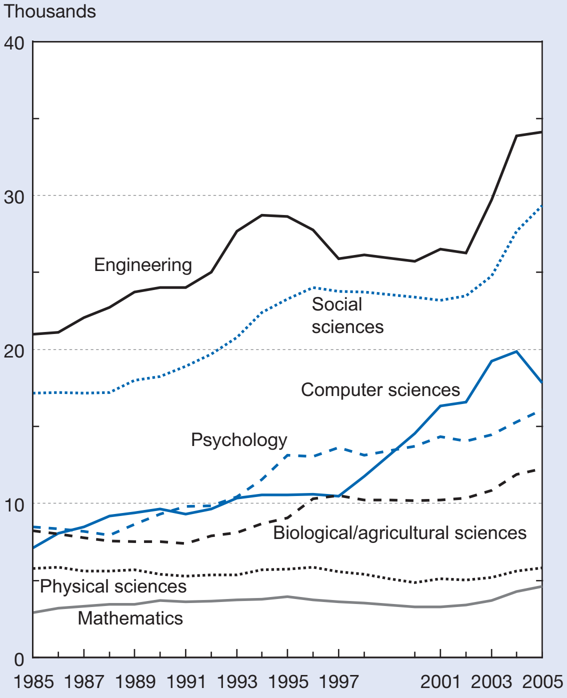
Master's degrees in S&E fields increased from 70,600 in 1985 to 120,000 in 2005 (appendix table 2-29). Increases occurred in most major S&E fields. Master's degrees in engineering and physical sciences dipped from 1995 to 2002 but increased in recent years, and master's degrees in computer sciences generally increased through 2004 but dropped in 2005 (figure 2-17).

Master's Degrees by Sex

Since 1985, the number of S&E master's degrees earned by women more than doubled, rising from 22,300 to 53,100 in 2005 (figure 2-18). The number of master's degrees earned by men grew more slowly from 48,200 in 1985 to 67,000 in 2005, with most of the growth between 2002 and 2004. As a result, the percentage of women earning master's degrees rose steadily during the past two decades. In 1985, women earned 32% of all S&E master's degrees; by 2005, they earned 44% (appendix table 2-29).

Women's share of S&E master's degrees varies by field. In 2005, women earned a majority of master's degrees in psychology (79%), biological sciences (60%), social sciences (56%), and agricultural sciences (53%); they earned their lowest share in engineering, although their share in 2005 (22%) was higher than their share in 1985 (11%) (appendix table 2-29). The number and percentage of master's degrees awarded to women in all major S&E fields (with the exception of computer sciences) increased since 1985. In computer sciences, the number of master's degrees awarded to women increased through 2004 but dropped in 2005, and the percentage of degrees awarded to women dropped from 34% in 2001 to 28% in 2005.

Figure 2-17
S&E master's degrees, by field: 1985–2005

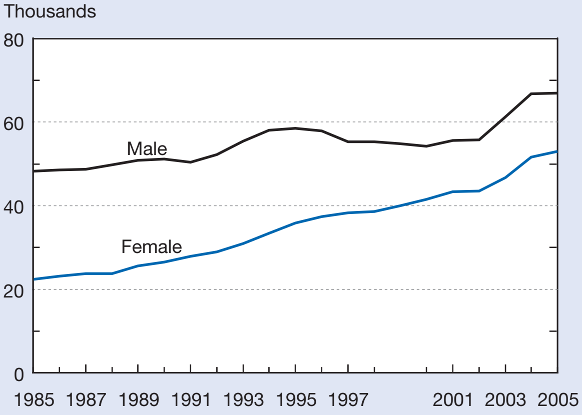


NOTES: Physical sciences include earth, atmospheric, and ocean sciences. Data not available for 1999.

SOURCES: 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 2008

Figure 2-18
S&E master's degrees, by sex: 1985–2005



NOTE: Data not available for 1999.

SOURCES: 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.

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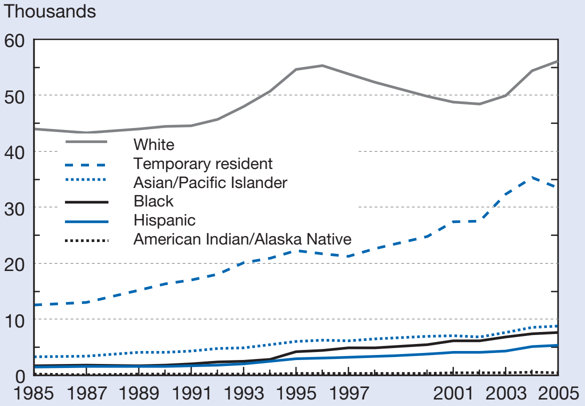
Master's Degrees by Race/Ethnicity

The number of S&E master's degrees awarded increased for all racial/ethnic groups from 1985 to 2005, although degrees to white students dropped from 1996 to 2002 before increasing again (figure 2-19).[14] Trends in the number of master's degrees by field were similar for most racial/ethnic groups except white. For most groups, the number of master's degrees in engineering, biological sciences, and social and behavioral sciences generally rose throughout the period 1985–2005. The number of master's degrees in physical sciences generally dropped, especially from 1995 to 2005, and the number of master's degrees in computer sciences generally increased but dropped sharply in 2005. Master's degrees awarded to American Indian/Alaska Native students generally followed this pattern except for drops in most fields in 2005. Master's degrees awarded to Asian/Pacific Islander students generally followed this pattern except for a drop in the number of engineering degrees from 1997 to 2002. For white students, the number of master's degrees awarded in most S&E fields dropped in the mid-1990s through 2002 before increasing again through 2005. As was the case for most racial/ethnic groups, the number of computer science

Figure 2-19
S&E master's degrees, by race/ethnicity and citizenship: 1985–2005



NOTES: Race/ethnicity includes U.S. citizens and permanent residents. Underrepresented minority includes black, Hispanic, and American Indian/Alaska Native. Data not available for 1986, 1988, and 1999.

SOURCES: 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 2-30.

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master's degrees earned by white students rose through 2004 but dropped sharply in 2005 (appendix table 2-30).

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 2005, up from 5% in 1985. Blacks and Hispanics also registered gains during this period (from 3% to 6% for blacks and from 2% to 4% for Hispanics). American Indians/Alaska Natives earned 0.4% of S&E master's degrees in 1985 and 2005. The percentage of S&E master's degrees earned by white students fell from 68% in 1985 to 47% in 2005 as the percentage of degrees earned by minorities and temporary residents increased (appendix table 2-30).

Master's Degrees by Citizenship

S&E master's degrees awarded to students on temporary visas rose from approximately 12,500 in 1985 to about 33,500 in 2005, and increased in most S&E fields during that period. The number of degrees generally rose through 2004 but dropped in 2005, especially in computer sciences and engineering. The number of physical sciences and biological sciences master's degrees earned by students on temporary visas dropped in the mid-1990s but increased from 2002 to 2005.

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. During the past two decades, the share of S&E master's degrees earned by temporary residents rose from 19% to 28%. Their degrees are heavily concentrated in computer sciences and engineering, where they earned 42% and 44%, respectively, of all master's degrees awarded in 2005 (appendix table 2-30). Within engineering, students on temporary visas earned more than half of master's degrees in chemical engineering (51%) and in electrical engineering (55%). Temporary residents also earned a high share of master's degrees in economics (49%).

S&E Doctoral Degrees

Global economic competition and the spreading conviction that highly educated workforces are key to successfully building growth economies increased interest both in the United States and abroad in the supply of foreign and domestic doctorate recipients and their migration across borders.

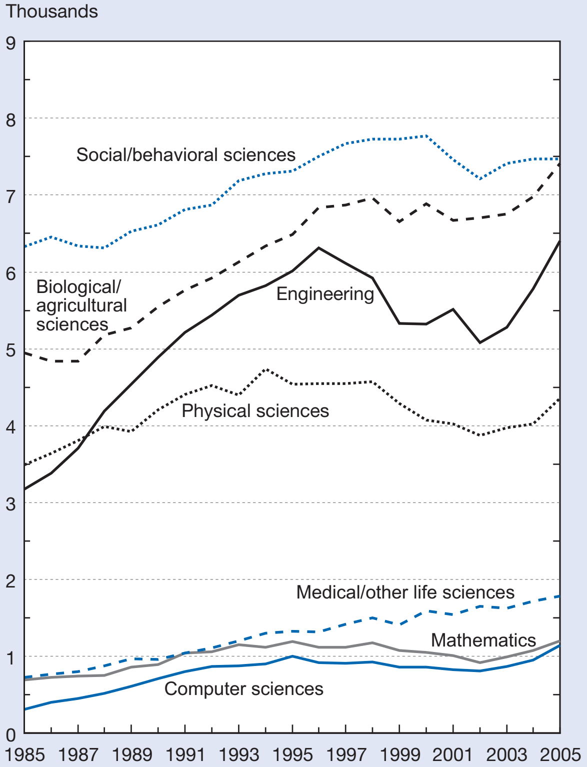
The number of S&E research doctorates conferred annually by U.S. universities reached a new peak of almost 30,000 in 2005.[15] After rising from the mid-1980s through 1998, the number of S&E doctorates declined through 2002 but increased in recent years. (For information on employment of recent doctorate recipients, see "Labor Market Conditions for Recent S&E Graduates" in chapter 3, Science and Engineering Labor Force, and "Trends in Academic Employment of Doctoral Scientists and Engineers" in chapter 5, Academic Research and Development.) The increases through the mid-1990s as well as the recent growth through 2005 largely reflected growth in the number of foreign degree recipients. The largest increases were in engineering and biological/agricultural sciences (figure 2-20). The 2003 through 2005 increases in earned doctorates reflect more degrees earned by both U.S. citizens and non-U.S. citizens (see the discussion in this chapter on 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 46% in 2005 (appendix table 2-31). During this period, women made gains in all major fields. However, as figure 2-21 shows, considerable differences by field continue. Women earn half or more of doctorates in non-S&E fields, in social/behavioral sciences, and in life sciences, but they earn considerably less than half of doctorates in physical sciences (29%), math/computer sciences (24%), and engineering (20%) (appendix table 2-31). Although the percentages of degrees earned by women in these fields is low, they are substantially higher than was the case in 1985 (16%, 17%, and 9%, respectively).

The increase in the proportion of S&E doctoral degrees earned by women resulted from 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 4,400 in 1985 to 7,500 in 2005 (appendix table 2-31). Meanwhile, the number of S&E doctorates earned by U.S. citizen men declined from 9,300 in 1985 to 8,600 in 2005. The increase in the number of S&E doctorates earned by women occurred in most major S&E fields. For example, the number of engineering doctorates earned by U.S. citizen women increased from 119 in 1985

Figure 2-20
S&E doctoral degrees earned in U.S. universities, by field: 1985–2005

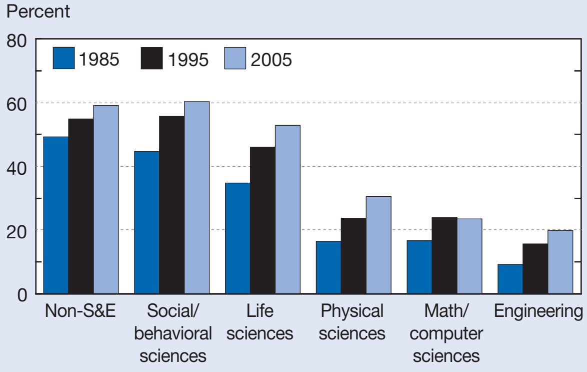


NOTE: Physical sciences include earth, atmospheric, and ocean sciences.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Earned Doctorates, WebCASPAR database, http://webcaspar.nsf.gov. See appendix table 2-31.

Science and Engineering Indicators 2008

Figure 2-21
U.S. citizen female share of doctoral degrees, by field: 1985, 1995, and 2005



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 2-31.

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to 396 in 2005; biological sciences doctorates from 1,032 to 2,024; physical sciences doctorates from 323 to 516; and social/behavioral sciences doctorates from 2,224 to 3,117. A decrease in the number of doctorates earned by men after the mid-1990s occurred in non-S&E fields as well as in engineering and in most science fields (except for biological sciences and medical/other life sciences).[16]

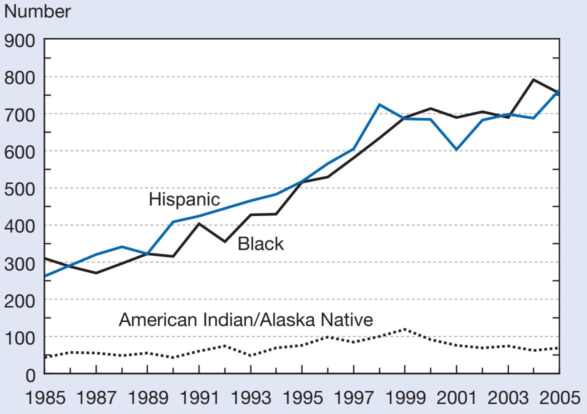
Doctoral Degrees by Race/Ethnicity

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 almost 1,600 S&E doctorates in 2005, accounting for 5% of all S&E doctorate degrees earned that year, up from 3% in 1985. (Their share of S&E doctorate degrees earned by all U.S. citizens rose from 4% to 10% in the same period.) Gains by all groups contributed to this rise. The number of S&E degrees earned by blacks and Hispanics more than doubled in this period and the number of S&E degrees earned by American Indians/Alaska Natives increased from 43 to 70 (figure 2-22).

The underrepresented minority share of doctorates in some S&E fields is greater than in others. In 2005, blacks, Hispanics, and American Indians/Alaska Natives as a group earned 11% of doctoral degrees in psychology, 9% in medical/other life sciences, 8% in social sciences, and 6% in biological sciences. In most other S&E fields they earned approximately 3% of doctoral degrees awarded in 2005 (appendix table 2-32). In non-S&E fields, they earned 11% of doctorates in 2005. Among U.S. citizens only, they earned 15% of non-S&E doctorates.

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 more than 4% of

Figure 2-22
U.S. citizen underrepresented minority S&E doctoral degrees, by race/ethnicity: 1985–2005



SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Earned Doctorates, WebCASPAR database, http://webcaspar.nsf.gov. See appendix table 2-32.

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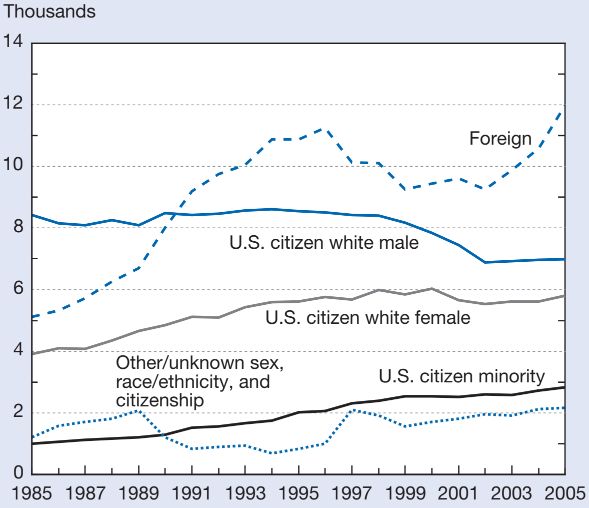
S&E doctorates in 2005, up from 2% in 1985. They earned relatively larger shares of doctoral degrees in biological sciences (7%) and medical sciences (8%), and relatively smaller shares in agricultural sciences (1%) and earth, atmospheric, and ocean sciences (2%).

The number of S&E doctorates earned by white U.S. citizens remained relatively stable over the past two decades, fluctuating from around 12,000 to 14,000 degrees awarded annually; however, the proportion of S&E doctoral degrees earned by white U.S. citizens decreased. The share of all doctoral S&E degrees earned by white U.S. citizens decreased from 63% in 1985 to 43% in 2005 as the number and percentage of S&E doctorates earned by non-U.S. citizens and minorities increased, and the white U.S. citizen share of degrees awarded to all U.S. citizens declined from 90% to 79% as the number and percentage of S&E doctorates earned by minorities increased (appendix table 2-32). Although the total number of doctoral S&E degrees earned by white U.S. citizens remained fairly stable over the past two decades, the number of S&E doctoral degrees earned by white male U.S. citizens declined in the mid-1990s through 2002 (from about 8,600 in 1994 to 6,900 in 2002) and remained around that same number through 2005 (figure 2-23). The number of degrees earned by white U.S. citizen females generally increased over much of the past three decades, with the exception of brief declines in 2001 and 2002. The drop in doctoral degrees to whites corresponds to the earlier drop in the college age population mentioned previously in this chapter. Although the number of white women in the college age population dropped, the percentages of white women in that age group earning doctorates in general and in S&E fields specifically both increased.

Figure 2-23
S&E doctoral degrees, by sex, race/ethnicity, and citizenship: 1985–2005



NOTES: Foreign includes permanent and temporary residents. Minority includes Asian/Pacific Islander, black, Hispanic, and American Indian/Alaska Native.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Earned Doctorates, WebCASPAR database, http://webcaspar.nsf.gov. See appendix table 2-32.

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Foreign S&E Doctorate Recipients

Foreign students, even those who stay in the United States after graduation, contribute to science in their own countries by collaborating in increasingly global scientific networks, generating new knowledge, and helping to increase scientific capacity (NSB 2000, 2002, 2004b, 2006; Wagner 2007).

Noncitizens, primarily those with temporary visas, account for the bulk of the growth in S&E doctorates awarded by U.S. universities from 1985 through 2005. During this period, the number of S&E doctorates earned by U.S. citizens fluctuated from approximately 14,000 to about 17,000, while the number earned by temporary residents rose from 4,200 to a peak of 10,800 in 2005. The temporary resident share of S&E doctorates rose from 21% in 1985 to 36% in 2005. The number of S&E doctorates earned by students with permanent resident visas increased from about 1,000 in 1985 to a peak of 3,614 in 1995, before falling to about 1,200 in 2005 (appendix table 2-32). (In the mid-1990s, the number of doctorates awarded to students with permanent resident visas 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.)

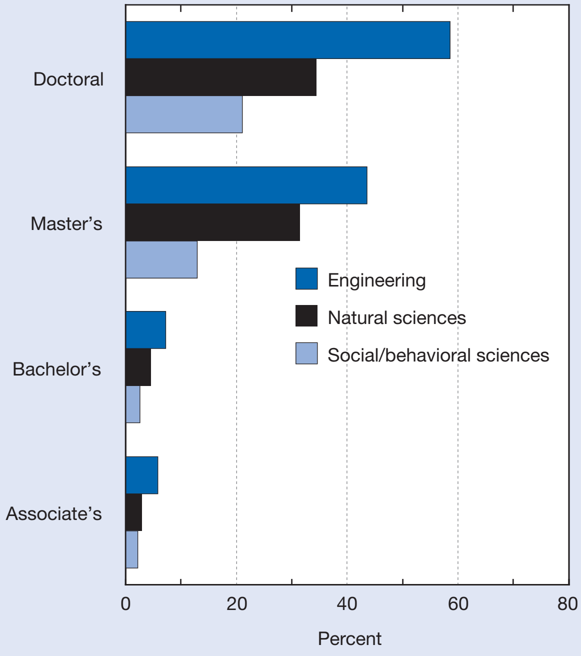
Foreign students on temporary visas earn a larger proportion of their degrees at the doctoral level than at any other level (figure 2-24). Their proportion in some fields is even higher. For example, in 2005, foreign students on temporary visas earned half or more of doctoral degrees awarded in engineering, mathematics, computer sciences, physics, and economics. They earned considerably lower proportions of doctoral degrees in other S&E fields, for example, 26% in biological sciences, 22% in medical/other life sciences, and 6% in psychology (appendix table 2-32).

Countries/Economies of Origin

The top 10 foreign countries/economies of origin of foreign S&E doctorate recipients together accounted for 65% of all foreign recipients of a U.S. S&E doctorate from 1985 to 2005 (table 2-8). All but 2 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, South Korea, and India. (Canada and Mexico were also among the top 10.)

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 brief decline and then increases in recent years (figure 2-25). Most of these degrees were awarded in engineering and biological and physical sciences (table 2-9). From 1985 to 2005, students from four Asian countries/economies (China, Taiwan, India, and South Korea) earned more than half of U.S. S&E doctoral degrees award-

Figure 2-24
Foreign share of U.S. S&E degrees, by degree and field: 2005



NOTES: Foreign includes temporary residents only. Natural sciences include physical, biological, earth, atmospheric, ocean, agricultural, and computer sciences and mathematics.

SOURCES: 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 2-26, 2-28, 2-30, and 2-32.

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Table 2-8
Foreign recipients of U.S. S&E doctorates, by country/economy of origin: 1985–2005

Country/economy	Number	Percent
All foreign recipients	189,346	100.0
Top 10 total	122,046	64.5
China	41,677	22.0
Taiwan	19,187	10.1
South Korea	18,872	10.0
India	18,712	9.9
Canada	6,231	3.3
Turkey	3,957	2.1
Thailand	3,479	1.8
Iran	3,386	1.8
Japan	3,295	1.7
Mexico	3,250	1.7
All others	67,300	35.5

NOTE: Foreign doctorate recipients include permanent and temporary residents.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Earned Doctorates, special tabulations (2006).

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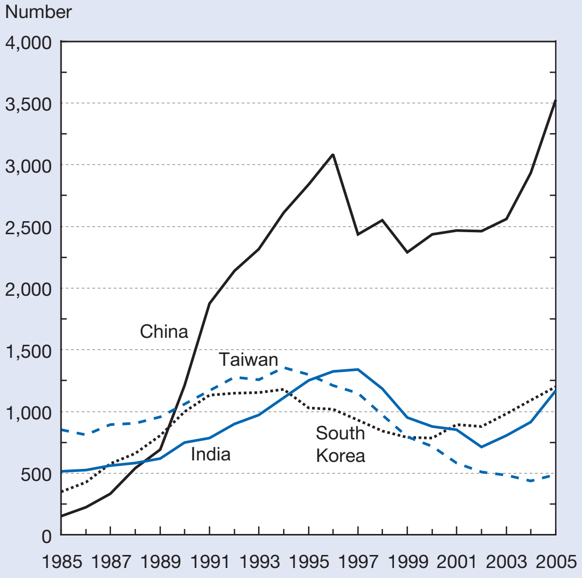
Figure 2-25
U.S. S&E doctoral degree recipients, by selected Asian country/economy of origin: 1985–2005



NOTE: Degree recipients include permanent and temporary residents.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Earned Doctorates, special tabulations (2007).

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ed to foreign students (98,400 of 189,300), almost four times more than students from Europe (25,500).

China had the largest number of students earning U.S. S&E doctorates during the 1985–2005 period. These students received almost 42,000 S&E doctoral degrees from U.S. universities, mainly in biological and physical sciences and engineering (table 2-9). The number of S&E doctorates earned by Chinese nationals increased from 151 in 1985 to more than 3,500 in 2005 (figure 2-25).[17]

Students from Taiwan received the second-largest number of S&E doctorates at U.S. universities. Between 1985 and 2005, students from Taiwan earned more than 19,000 S&E doctoral degrees, mainly in engineering and biological and physical sciences (table 2-9). In 1985, 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 854 in 1985 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 488 in 2005 (figure 2-25).

Students from India earned more than 18,700 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 (1,515) of U.S. doctoral degrees awarded to any foreign group in computer sciences.

Table 2-9
Asian recipients of U.S. S&E doctorates, by field and country/economy of origin: 1985–2005

Field	Asia	China	Taiwan	India	South Korea
All fields	153,117	44,345	22,914	21,623	24,139
S&E	130,426	41,677	19,187	18,712	18,872
Engineering	48,166	12,784	8,816	8,172	7,273
Science	82,260	28,893	10,371	10,540	11,599
Agricultural sciences	5,313	1,313	709	434	728
Biological sciences	20,973	9,957	2,658	2,668	2,132
Computer sciences	5,850	1,360	970	1,515	745
Earth, atmospheric, and ocean sciences	2,947	1,345	388	243	366
Mathematics	6,236	2,692	739	575	829
Medical/other life sciences	4,026	813	753	727	413
Physical sciences	19,735	8,934	2,234	2,479	2,429
Psychology	2,005	297	297	238	318
Social sciences	15,175	2,182	1,623	1,661	3,639
Non-S&E	22,691	2,668	3,727	2,911	5,267

NOTE: Foreign doctorate recipients include permanent and temporary residents.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Earned Doctorates, special tabulations (2006).

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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 2-25). The number of S&E doctoral degrees earned by students from India increased from 2003 through 2005.

Students from South Korea earned almost 19,000 U.S. S&E doctorates from 1985 to 2005, mainly in engineering and biological, social, and physical sciences. The number of S&E doctoral degrees earned by South Korean students increased from about 350 in 1985 to 1,178 in 1994, declined to a low of about 800 in the late 1990s, and increased to 1,200 in 2005 (figure 2-25).

Europe. European students earned far fewer U.S. S&E doctorates (25,500) than did Asian students (130,400) between 1985 and 2005, and they tended to focus less on engineering than did their Asian counterparts (table 2-10). Western European countries whose students earned the largest number of U.S. S&E doctorates from 1985 to 2005 were Germany, the United Kingdom, Greece, Italy, and France, in that order. From 1985 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, although doctorate recipients from Germany declined in recent years (figure 2-26). 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 2-10).

The number of Central and Eastern European students earning S&E doctorates at U.S. universities increased from fewer than 70 in 1985 to more than 800 in 2005 (figure 2-27). A higher proportion of Central and Eastern European U.S. doctorate recipients (88%) than of Western European doctorate recipients (73%) earned their doctorates in S&E fields. Western Europeans earned U.S. S&E doctorates mainly in engineering and biological, physical, and social sciences. Central and Eastern Europeans earned U.S. S&E doctorates mainly in engineering, biological sciences, physical sciences, and mathematics (table 2-10).

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 1985 to almost 400 in 2005. In all, 64% of Canadian doctoral degree students in U.S. universities earned S&E doctorates, mainly in social and biological sciences (figure 2-28; table 2-10). Mexican doctoral degree students in U.S. universities are more concentrated in S&E fields than are Canadian students: 85% of doctoral degrees earned by Mexican students at U.S. universities were in S&E fields, mainly engineering and agricultural, biological, and social sciences. The number of doctoral degree recipients from Mexico increased from 111 in 1985 to more than 200 in 2005.

Stay Rates

Of the approximately 3.4 million immigrant scientists and engineers residing in the United States in 2003, about 30% initially came to the United States for educational opportunities and then remained in this country (NSF/SRS 2007b). This section examines data on foreign S&E doctorate recipients' plans for staying in the United States at the time of doctorate receipt. Chapter 3 provides data based on examination of Social Security records on the percentage of foreign students with U.S. S&E doctorates who remain in the U.S. labor force up to 5 years after graduation.

Table 2-10
European and North American recipients of U.S. S&E doctorates, by field and region/country of origin: 1985–2005

	Europe[a]				North America		
Field	All	Western	Scandinavia	Central and Eastern	All	Canada	Mexico
All fields	32,974	22,380	1,990	8,604	13,601	9,778	3,823
S&E	25,465	16,341	1,514	7,610	9,481	6,231	3,250
Engineering	5,189	3,439	275	1,475	1,585	848	737
Science	20,276	12,902	1,239	6,135	7,896	5,383	2,513
Agricultural sciences	734	553	60	121	796	251	545
Biological sciences	3,655	2,386	215	1,054	1,823	1,274	549
Computer sciences	1,233	743	70	420	262	181	81
Earth, atmospheric, and ocean sciences	982	680	81	221	360	214	146
Mathematics	2,591	1,250	107	1,234	483	306	177
Medical/other life sciences	578	462	65	51	566	477	89
Physical sciences	5,216	2,822	222	2,172	1,038	765	273
Psychology	969	768	88	113	865	779	86
Social sciences	4,318	3,238	331	749	1,703	1,136	567
Non-S&E	7,509	6,039	476	994	4,120	3,547	573

[a] See figure 2-27 notes for countries included in Western Europe, Scandinavia, and Central 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 (2006).

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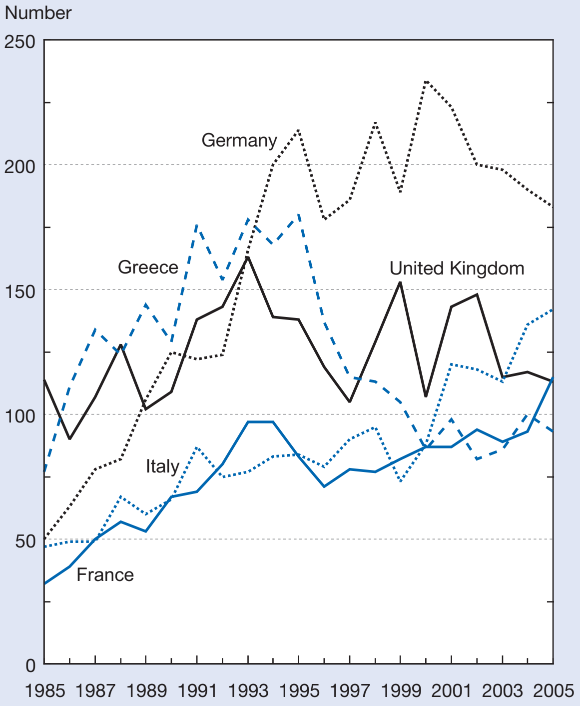
Figure 2-26
U.S. S&E doctoral degree recipients, by selected Western European country: 1985–2005



NOTE: Degree recipients include permanent and temporary residents.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Earned Doctorates, special tabulations (2007).

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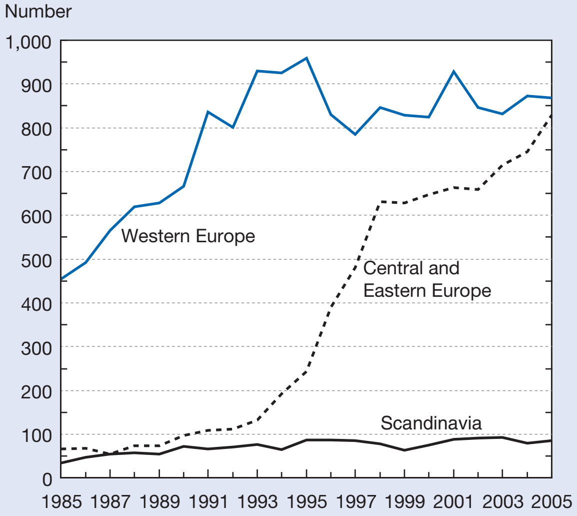
Figure 2-27
U.S. S&E doctoral degree recipients from Europe, by region: 1985–2005



NOTES: Degree recipients include permanent and temporary residents. Western Europe includes Andorra, Austria, Belgium, France, Germany, Gibraltar, Greece, Ireland, Italy, Luxembourg, Malta, Monaco, Netherlands, Portugal, Spain, and Switzerland. Central and Eastern Europe includes Albania, Bulgaria, Czech Republic, Slovakia, Hungary, Poland, Romania, Russia, Armenia, Azerbaijan, Belarus, Estonia, Georgia, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Moldova, Tadjikistan, Turkmenistan, Ukraine, Uzbekistan, Yugoslavia, Bosnia-Herzegovina, 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 (2007).

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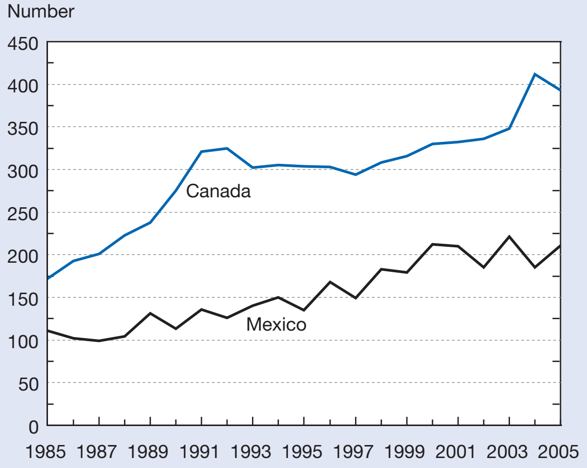
Figure 2-28
U.S. S&E doctoral degree recipients from Canada and Mexico: 1985–2005



NOTE: Degree recipients include permanent and temporary residents.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Earned Doctorates, special tabulations (2007).

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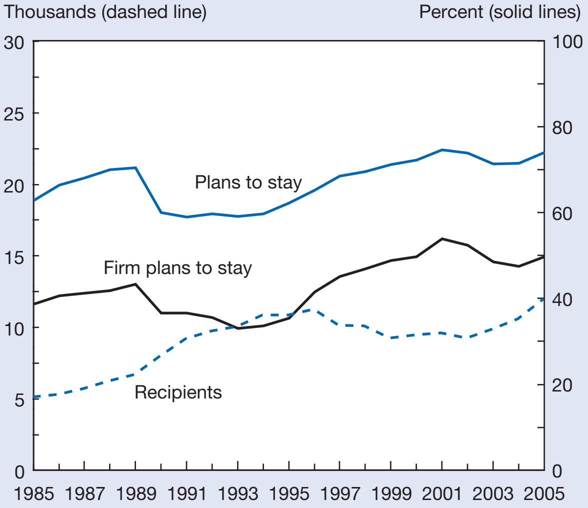
Figure 2-29
Plans of foreign recipients of U.S. S&E doctorates to stay in United States: 1985–2005



NOTES: Degree recipients include permanent and temporary residents. See appendix table 2-33 for plans to stay by place of origin and field of study in 4-year increments.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Earned Doctorates, special tabulations (2007).

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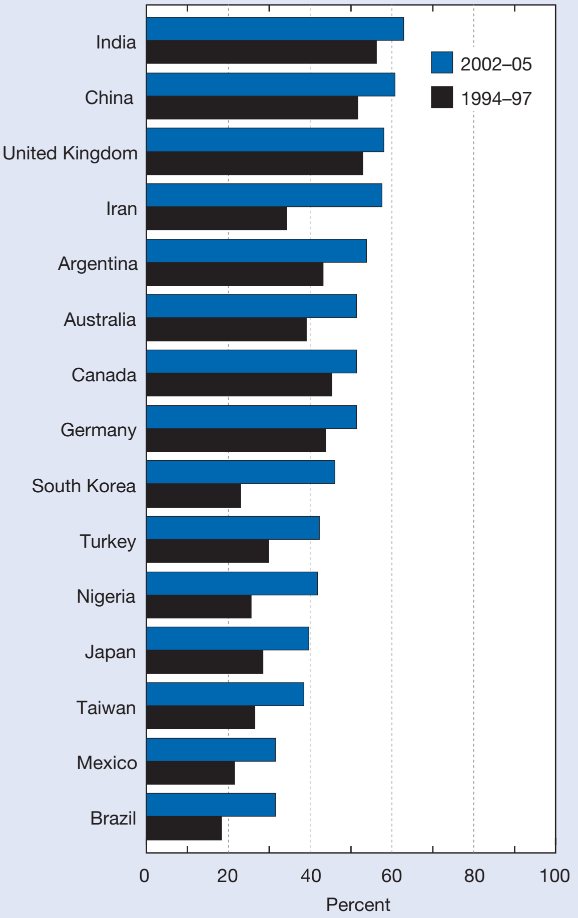
At the time of doctorate receipt, almost three-quarters of foreign recipients of U.S. S&E doctorates plan to stay in the United States and about half had either accepted an offer of postdoctoral study or employment or are continuing employment in the United States. Until the early 1990s, about half of 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 1994–97 period, for example, of the foreign S&E doctoral degree recipients who reported their plans, 71% planned to remain in the United States after receiving their degree and 39% already had firm offers for postdoctoral study or employment. In the 2002–05 period, 74% of foreign doctoral recipients in S&E fields with known plans intended to stay in the United States and 49% had firm offers to do so (appendix table 2-33). Higher percentages of foreign doctorate recipients in physical sciences and mathematics/computer sciences and lower percentages of those in social/behavioral sciences reported firm plans to stay. The percentage of students who had firm plans to remain in the United States dropped after 2001 but increased in 2005 (figure 2-29).

Stay rates vary by place of origin. In the 2002–05 period, more than 90% of U.S. S&E doctoral recipients from China and 88% of those from India reported plans to stay in the United States, and 60% and 63%, respectively, reported accepting firm offers for employment or postdoctoral research in the United States (figure 2-30; appendix table 2-33). China and India are the two major countries of origin from which the percentage of U.S. S&E doctorate recipients with definite plans to stay in the United States dropped from 1998–2001 to 2002–05. The drops were almost entirely among computer science doctorate recipients from India and engineering doctorate recipients from India and China. Stay rates for Chinese and Indian U.S. doctorate recipients in the biological/agricultural/health sciences and physical/earth/atmospheric/ocean sciences increased or stayed about the same from 1998–2001 to 2002–05, and those in social/behavioral sciences stayed about the same or dropped slightly.

Doctorate recipients from Taiwan, Japan, and South Korea were less likely than those from India and China to stay in the United States. Over the same 2002–05 period, 39% of S&E doctoral degree recipients from Taiwan, 41% of those from Japan, and 43% of those from South Korea reported accepting firm offers to remain in the United States.

Among U.S. S&E doctoral degree recipients from Europe, a relatively high percentage from the United Kingdom planned to stay, whereas smaller percentages from Greece, Italy, and Spain (compared with other Western European countries) planned to stay after graduation. The percentage of 2002–05 doctoral degree students who had firm plans to stay in the United States was higher for Canada (51%) than for Mexico (31%) (appendix table 2-33).

Figure 2-30
Short-term stay rates of foreign recipients of U.S. S&E doctorates, by place of origin: 1994–97 and 2002–05



NOTES: Short-term stay rates are those with firm commitments of postaward or postdoctoral employment. Longer-term stay rates may differ. See appendix table 2-33 for plans to stay by place of origin and field of study in 4-year increments.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Earned Doctorates, special tabulations (2007).

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Postdocs in U.S. Higher Education

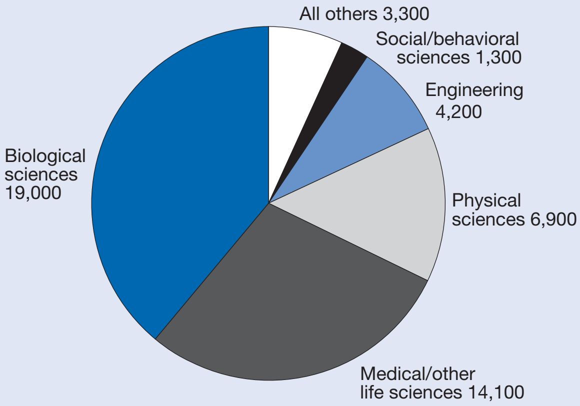
Postdoctoral fellowships provide recent doctorate recipients with "an opportunity to develop further the research skills acquired in their doctoral programs or to learn new research techniques" (Association of American Universities 1998). Typically, postdoctoral fellows or "postdocs" have temporary appointments 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). Postdoctoral fellows are also important contributors to academic research. They bring a new set of techniques and perspectives to the laboratory that broadens the experience of the research team and can make them more competitive for additional research funding. Chapter 3 provides more detail on postdoctoral employment, including reasons for and length of postdoc position as well as salaries and subsequent employment. Chapter 5 provides more detail on postdocs in the academic R&D setting.

Since 1985, the number of doctoral degree recipients with science, engineering, and health postdoctoral appointments at U.S. universities more than doubled from 22,400 to 48,700 in 2005 (appendix table 2-34). More than two-thirds of those were in biological, medical, and other life sciences (figure 2-31).[18]

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 8,900 in 1985 to 27,000 in 2005. The number of U.S. citizen and permanent resident S&E postdocs at these institutions increased more modestly from approximately 13,500 in 1985 to 21,700 in 2005 (figure 2-32; appendix table 2-34). Temporary visa holders accounted for 55% of S&E postdocs in 2005.

An increasing share of academic S&E postdocs are funded through federal research grants. In fall 2005, 57% of S&E postdocs at U.S. universities were funded through this mechanism, up from 50% in 1985. Federal fellowships and traineeships funded a declining share of S&E postdocs—14%

Figure 2-31
Postdoctoral students at U.S. universities, by field: 2005



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 2-34.

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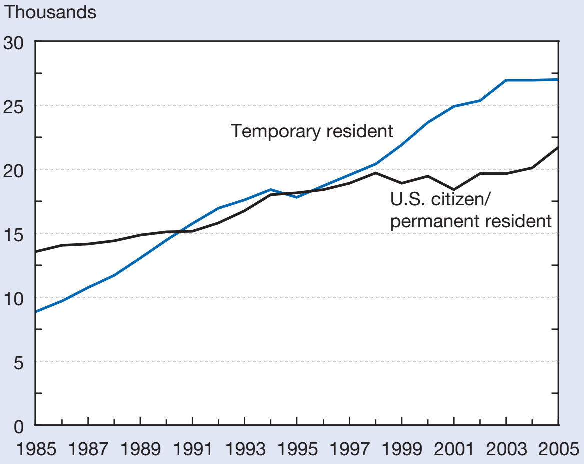
Figure 2-32
Postdoctoral students at U.S. universities, by citizenship status: 1985–2005



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 2-34.

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in 2005, down from 22% in 1985. In 2005, the remainder (about 30%) of S&E postdocs were funded through nonfederal sources (table 2-11).

Global Trends in Higher Education in S&E

In the 1990s, many countries worldwide expanded their higher education systems as well as access to higher education in their country. At the same time, flows of students worldwide increased, particularly from developing countries to more developed countries, and from Europe and Asia to the United States. More recently, a number of countries adopted policies to encourage the return of students who studied abroad, to attract foreign students, or both.

Educational Attainment

Educational attainment of the U.S. population has long been among the highest in the world, but other countries are now catching up (OECD 2006). The United States continues to have the highest percentage of the population ages 25–64 with a bachelor's degree or higher, although among the younger age group (ages 25–34), the United States (30%) lags behind Norway (37%), Israel (34%), the Netherlands (32%), and South Korea (31%) in the percentage of the population with at least a bachelor's degree (figure 2-33; appendix table 2-35).

The percentage of the population with postsecondary degrees of any sort increased greatly in Europe and in many Asian countries over the past decade. Many other countries, including Russia, Israel, Belgium, Canada, Finland, and Sweden have traditionally had relatively high percentages of the population with education levels broadly comparable to U.S. associate's degrees (*tertiary type B* in international classification). Recently, increases in population shares with this level of education have occurred in France, Ireland, Japan, and South Korea, among other countries; these increases are often accompanied by increases in those with bachelor's level qualifications (*tertiary type A*) or better. In total postsecondary education attainment of the population ages 25 to 64 (including 2-year and 4-year or higher degrees), the United States ranks 4th (behind Russia, Israel, and Canada), and it ranks 10th (behind Russia, Canada, Japan, Israel, South Korea, Sweden, Belgium, Ireland, and Norway) in the percentage of the younger population (ages 25–34) with any postsecondary degree (appendix table 2-36).

First University Degrees in S&E Fields

In 2004, almost 11 million students worldwide earned a first university degree[19] with almost 4 million of these in S&E fields (appendix table 2-37). These worldwide totals include only countries for which relatively recent data are available (primarily countries in the Asian, European, and American regions), and therefore are likely an underestimation. Asian universities accounted for 1.7 million of the world's S&E

Table 2-11
Source of funding of S&E postdoctoral students: 1985–2005
(Percent distribution)

Source	1985	1987	1989	1991	1993	1995	1997	1999	2000	2001	2002	2003	2004	2005
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	100.0
Federal fellowships	10.6	9.5	9.4	9.0	8.5	8.8	9.0	9.4	9.1	8.3	8.7	7.9	7.9	7.9
Federal traineeships	11.3	10.6	8.9	8.8	8.5	7.6	7.2	6.6	6.0	5.7	6.0	5.7	5.5	5.8
Federal research grants	50.0	50.9	51.6	51.8	52.1	51.9	51.7	53.2	54.5	54.7	55.8	56.0	57.9	56.6
Nonfederal sources	28.1	29.1	30.1	30.5	30.9	31.6	32.1	30.7	30.3	31.3	29.5	30.4	28.8	29.8

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) database, http://webcaspar.nsf.gov.

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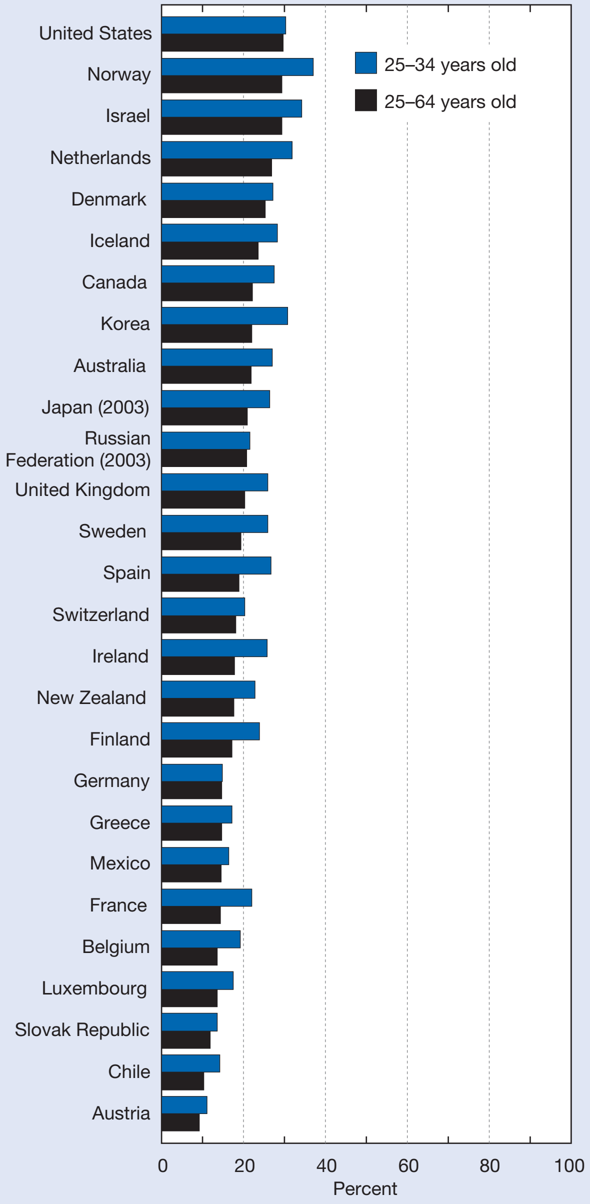
Figure 2-33

Attainment of tertiary-type A and advanced research programs, by country and age group: 2004



NOTES: Tertiary-type A programs (International Standard Classification of Education [ISCED] 5A) largely theory-based and designed to provide sufficient qualifications for entry to advanced research programs and professions with high skill requirements such as medicine, dentistry, or architecture and have a minimum duration of 3 years' full-time equivalent, although typically last ≥4 years. In United States, correspond to bachelor's and master's degrees. Advanced research programs are tertiary programs leading directly to award of an advanced research qualification, e.g., doctorate.

SOURCE: Organisation for Economic Co-operation and Development (OECD), Education at a Glance: OECD Indicators 2006 (2006).

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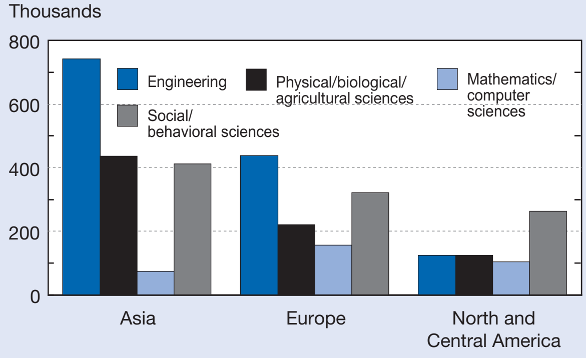
first university degrees in 2004, more than 700,000 of them in engineering (figure 2-34). Students across Europe (including Eastern Europe and Russia) earned more than 1 million S&E degrees, and students in North and Central America more than 600,000 in 2004.

In the United States, S&E degrees are 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, especially engineering, is higher. More than half of first degrees were in S&E fields in Japan (63%), China (56%), Singapore (59%), Laos (57%), and Thailand (69%). Many of these countries/economies traditionally awarded a large proportion of their first degrees in engineering. In the United States, about 5% of all bachelor's degrees are in engineering. However, in Asia, 20% are in engineering, and in many other countries worldwide, more than 10% are in engineering. About 12% of all bachelor's degrees in the United States and worldwide are in natural sciences (physical, biological, computer, and agricultural sciences, and mathematics).

The number of first university S&E degrees awarded in China, South Korea, and the United Kingdom more than doubled between 1985 and 2005; those in the United States generally increased; and those in Japan decreased in recent years (appendix table 2-38). In China, the number of first university degrees in engineering more than doubled between 2000 and 2004 and quadrupled over the past two decades (figure 2-35). Degrees in the physical and biological sciences also greatly increased in China in those years. (See sidebars "Recent Developments in Higher Education in China" and "Recent Developments in Higher Education in India") In South Korea, the number of first university degrees in engineering doubled

Figure 2-34

First university S&E degrees in Asia, Europe, and North and Central America, by field: 2004



NOTE: Physical sciences include earth, atmospheric, and ocean sciences.

SOURCES: Organisation for Economic Co-operation and Development, Education Online Database, http://www.oecd.org/education/database/; United Nations Educational, Scientific, and Cultural Organization (UNESCO), Institute for Statistics, special tabulations (2006); and national sources. See appendix table 2-37 for countries/economies included in each region.

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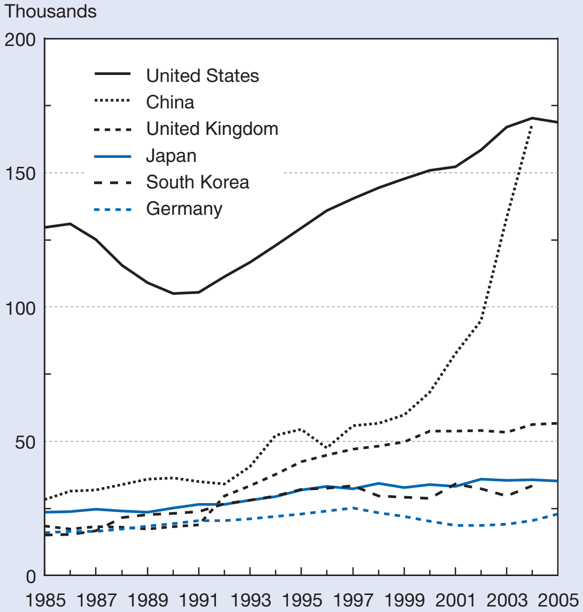
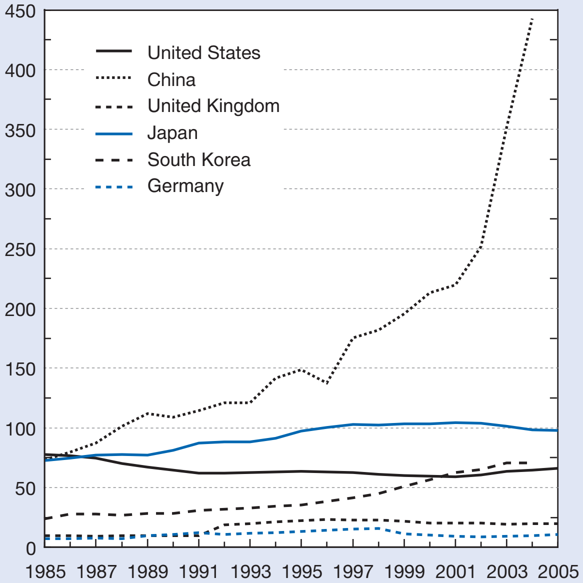
Figure 2-35
First university natural sciences and engineering degrees, by selected countries: 1985–2005



Natural Sciences



Engineering

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, Ministry of Education, Culture, Sports, Science and Technology, Higher Education Bureau, Monbusho Survey of Education; South Korea—Organisation for Economic Co-operation and Development, Education Online Database, http://www.oecd.org/education/database; United Kingdom—Higher Education Statistics Agency; Germany—Federal Statistical Office, Prüfungen an Hochschulen; and United States—National Science Foundation, Division of Science Resources Statistics, WebCASPAR database, http://webcaspar.nsf.gov. See appendix table 2-38.

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between 1995 and 2005 and increased almost threefold between 1985 and 2005. In both the United States and United Kingdom, the number of first university degrees in mathematics/computer sciences and social/behavioral sciences generally increased over the past two decades, while the number awarded in physical/biological sciences and engineering dipped in recent years (although in the United States, degrees in those disciplines have since rebounded). In Japan, the number of first university S&E degrees rose in the 1990s but decreased from 2002 through 2005. In Germany, the number of first university S&E degrees dropped from 1997 through 2001 but increased in recent years.

Global Comparison of Participation Rates by Sex

Women earned half or more of first university degrees in S&E in many countries around the world in 2004, including the United States, Canada, Greece, Portugal, Panama, and several countries in Asia, the middle East, and Eastern

Recent Developments in Higher Education in China

Major education reform efforts in China began in the late 1990s. These efforts focused on consolidating and strengthening higher education institutions, expanding disciplines offered, increasing funding, and improving teaching. As a consequence, enrollment in higher education in China increased sharply (Hsiung 2007). Since 1998, undergraduate enrollment in colleges and universities increased from 0.3 million to 13.3 million in 2004, and 4-year degrees increased from 405,000 to 1.2 million (National Bureau of Statistics of China 2005). Although enrollment and degree production increased exponentially, the per capita rate of college attendance remains low (Hsiung 2007). In addition to expansion of 4-year colleges and universities, vocational and technical education also expanded. The number of vocational and technical schools increased from 101 in 1998 to 872 in 2004, and enrollments rose to 5.96 million students (45% of all college students) in 2004 (Hsiung 2007). Current reform efforts focus on improving quality of instruction, slowing the growth in college enrollment to 5% per year, and targeting advanced education.

The increased growth in enrollment and degree production over the past few years has increasingly been outside of S&E fields. Historically, almost half of bachelor's recipients in China earned degrees in engineering, but although the numbers of degrees in engineering have increased, the percentage has been steadily decreasing over time. In 1994, 46% were in engineering; by 2004, 37% were in engineering (appendix table 2-38) as the number and percentage of degrees in business, literature, education, and law increased.

Europe. A number of countries in Europe are not far behind, with more than 40% of first university S&E degrees earned by women. In many Asian and African countries, women generally earn about one-third or less of the first university degrees awarded in S&E fields (appendix table 2-39). In the United States, Canada, Japan, and many smaller countries, over half of the S&E first university degrees earned by women are in the social and behavioral sciences. In a few countries (e.g., El Salvador, South Korea, and several countries in Eastern Europe), more than 40% of S&E first university degrees earned by women are in engineering, compared with 6% in the United States.

Recent Developments in Higher Education in India

Over the past two decades, higher education in India expanded rapidly (Agarwal 2006). Enrollment increased from 2.8 million in 1980 to 9.9 million in 2003 (Ministry of Science and Technology 2006). Most of the growth is due to an increase in the number of private colleges, many of which are polytechnics and industrial training institutes. Foreign education providers also increased their presence. In 2005, 131 foreign providers of higher education, mainly from the United States and United Kingdom, enrolled students mostly in vocational or technical fields (Agarwal 2006). Despite high numbers of students enrolled, the percentage of the college age population who enroll in higher education in India is low (13%) (Thorat 2006).

The growth of higher education in India resulted in several challenges, including questions of adequacy of facilities, space, and resources; institutional quality and standards; and quality of faculty and instructional methods (Chatterjea and Moulik 2006). There is wide disparity in the perceived quality of schools. The Indian Institutes of Management and the Indian Institutes of Technology are generally regarded as top-quality schools. According to Giridharadas (2006), graduates of second-tier schools face high unemployment as their knowledge and skills are considered not up to par. Another observer (Agarwal 2006) states that the expansion of higher education also resulted in mismatches between supply and demand. He reported that in 2001, about 17% of higher education graduates were unemployed and nearly 40% were not, or were not fully, productively employed.

Although data on enrollments are available, up-to-date definitive statistics on Indian higher education degrees are not. Higher education institutions are not required to provide information and response rates to voluntary data collections are low.

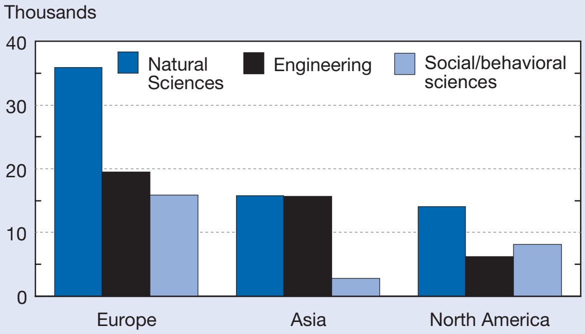
Global Comparison of S&E Doctoral Degrees

Almost 150,000 S&E doctoral degrees were earned worldwide in 2004. Of these, more than 80% were earned outside the United States (appendix table 2-40). The United States awarded the largest number of S&E doctoral degrees (more than 26,000), followed by Russia (16,000), China (almost 15,000), and Germany (more than 12,000). Close to 40% of these S&E doctoral degrees in the United States and worldwide were earned in the physical/biological sciences. Figure 2-36 shows the breakdown of S&E doctoral degrees by major region and selected fields.

Women earned 37% of S&E doctoral degrees awarded in the United States and about 34% of those earned worldwide in 2004. The percentage of S&E doctoral degrees earned by women varied widely by country/economy, from less than 20% in South Korea, Taiwan, Japan, Iran, and Ghana, to more than 50% in Kyrgyzstan, the Philippines, Uganda, Portugal, Latvia, and Lithuania (appendix table 2-41).

The number of S&E doctoral degrees awarded in the United Kingdom and in many Asian countries rose steeply in the past two decades (appendix tables 2-42 and 2-43). The United States awards the largest number of natural sciences and engineering doctoral degrees, but China is catching up (figure 2-37). In the United Kingdom, as well as in Germany and the United States, most S&E doctoral degrees are in the physical and biological sciences. The numbers of doctoral degrees in those fields stagnated or declined from the late 1990s through 2005, although the number of these degrees in the United States experienced a recent upturn. Most of the recent growth in S&E doctoral degrees in the United Kingdom was due to an increase in the number of social and behavioral sciences doctorates.

Figure 2-36
S&E doctoral degrees earned in Europe, Asia, and North America, by field: 2004 or most recent year



NOTES: Natural sciences include physical, biological, earth, atmospheric, ocean, agricultural, and computer sciences and mathematics. Asia includes China, India, Japan, South Korea, and Taiwan. Europe includes Western, Central, and Eastern Europe. North America includes United States and Canada.

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, accessed 3 April 2007; and national sources. See appendix table 2-40.

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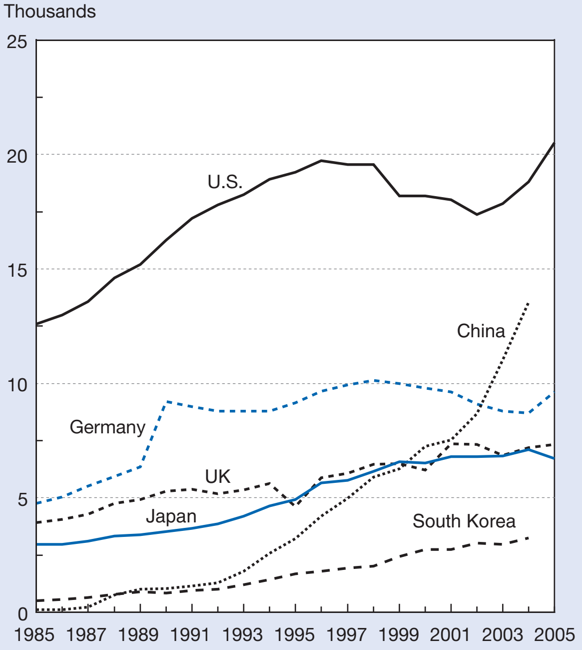
Figure 2-37
Natural sciences and engineering doctoral degrees, by selected country: 1985–2005



UK = United Kingdom

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, Ministry of Education, Culture, Sports, Science and Technology, Higher Education Bureau, Monbusho Survey of Education; South Korea—Organisation for Economic Co-operation and Development, Education Online database, http://www.oecd.org/education/database/; United Kingdom—Higher Education Statistics Agency; and Germany—Federal Statistical Office, Prüfungen an Hochschulen. See appendix tables 2-42 and 2-43.

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In Asia, China was the largest producer of S&E doctoral degrees (almost 15,000). The number of S&E doctorates awarded in China rose more than sixfold between 1993 and 2004, and the number of S&E doctorates awarded in South Korea, Taiwan, and Japan also greatly increased. In China, South Korea, Japan, and Taiwan, more than half of S&E doctorates were awarded in engineering. In India, the number of S&E doctoral degrees rose more modestly, although there was still a 58% increase from 1985 through 2003, and most doctorates were awarded in the physical and biological sciences (appendix table 2-43).

Global Student Mobility

International migration of students and highly skilled workers expanded in the past two decades, and countries are increasingly competing for foreign students. 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, whereas 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 2004).

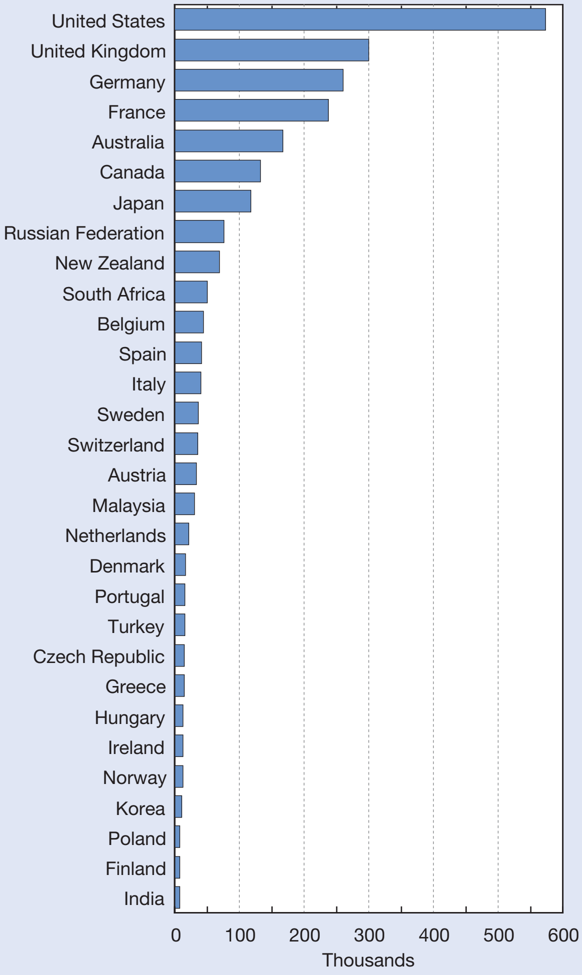
The population of individuals ages 20–24 (a proxy for the college-age population) decreased in Europe, the United States, China, and Japan in the 1990s and is projected to continue decreasing in Europe and Japan (appendix table 2-44). Some countries expanded recruitment of foreign students as their own populations of college-age students decreased, both for attraction of highly skilled workers and also for increased revenue for colleges and universities. (See sidebar "Transnational Higher Education.")

The U.S. share of foreign students worldwide declined in recent years, although the United States remains the destination of the largest number of foreign students worldwide (both undergraduate and graduate) of all Organisation for Economic Co-operation and Development (OECD) countries (figure 2-38). In 2004, the United States received 22% of foreign students worldwide, down from 25% in 2000 (OECD 2006). Other countries that are among the top destinations for foreign students include the United Kingdom (11%), Germany (10%), and France (9%). Although they have lower numbers of foreign students than the United States, several other countries have higher percentages of higher education

Transnational Higher Education

Universities in the United States and abroad are establishing branch campuses and programs in other countries. In the past, cross-border higher education largely involved study abroad programs. More recently, it involved establishing programs for foreign students in their home countries. For countries in which these branch campuses are established, these efforts provide a means to curb "brain drain," increase educational opportunities, and potentially attract more international students (McBurnie and Ziguras 2006). Some of the major sites for transnational delivery of higher education include China, India, and Singapore. For countries that establish branch campuses abroad, the benefits of these efforts include increased enrollment and revenue, greater opportunities for student and staff mobility, and prestige. The major countries providing transnational higher education include the United States, Canada, the United Kingdom, and Australia. The United States accounts for the majority of institutions offering transnational delivery (Verbik and Merkley 2006). Problems with this type of delivery include issues of governance, quality control, and access; the stability of the institution; and the range of disciplines offered.

Figure 2-38
Foreign students enrolled in tertiary education, by country: 2004



NOTES: Austria excludes tertiary-type B programs, e.g., associate's. Poland excludes advanced research programs, e.g., doctorate.
SOURCE: Organisation for Economic Co-operation and Development (OECD), Education at a Glance: OECD Indicators 2006 (2006).

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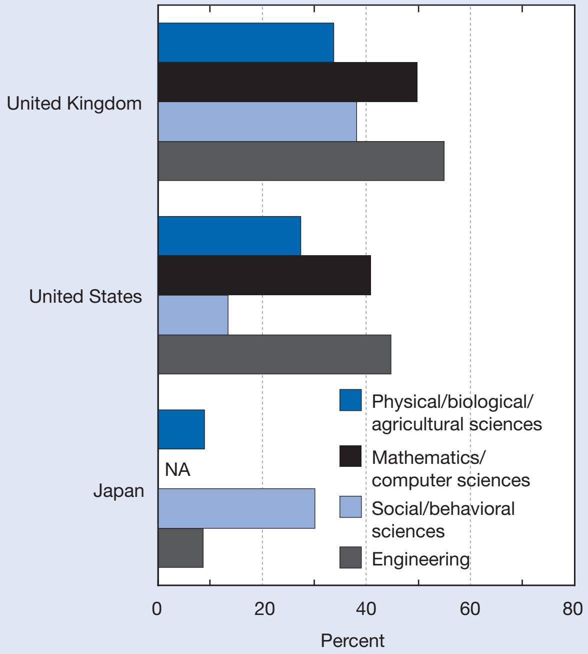
students (both undergraduate and graduate) who are foreign. In Australia 17% of students in higher education are foreign; in Switzerland and the United Kingdom, 13%; and in Austria, 11%, compared with 3% in the United States. Many countries (the United Kingdom, Germany, France, and New Zealand) recently instituted policies to help facilitate immigration of foreign students (Suter and Jandl 2006). Major policy efforts in Europe promoted increased international mobility of students. In the European Union, a substantial number of foreign students come from other European Union countries, but large numbers are also from Eastern Europe, Africa, and Asia, especially China and India (Kelo, Teichler, and Wächter 2006; Suter and Jandl 2006).

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 also increased, especially at the graduate level, with increasing flows of students from China and India. From 1994 to 2005, foreign students increased from 29% to 43% of all graduate students studying S&E in the United Kingdom. In graduate engineering, foreign student enrollment more than doubled from 9,300 (35% of enrollment) to 21,400 (55% of enrollment) (figure 2-39; appendix table 2-45). Students from China, Greece, India, and Pakistan accounted for most of the increase in foreign graduate engineering enrollment. The prime minister's current Initiative for International Education calls for attracting an additional 100,000 international students by 2011 and provides about $48 million in funding to increase the number of international students in the United Kingdom. It also calls for diversifying the countries from which they draw students and also maintaining quality. The previous initiative (which exceeded its goals), called for increasing the number of students by 75,000 between 1999

Figure 2-39
S&E foreign graduate student enrollment, by selected industrialized country and field: 2005



NA = not available

NOTES: Physical sciences include earth, atmospheric, and ocean sciences. Japanese data include mathematics in natural sciences and computer sciences in engineering. Foreign graduate enrollment in U.S. data includes temporary residents only; United Kingdom 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 (2007); Japan—Government of Japan, Ministry of Education, Culture, Sports, Science and Technology, special tabulations (2007). See appendix tables 2-22, 2-45, and 2-46.

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and 2005. An increase in foreign students results in revenue for higher education institutions. Additionally, foreign students are allowed to work in the United Kingdom for up to 12 months after graduation under certain circumstances (British Council 2007).

About 100,000 foreign students studied in Japanese universities in 2005, almost 60,000 of them in S&E fields. Foreign S&E student enrollment in Japan is concentrated at the undergraduate level, accounting for 69% of all foreign S&E students. Foreign undergraduates, however, represent only 3% of all undergraduate S&E students. Although smaller in number, foreign graduate students account for 13% of graduate S&E students in Japan. About 18,000 foreign S&E graduate students were enrolled in Japanese universities in 2005, more than half of them from China (appendix table 2-46).

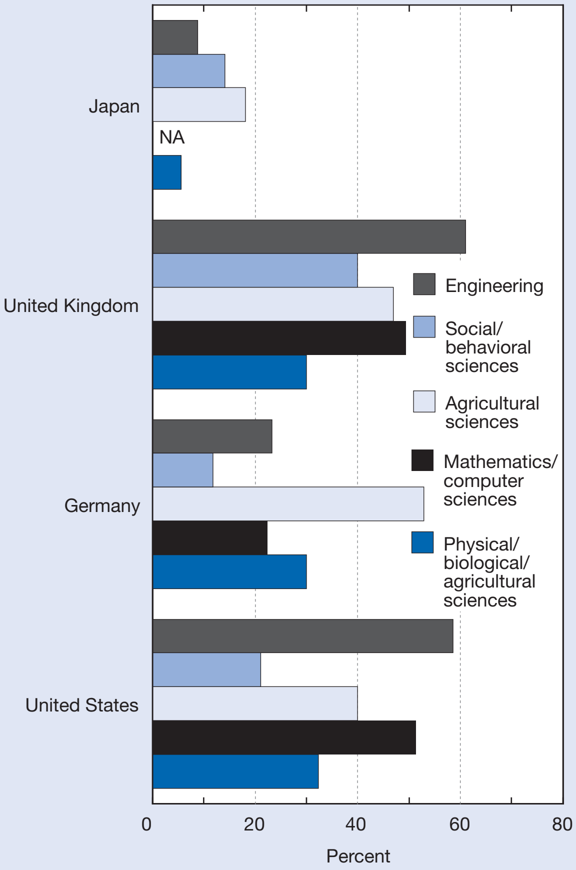
Foreign students are an increasing share of enrollment in Canadian universities. Foreign S&E students accounted for about 7% of undergraduate and 23% of graduate S&E enrollment in Canada in 2004, up from 5% and 22% in 1994. At both the undergraduate and graduate levels, foreign S&E students are higher percentages of students in mathematics/computer sciences and engineering than they are in other fields. Asian countries/economies were the top places of origin of foreign S&E graduate and undergraduate students in Canada. China alone accounts for 19% of foreign S&E graduate students and 15% of foreign S&E undergraduate students in Canada. The United States is also among the top countries of origin of foreign students, accounting for 5% of foreign S&E graduate students and 10% of foreign S&E undergraduate students in Canada (appendix table 2-47).

Australia actively recruited foreign students in recent years. Foreign students accounted for 15% of S&E undergraduate and 32% of S&E graduate students in Australian universities in 2005 (appendix table 2-48). At both the undergraduate and graduate levels, foreign S&E students are concentrated in mathematics/computer sciences and engineering. About three quarters of foreign students (in all fields) in Australia are from Asia, mainly China and India (IIE 2007).

International Comparison of Foreign Doctoral Degree Recipients

As in the United States, foreign students are a large share of S&E doctoral degree recipients in the United Kingdom. In 2005, 42% of S&E doctorates from the United Kingdom and 41% of S&E[20] 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 60% of the doctorates awarded in engineering. Foreign students account for about 10% of S&E doctorate recipients in Japan and 25% in Germany (figure 2-40; appendix table 2-49).

Figure 2-40
S&E doctoral degrees earned by foreign students, by selected industrialized country and field: 2005 or most recent year



NA = not available

NOTES: Physical sciences include earth, atmospheric, and ocean sciences. Japanese data for university-based doctorates only; exclude *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 2005; Japan—Government of Japan, Ministry of Education, Culture, Sports, Science and Technology, special tabulations; United Kingdom—Higher Education Statistics Agency, special tabulations (2007); United States—National Science Foundation, Division of Science Resources Statistics, Survey of Earned Doctorates, WebCASPAR database, http://webcaspar.nsf.gov. See appendix table 2-49.

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Conclusion

S&E higher education in the United States is attracting growing numbers of students. The number of bachelor's degrees and master's degrees awarded in all fields and in S&E fields continues to rise, reaching new peaks in 2005. Graduate enrollment in S&E fields is also increasing, reaching a new peak in 2005. After declining in the late 1990s and early 2000s, the number of S&E doctorates awarded increased in the past several years.

Most of the growth in S&E education occurred in science fields. In engineering, bachelor's and master's degrees increased in recent years, but have not yet attained the levels of the 1980s. Engineering enrollment, both undergraduate and graduate, and engineering doctorates declined somewhat in recent years. Computer science enrollments and degrees followed trends similar to those of engineering.

Foreign student enrollment in graduate S&E programs dropped in recent years. The number of entering foreign students dropped after September 11, 2001, and only began to rise again in 2005. 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.

Globalization of higher education continues to expand. Although the United States continues to attract the largest number and fraction of foreign students worldwide, both numbers and percentages decreased in recent years. Most countries in Europe and several in Asia expanded access to higher education, resulting in increases in educational attainment since 1990. Some of the reduction in foreign students in the United States may be due to increased opportunities for students in their home countries. Some may also be due to increased competition for foreign students from other countries. Universities in several other countries, including Australia, the United Kingdom, Canada, Japan, and Germany, expanded their enrollment of foreign S&E students.

Notes

1. New efforts to develop indicators of the linkage between human capital (e.g., degrees granted, size and flows of the scientific work force) and growth in high- and medium-high technology-intensive manufacturing industries are underway (Hansen et al. 2007). Preliminary results indicate a significant correlation between doctorates awarded in natural sciences and engineering per capita population and productivity (measured by patent applications per capita population) in high and medium-high technology-intensive manufacturing industries.

2. *Physical sciences* include earth, atmospheric, and ocean sciences.

3. Research institutions are classified according to the 1994 Carnegie classification. See *Science and Engineering Indicators 2006* (NSB 2006) for definitions of the various classification categories.

4. Financial aid is calculated for all full-time students, both in state and out of state, so net price may be underestimated.

5. For information on debt levels of clinical versus nonclinical psychology doctorates in 1993–96, see "Psychology Doctorate Recipients: How Much Financial Debt at Graduation?" (NSF 00-321) at http://www.nsf.gov/statistics/issuebrf/sib00321.htm.

6. Based on previous projections, NCES has estimated that the mean absolute percentage error for bachelor's degrees projected 9 years out was 8.0.

7. 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 non-S&E fields after their freshman year, and general attrition from bachelor's degree programs. (See sidebar "Persistence, Retention, and Attainment in Higher Education and in S&E.")

8. *Physical sciences* include earth, atmospheric, and ocean sciences.

9. Data for racial/ethnic groups are for U.S. citizens and permanent residents only.

10. About 17% of 2001 and 2002 S&E bachelor's degree recipients had previously earned an associate's degree (NSF 2006a).

11. Data for racial/ethnic groups are for U.S. citizens and permanent residents only.

12. See the NSF report series *Science and Engineering Degrees* (http://www.nsf.gov/statistics/degrees/) for longer degree trends and *Women, Minorities, and Persons with Disabilities in Science and Engineering: 2007* (http://www.nsf.gov/statistics/women/) for more detail on enrollments and degrees by sex and by race/ethnicity.

13. Data for racial/ethnic groups are for U.S. citizens and permanent residents only.

14. Data for racial/ethnic groups are for U.S. citizens and permanent residents only.

15. Data on doctorates comes from the NSF Survey of Earned Doctorates, which collects data on research doctorates only (i.e., doctorates that require original research and typically entail writing a dissertation). The survey does not collect data on professional degrees (e.g., M.D., D.D.S., J.D., Psy.D., and D.Min.). For the most recent data available, including data by detailed field and data on math and science education doctorates, see http://www.nsf.gov/statistics/doctorates/.

16. See the NSF report series *Science and Engineering Degrees* (http://www.nsf.gov/statistics/degrees/) for longer degree trends and *Women, Minorities, and Persons with Disabilities in Science and Engineering: 2007* (http://www.nsf.gov/statistics/women/) for more detail on enrollments and degrees by sex and by race/ethnicity.

17. The number of doctoral S&E degrees earned by students in Chinese universities continued to increase throughout this period, from 125 in 1985 to 14,858 in 2004.

18. For more information about the distribution of postdoc positions according to sex, see *Women, Minorities, and Persons with Disabilities in Science and Engineering: 2007* at http://www.nsf.gov/statistics/wmpd.

19. 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 (e.g., laureata in Italy, diplome in Germany, maitrise in France, and bachelor's degree in the United States and in Asian countries).

20. Excluding doctorates in medical/health fields.

Glossary

Debt burden: Student loan payments as a percent of salary.

Dual enrollment courses: Classes taken on a high school campus for which a student receives course credit at both the high school and community college levels.

First university degree: 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 (e.g., laureata in Italy, diplome in Germany, maitrise in France, and bachelor's degree in the United States and in Asian countries).

Internationally mobile students: Those individuals who are not citizens of the country in which they study.

Net price: The published price of an undergraduate college education minus the average grant aid and tax benefits that students receive.

Stay rate: The proportion of students on temporary visas who have plans to stay in the United States immediately after degree conferral.

Tertiary type A programs: Higher education programs that are largely theory-based and designed to provide sufficient qualifications for entry to advanced research programs and to professions with high skill requirements, such as medicine, dentistry, or architecture, and have a minimum duration of 3 years, although they typically last 4 or more years. These correspond to bachelor's or master's degrees in the United States.

Tertiary type B programs: Higher education programs that focus on practical, technical, or occupational skills for direct entry into the labor market and have a minimum duration of 2 years. These correspond to associate's degrees in the United States.

Underrepresented minority: Blacks, Hispanics, and American Indians/Alaska Natives are considered to be underrepresented minorities in S&E.

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Science and Engineering Labor Force

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Highlights

The S&E workforce in the United States has grown rapidly for decades.

- From 1950 to 2000, employment in S&E occupations grew from fewer than 200,000 to approximately 4.8 million workers. The average annual growth rate of 6.7% contrasts with a 1.6% annual average growth rate for total employment.
- Between 1990 and 2000, S&E occupations grew at a lower average annual rate of 3.6%, but this was more than triple the rate of growth of other occupations. Different data sources suggest the same rate of employment growth in 2005.
- 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. The loose fit between degrees and occupations and the immigration of S&E workers helped to account for the different rates of degree and occupation growth.

The S&E labor force does not include just those in S&E occupations.

- Approximately 12.9 million workers said in 2003 that they needed at least a bachelor's degree level of knowledge in S&E fields in their jobs. However, in that year only 4.9 million were in occupations formally defined as S&E.
- Fifteen million workers in 2006 had an S&E degree as their highest degree and 17 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.
- Fifty-five percent of S&E degree holders who spent at least 10% of their work hours on R&D were in non-S&E occupations.

S&E occupations have generally recovered from unusually high unemployment in the most recent recession.

- Unemployment in S&E occupations declined to 1.6% in 2006, down from the 20-year high of 4.0% in 2003.
- Unemployment rates also declined in the S&E-related occupational categories of technicians and computer programmers to 3.1% and 2.8%, respectively, in 2006.

Changes between 1993 and 2003 in median real salary for recent S&E graduates indicate increasing relative demand for S&E skills during the past decade.

- The mean real salary for recent S&E bachelor's degree recipients increased in all fields, averaging 15% across all fields of degree.
- The largest increases for recent bachelor's degree recipients were in computer and mathematical sciences (23.3%) and engineering (20.4%),

Retirements from the S&E labor force are likely to become more significant over the next decade.

- Twenty-six 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, 40% are age 50 or over.
- By age 62, half of S&E bachelor's degree holders had left full-time employment. Doctoral 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, as were 40% of doctorate holders in S&E occupations.
- At least 41% of the foreign-born university educated in the United States in 2003 had their highest degree from a foreign educational institution.
- About half of S&E doctorate holders in U.S. postdoc positions may have earned their doctorates outside of the United States.

The capability for doing science and technology work has increased throughout the world.

- From 1994 to 2004, R&D employment outside the United States by U.S. firms increased by 76%, compared with a 31% increase in R&D employment by the same firms in the United States, and an 18% increase in U.S. R&D employment at the U.S. subsidiaries of foreign firms.

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 nonacademic S&E occupations in 1980 and 26% in 2005. Women are a higher proportion of nonacademic S&E occupations at the doctoral level, increasing from about 23% in 1990 to 31% in 2005.
- The proportion of blacks in nonacademic S&E occupations increased from less than 3% in 1980 to 5% in 2005. The proportion of Hispanics increased from 2% to 5% in 2005. At the doctoral level, blacks, Hispanics, and American Indians/Alaska Natives combined represented just over 4% of employment in nonacademic S&E occupations in 1990, rising to 6% in 2005.

Postdoc positions have become an increasingly important stage in the career paths of S&E doctorate recipients.

- Across all S&E fields, the proportion of U.S. S&E doctorate holders reporting ever holding a postdoc position reached 46% for the 2002–05 graduation cohort. Proportions are highest in the life sciences and the physical sciences.
- There has been a steady growth in the availability of employment benefits for postdocs, with 90% now reporting having medical benefits and 49% reporting retirement benefits.
- Former postdocs are moderately more likely than those with no postdoc experience to be in tenured or tenure-track positions, to have R&D as a major work activity, and to report that their job is closely related to their field of degree. However, these relationships are not necessarily causal.

Introduction

Chapter Overview

Although workers with S&E skills make up only a small 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 of the last century, the size of the S&E labor force grew dramatically—with employment in S&E occupations expanding 25-fold 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 rate 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 any or all 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. The first provides a general profile of the U.S. S&E labor force. This includes demographic characteristics (population size, sex, nativity, 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 surveys of S&E degree holders[1]—the National Survey of College Graduates (NSCG), the National Survey of Recent College Graduates (NSRCG), and the Survey of Doctorate Recipients (SDR). When combined in a way to form a single profile of the S&E-educated population in the United States, these three surveys are known as the Scientists and Engineers Statistical Data System (SESTAT).

The second section looks at the labor market conditions for recent S&E 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.

The third section examines the age and retirement profiles 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 different 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 proportions of women and ethnic minorities in the S&E labor force continue to grow, but with the exception of Asians/Pacific Islanders, they remain smaller than their respective 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 who is a scientist or an 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?”)

Estimates of the size of the S&E workforce in 2006 ranged from approximately 5 million to more than 21 million individuals, depending on the definition and perspective used (table 3-1). In that year, 17.0 million individuals had at least one degree in an S&E field and 21.4 million had either an S&E degree or a degree in an S&E-related field such as health or technology. 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, as S&E skills are used in a wide variety of occupations. A smaller number, 14.5 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 2006 NSF SESTAT data estimated 5.0 million workers, whereas the

Who Is a Scientist or an Engineer?

The terms scientist and engineer have many definitions, none of them perfect. 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 about 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 from an analysis of the S&E labor force an individual who has both a bachelor's degree in engineering and a master's degree in business administration.
- **Need for S&E knowledge.** Many individuals identify their jobs as requiring at least a bachelor's degree level of knowledge in S&E, although not all of them have such a degree.

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*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 partially avoid 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 and 2006

Concept	Education coverage	Source	Number
Occupation			
Employment in S&E occupations	All	2006 BLS Occupational and Employment Statistics Survey	5,408,000
Employment in S&T or "STEM" occupations	All	2006 BLS Occupational and Employment Statistics Survey	7,442,000
Employment in S&E occupations	Bachelor's and above	2006 NSF SESTAT data	5,024,000
Employment in S&E occupations	Bachelor's and above	2005 American Community Survey	3,858,000
Employment in S&E occupations	All	2005 American Community Survey	5,301,000
Education			
Highest degree in S&E field	Bachelor's and above	2006 NSF SESTAT data	14,531,000
Any degree in S&E field	Bachelor's and above	2006 NSF SESTAT data	17,034,000
Any degree in S&E or S&E related fields	Bachelor's and above	2006 NSF SESTAT data	21,378,000
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; SESTAT = Scientists and Engineers Statistical Data System

SOURCES: NSF, Division of Science Resources Statistics, SESTAT database, 2003 and 2006 (preliminary data for 2006), http://sestat.nsf.gov; BLS, Occupational and Employment Statistics Survey, May 2006; and Census Bureau, American Community Survey (2005).

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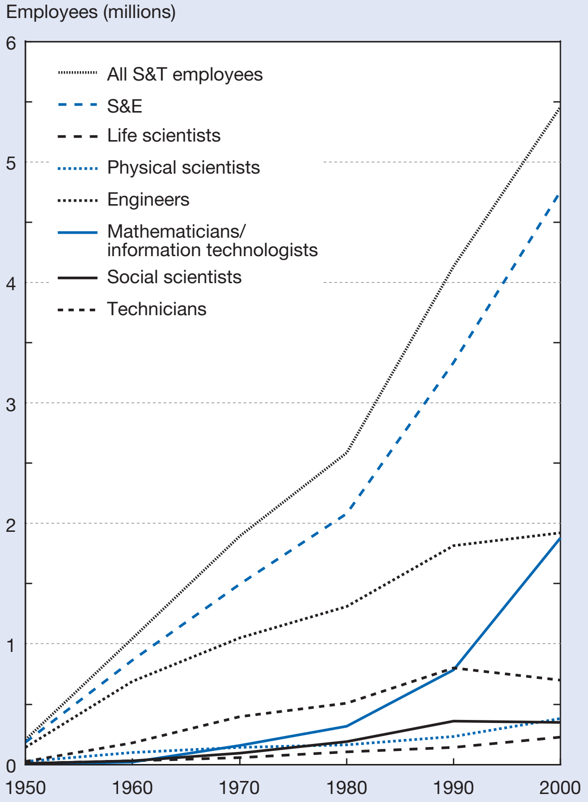
Census Bureau's 2005 American Community Survey estimated 3.9 million. Occupation-based estimates not limited to college graduates include 5.4 million in May 2006 from the Bureau of Labor Statistics (BLS) Occupational Employment Statistics Survey (OES) and 5.3 million from the 2005 American Community Survey. OES and NSF SESTAT occupational estimates include postsecondary teachers in S&E fields, but estimates from the American Community Survey, the Current Population Survey (CPS), and the decennial census have to exclude postsecondary teachers, as no information on field is collected.

Terminology referring to the technical labor force can be confusing. Sometimes a study will refer to the science and technology (S&T) or to the STEM (science, technology, engineering, and math) labor force. These terms are approximately equivalent, and as used in this chapter include all S&E occupations with the addition of technicians, programmers, technical managers, and a small number of nonhealth S&E-related occupations such as actuary and architect. In addition, some recent reports from private organizations have used the label "S&E labor force" to discuss what is labeled here as "S&T occupations." The estimate from the May 2006 OES of individuals employed in S&T occupations is 7.4 million.

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 (NS&E) and 5.3 million a need for knowledge of the social sciences (1.6 million reported a need for both social science and NS&E knowledge). That the need for S&E knowledge is more than double the number in formal S&E occupations suggests the pervasiveness of the need for technical knowledge in the modern workplace.

Figure 3-1
Science and technology employment: 1950–2000



S&T = science and technology

NOTE: Data include 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: Adapted from Lowell BL, Regets MC, A Half-Century Snapshot of the STEM Workforce, 1950 to 2000, Commission on Professionals in Science and Technology (2006).

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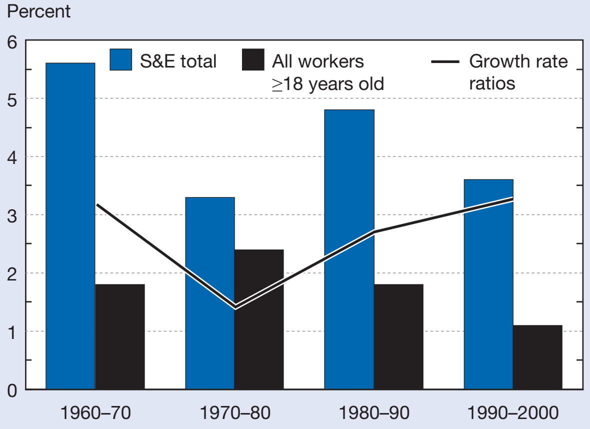
S&E Workforce Growth

Occupation classifications allow examination of growth in at least one measure of scientists and engineers over extended periods (for a discussion of even longer time periods, see the sidebar "Scientists Since Babylon"). According to data from the decennial censuses, the number of workers in S&E occupations grew to 4.8 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 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 (figure 3-2). S&E employment grew between 1990 and 2000 at a 3.6%

Figure 3-2
Average annual growth rates of S&E occupations versus all workers: 1960–2000



SOURCE: National Science Foundation, Division of Science of Science Resources Statistics, decennial census data, special tabulations.

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Scientists Since Babylon

In the early 1960s a prominent historian of science, Derek J. de Solla Price, examined the growth of science and the number of scientists over very long periods in history, titling one book *Science Since Babylon* (1961). Using a number of empirical measures (most over at least 300 years), Price found that science, and the number of scientists, tended to double about every 15 years, with measures of higher-quality science and scientists tending to grow slower (doubling every 20 years) and measures of lower-quality science and scientists faster (every 10 years).

One implication of this long-term exponential growth often cited in popular science writing is that "80 to 90 percent of all the scientists that ever lived are alive today" (Price 1961). This insight follows from the likelihood that most of the last 45 years' (a period of three doublings) production of new scientists would still be alive. Price was interested in many implications of these growth patterns, but in particular the idea that this growth could not continue indefinitely and that the number of scientists would reach "saturation." Not everyone is either capable of becoming, or wants to become, a scientist, and society will always need people to perform other jobs. Even if no other limits applied, the number of scientists could not exceed the size of the population. Although not predicting exactly when growth in the number of scientists would slow, Price was concerned (in 1961) that saturation had already begun.

How different are the growth rates in the number of scientists and engineers in recent periods from what Price estimated for past centuries? A doubling every 10 years would imply an annual average growth rate of 7.1%; every 15 years an average annual rate of 4.7%; and every 20 years an annual average growth rate of 3.5%. Table 3-2 shows growth rates for some measurements of the S&E labor force in the United States and elsewhere in the world for a period of available data. Of these measures, the number of S&E doctorate holders in the United States labor force showed the lowest average annual growth of 3.0% (doubling in 24 years if this growth rate were to continue). The number of doctorate holders employed in S&E occupations in the United States showed faster average annual growth of 4.6% (doubling in 16 years if continued). There are no global counts of individuals in S&E, but the Organisation for Economic Co-operation and Development (OECD) does count "researchers" in the developed countries that are OECD members. In the OECD countries, the number of researchers grew at an average annual rate of 3.4% (21 years to double). Very limited data exists on the population of scientists and engineers in most developing countries, but OECD data for researchers in China show a 7.4% average annual grow rate (10 years to double).

All of these numbers are broadly consistent with a continuation of growth in S&E labor exceeding the rate of growth in the general labor force, both in the United States and in the world as a whole. Because none of the measures are the same as those used by Price, it is impossible to say that there has been a slowing in growth. What about the ultimate limit to growth for scientists and engineers in the United States? If the 1990s growth rates shown in figure 3-2 for the number employed in S&E occupations and for the total labor force were to continue indefinitely, all U.S. workers in 2135 would be in S&E occupations.

Table 3-2
Growth rates for selected S&E labor force measurements

Measurement	Source	Years	First year	Last year	Average annual growth rate (%)
Researchers in OECD countries	OECD	1995–2002	2,815,000	3,559,000	3.4
Doctorate holders in U.S. nonacademic S&E occupations	U.S. Census	1990–2005	200,000	390,000	4.6
College graduates in U.S. nonacademic S&E occupations	U.S. Census	1990–2005	2,362,000	4,111,000	3.8
S&E doctorate holders in U.S.	NSF/SRS SESTAT	1993–2003	590,000	796,000	3.0
S&E bachelor's degree and above holders in U.S.	NSF/SRS SESTAT	1993–2003	11,022,000	15,684,000	3.6
Researchers in China	OECD	2000–03	695,000	862,000	7.4

NSF/SRS = National Science Foundation, Division of Science Resources Statistics; OECD = Organisation for Economic Co-operation and Development; SESTAT = Scientists and Engineers Statistical Data System

SOURCES: NSF/SRS, SESTAT database, 1993 and 2003, http://sestat.nsf.gov; Census Bureau, Public Use Microdata Sample, 1990; American Community Survey, 2005; and OECD, Main Science and Technology Indicators (2006).

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average annual rate (and S&T employment at a 2.8% average annual rate) compared with 1.1% for the whole workforce. Although the growth rate for S&E occupations was somewhat less in the 1990s than in the 1980s, it actually increased relative to the growth of all workers.

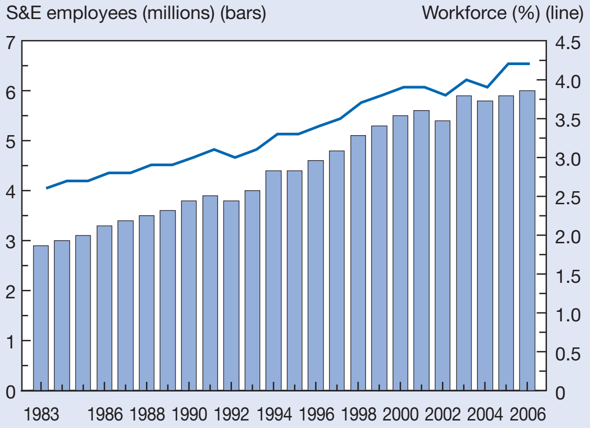
In all broad categories of S&E fields, employment in the occupations directly associated with the category has grown faster than new degree production (see chapter 2 for a fuller discussion of S&E degrees). Average annual growth rates of employment and degree production are shown in figure 3-3 for 1980–2000. Although S&E 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 CPS from 1983 to 2006 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 4.2% in 2006. Also noteworthy are the decreases in employment in S&E occupations in 1992 and again in 2002, evidence that S&E employment is not exempt from economic downturns (figure 3-4).

Projected Demand for S&E Workers

The most recent occupational projections from BLS, for 2004–14, forecast that total employment in occupations that NSF classifies as S&E will increase at nearly double the overall growth rate for all occupations (figure 3-5). 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.

Figure 3-4
U.S. workforce in S&E occupations: 1983–2006



SOURCE: National Science Foundation, Division of Science Resources Statistics, special tabulations from Bureau of Labor Statistics, Current Population Survey Monthly Outgoing Rotation files (1983–2006).

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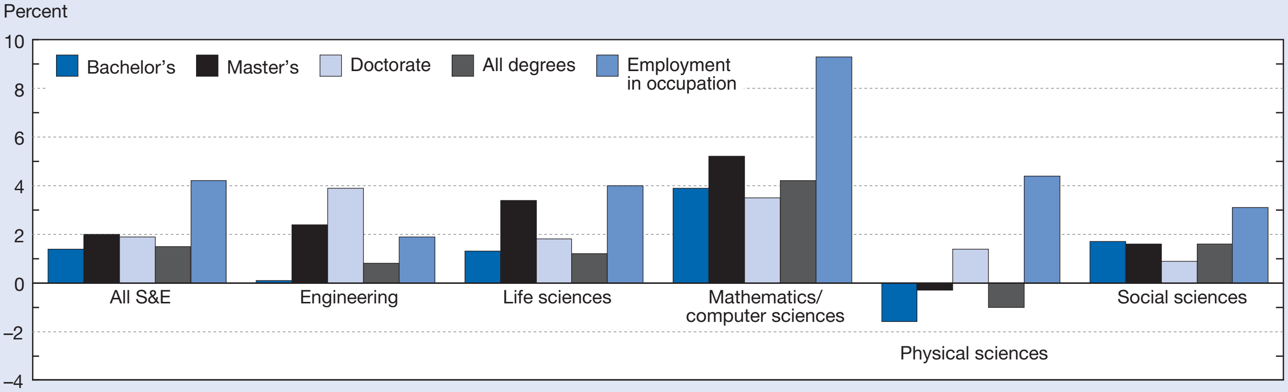
S&E occupations are projected to grow by 26% from 2004 to 2014, while employment in all occupations is projected to grow 13% over the same period (BLS 2006).[2] However, S&E occupations may be particularly difficult to forecast. Many spending decisions on R&D by corporations and governments are difficult 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.

Figure 3-3
Annual average growth rate of degree production and occupational employment, by S&E field: 1980–2000



SOURCES: Census Bureau, Public Use Microdata Sample (PUMS), 1980–2000; and National Science Foundation, Division of Science Resources Statistics, data on degree production and special tabulations.

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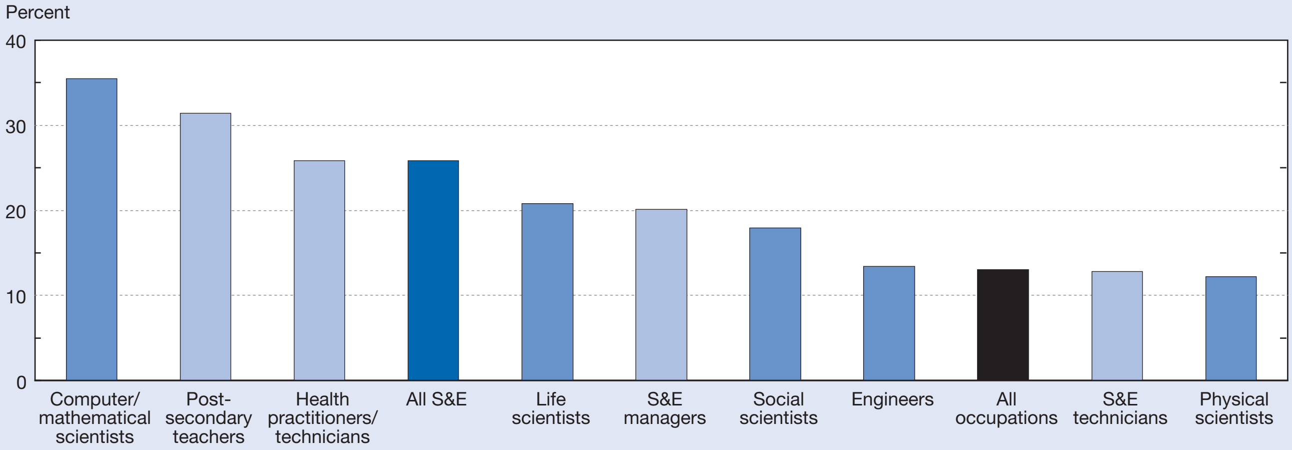
Figure 3-5
Projected increase in employment, for S&E and selected other occupations: 2004–14



SOURCE: Bureau of Labor Statistics, Office of Occupational Statistics and Employment Projections. See appendix table 3-7.

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Approximately 73% of BLS's projected increase in S&E jobs is in computer-related occupations (table 3-3). Aside from computer-related occupations, life scientists, social scientists, and engineers all have projected growth rates above those for all occupations.[3] An occupation of interest to the S&E labor market, "postsecondary teacher" (which includes all fields of instruction), is projected to grow almost as fast as computer occupations, rising from 1.8 to 2.3 million over the decade between 2004 and 2014.

BLS also forecasts that job openings in NSF's list of S&E occupations over the 2004–14 period will be a slightly greater proportion of current employment than for all occupations: 42% versus 38% (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 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

Table 3-3
S&E employment and job openings, by occupation: 2004 and projected 2014
(Thousands)

Occupation	2004	2014	Change	Job openings	10-year total growth (%)	10-year job openings as percent of 2004 employment
All occupations	145,612	164,540	18,928	54,680	13.0	37.5
All S&E	5,120	6,440	1,319	2,186	25.8	42.7
Computer/mathematical scientists	2,698	3,656	958	1,273	35.5	47.2
Engineers	1,449	1,644	195	507	13.4	35.0
Life scientists	232	280	48	103	20.8	44.6
Physical scientists	250	281	30	94	12.2	37.4
Social scientists/related occupations	492	580	88	209	17.9	42.5
Selected other occupations						
S&E managers	513	616	103	200	20.1	39.0
S&E technicians	874	986	112	303	12.8	34.7
Postsecondary teachers/administrators	1,760	2,312	553	953	31.4	54.1
Computer programmers	455	464	9	117	2.0	25.6
Healthcare practitioner/technical occupations	6,805	8,561	1,756	3,047	25.8	44.8

NOTE: Bureau of Labor Statistics (BLS) does not make projection for S&E occupations as a group; numbers in table based on sum of BLS projections in those occupations that National Science Foundation considers S&E.

SOURCE: BLS, Office of Occupational Statistics and Employment Projections, National Industry-Occupation Employment Projections 2004–14 (2005).

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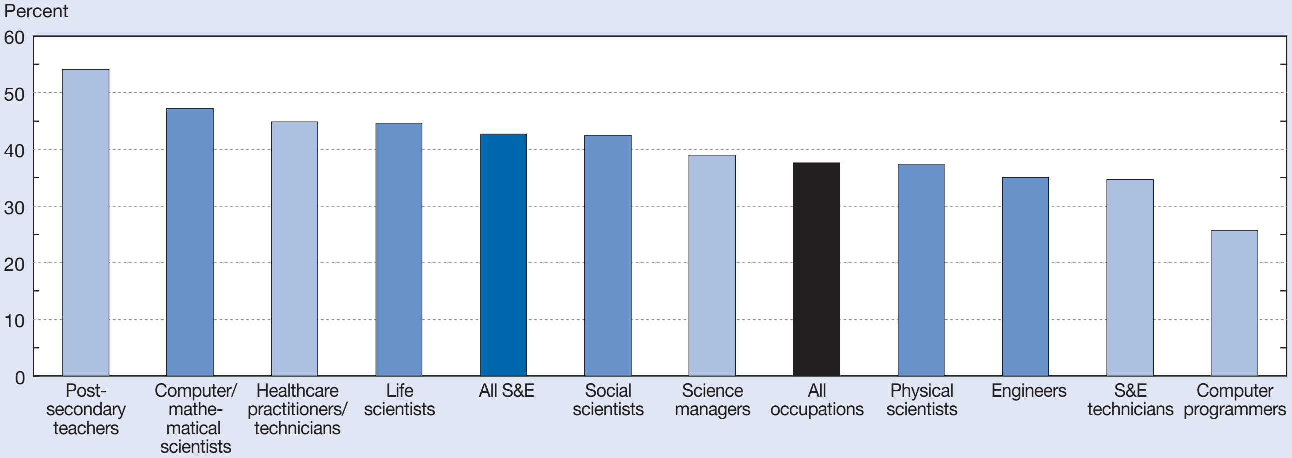
Figure 3-6
Projected job openings as percentage of 2004 employment, for S&E and selected other occupations: 2004–14



SOURCE: Bureau of Labor Statistics, Office of Occupational Statistics and Employment Projections. See appendix table 3-7.

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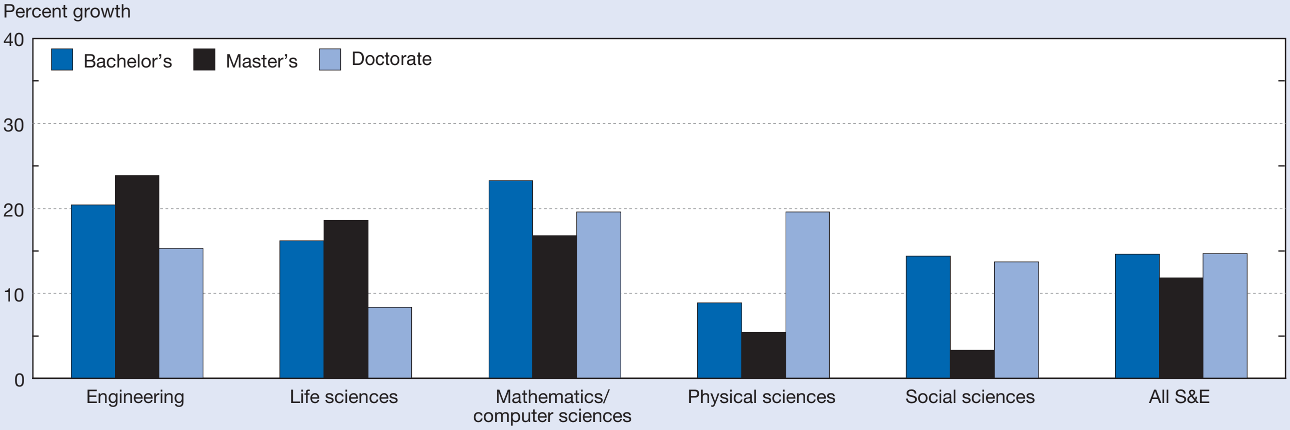
employment, scientists and engineers are still on average younger than the labor force as a whole. Retirement is also the likely reason that S&E job openings are less dominated by computer-related occupations, which have younger age distributions than other S&E areas.

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 or skill sets 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 between projections of labor supply and market demand impossible.

One indicator of the level of labor market demand, compared with the supply of individuals with those skills, is the changes observed over time in the pay received by individuals with similar sets of skills.[4] The changes between 1993 and 2003 in real (inflation-adjusted) mean salary for recent graduates in S&E fields are shown in figure 3-7 and actual means for 2003 in figure 3-8. On average real mean earnings increased for recent S&E bachelor’s degree graduates

Figure 3-7
Inflation-adjusted change in mean salary 1–5 years after degree, by field and level of highest degree: 1993–2003



SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), 1993 and 2003, http://sestat.nsf.gov.

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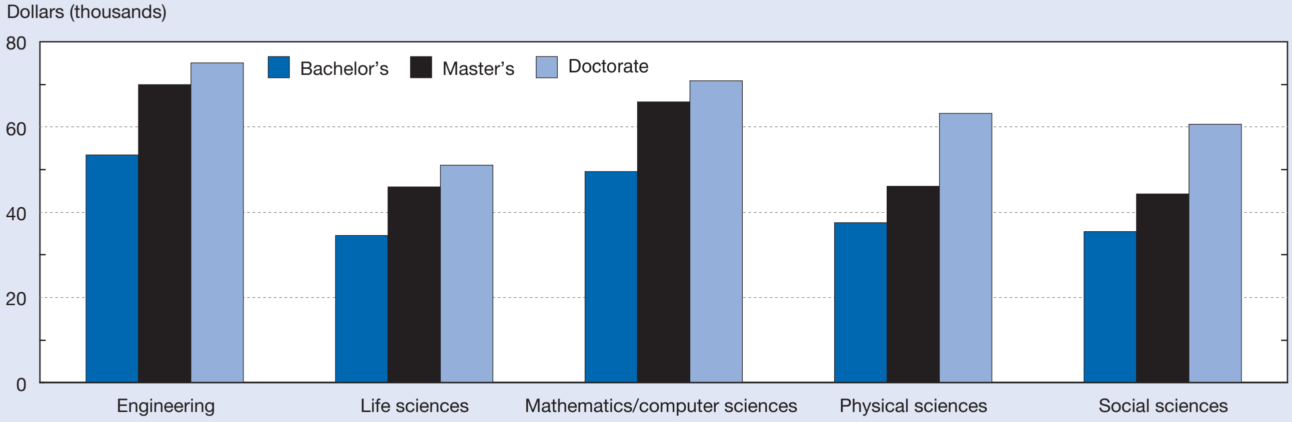
Figure 3-8
Mean salaries of S&E and S&E-related degree recipients 1–5 years after degree, by field and level of highest degree: 2003



SOURCE: National Science Foundation. Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), 2003, http://sestat.nsf.gov.

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by 15%, ranging from 9% in the physical science to 23% for those with mathematical and computer science bachelor's degrees. Recent engineering bachelor's recipients showed the second highest real growth in salary of 20%.

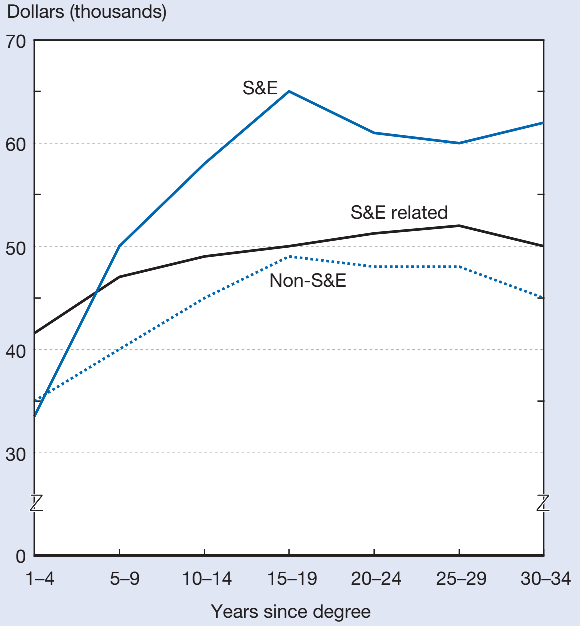
Among recent S&E master's degree recipients, real mean salaries increased 12%, ranging from 3% in the social sciences to 24% in engineering.

Among recent doctoral degree recipients, the increase in median real salary was greatest for those in the physical sciences and mathematical and computer science (each 20%) and smallest was in the life sciences (8%). 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 lower-paying postdoc positions.

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. After the first 4 years, holders of S&E bachelor's degrees earn more than those with non-S&E degrees at every year since degree. Median salaries for S&E bachelor's degree holders in 2003 peaked at $65,000 at 15–19 years after degree, compared with $49,000 for those with non-S&E bachelor's degrees. Median salaries of individuals with bachelor's degrees in S&E-related fields (such as technology, architecture, or health) peaked at $52,000 at 25–29 years after degree—much less than for S&E graduates but higher than for non-S&E bachelor's holders at most years since degree.

Figure 3-9
Median salaries for bachelor's degree holders, by years since degree: 2003



NOTE: S&E related defined within National Science Foundation's labor force surveys as including technician and health fields, as well as some smaller fields such as actuarial science.

SOURCE: National Science Foundation, Division of Science Resources Statistics, National Survey of College Graduates, 2003.

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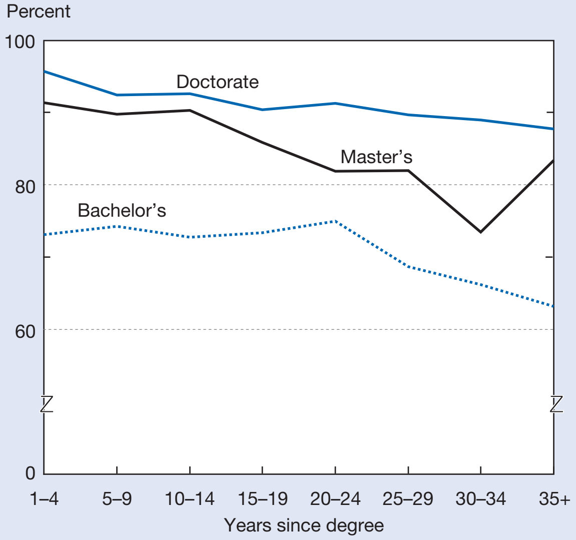
How Are People With an S&E Education Employed?

Although most 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 3-4).

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 degree tends to fall with time since receipt of 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.

Figure 3-10
Individuals with highest degree in S&E employed in jobs closely or somewhat related to highest degree, by years since highest degree: 2003



SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), 2003, http://sestat.nsf.gov.

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Even when a stricter criterion ("closely related") is used for the fit between an individual's job and field of degree, the data indicate that many recent bachelor's degree recipients work in jobs that use skills developed during their college S&E training (figure 3-11). In natural science and engineering fields, about half of individuals from 1 to 4 years after graduation characterized their jobs as closely related to their field of degree. Among the major disciplines in this group, the proportion of bachelor's degree holders reporting a close relationship between their job and their college major was highest in engineering (59%), followed by computer and mathematical sciences (57%), physical sciences (54%), and life sciences (48%). The comparable figure for social science graduates (28%) was substantially lower. According to this stricter definition of relatedness of job and degree, as with relatedness in general, relatedness declines only slowly with years since degree.

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 3-5). This included 1.6 million in management and management-related occupations, of whom

Table 3-4
Individuals with highest degree in S&E 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
Doctorate	165	42.3	36.6	21.2

[a] Includes professional degrees.

NOTES: Non-S&E occupations include Scientists and Engineers Statistical Data System (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, SESTAT database, 2003, http://sestat.nsf.gov.

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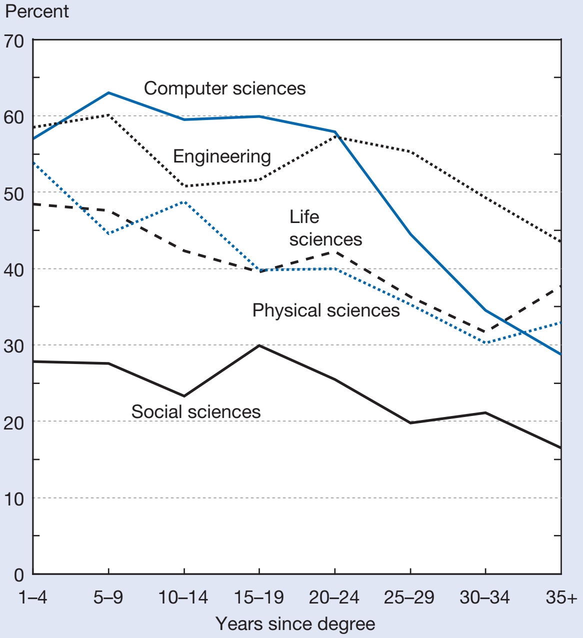
Figure 3-11

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), 2003, http://sestat.nsf.gov.

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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 at least somewhat 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 more than two-decades-long view of unemployment trends in S&E occupations, regardless of education level, comes from the CPS data for 1983–2006. Unemployment of college degree holders in S&E occupations fell to 1.6% in 2006, reflecting a recovery from employment difficulties earlier in the decade. This compares to a 4.6% unemployment rate for all workers in 2006 and a 2.2% unemployment rate for other college graduates. Unemployment rates also declined in the S&E-related occupational categories of technicians and computer programmers (not limited by education level) to 3.1% and 2.8%, respectively.

During this 22-year period, the unemployment rate for all individuals in S&E occupations ranged from a low of 1.3% in 1997 and 1998 to a high of 4.0% 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%), for all workers with a bachelor's degree or higher (ranging from 1.8% to 7.8%), or for S&E technicians (ranging from 2.0% to 6.1%). During most of the period, computer programmers had an unemployment rate similar to that of S&E occupations, but greater volatility (ranging from

Table 3-5

Individuals with highest degree in S&E employed in non-S&E occupations, by occupation and relation of degree to job: 2003

(Percent)

		Degree related to job		
Occupation	*n* (thousands)	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 S&E related	44	70.0	24.7	5.3
Other non-S&E	1,743	20.7	28.8	50.5

NOTES: Non-S&E occupations includes Scientists and Engineers Statistical Data System (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, SESTAT database, 2003, http://sestat.nsf.gov.

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1.2% to 6.7%). The most recent recession (in 2001) appears to have had a strong effect on S&E employment, with the differential between S&E and general unemployment falling to only 1.9 percentage points in 2002, compared with 6.9 percentage points in 1983 (figure 3-12). During 2002 and 2003, unemployment of college graduates in S&E occupations rose above that of other college graduates by 0.8 percentage points in each year. This may have been because of the unusually strong reductions in R&D in the information and related technology sectors (see chapter 4).

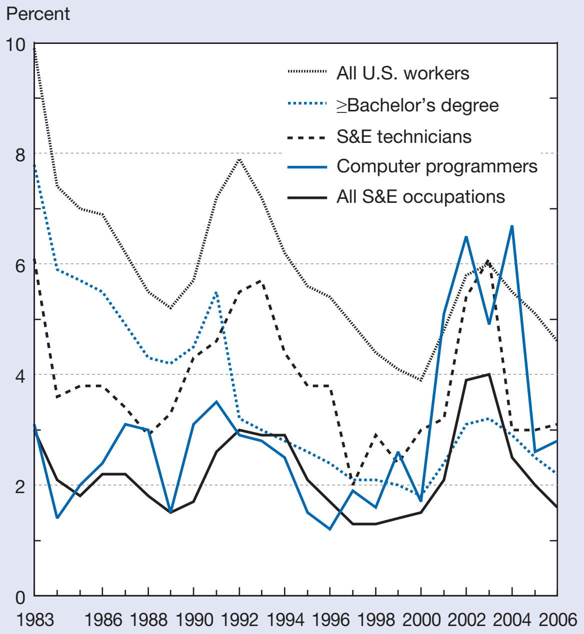
Figure 3-13 compares unemployment rates over career cycles for bachelor's and doctoral degree holders in 1999 and in 2003. Looking at field of degree rather than occupation includes individuals who might have left an S&E occupation for negative economic reasons in addition to the larger portion of the S&E labor force who have other occupational titles. 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 proportion of bachelor's degree holders than on doctoral degree holders who said they were working involuntarily out of the field (IOF) of their highest degree (figure 3-14). For doctoral degree holders, IOF rates changed little between 1999 and 2003. IOF rates actually dropped for recent doctoral 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.

S&E Employment From Occupational Employment Statistics Survey

Estimates of employment in S&E occupations in the United States from the OES survey of employers reached 5.4 million in May 2006 (table 3-6). This was up 6.3% from May 2004 (a 3.1% average annual rate) and exceeded the 1.7% average annual increase in employment in all occupations.

Figure 3-12
Unemployment rate, by occupation: 1983–2006



SOURCE: National Bureau of Economic Research, Merged Outgoing Rotation Group Files; Bureau of Labor Statistics, Current Population Survey.

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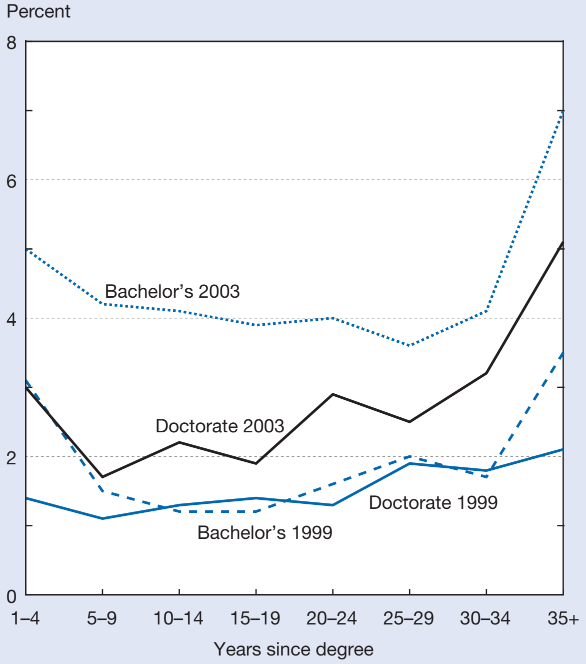
Figure 3-13
Unemployment rates for individuals with highest degree in S&E, by years since highest degree: 1999 and 2003



SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), 1999 and 2003, http://sestat.nsf.gov.

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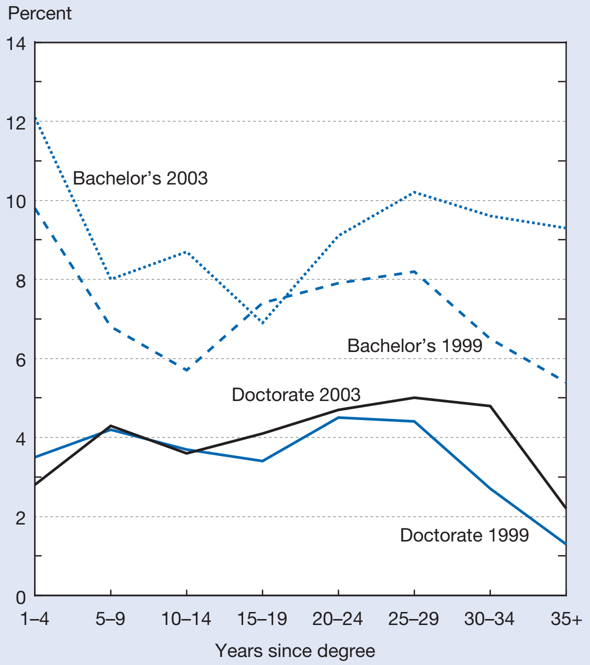
Figure 3-14

Involuntarily out-of-field rates of individuals with highest degree in S&E, 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 2003, http://sestat.nsf.gov.

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Table 3-6

Employment and employment growth in science and technology and related occupations: May 2004–May 2006

Occupation	2006 occupation total (*n*)	Average annual growth rate (%)
All U.S. employment	132,604,980	1.7
Science and technology occupations	7,441,780	1.9
S&E occupations	5,407,710	3.1
Social scientists	536,880	5.4
Physical scientists	291,380	3.2
Mathematical/computer scientists	2,743,560	3.4
Life scientists	291,980	3.2
Engineers	1,543,900	1.9
Technology occupations	2,034,070	–1.0
Technicians/programmers	1,560,250	–0.7
Technical managers	473,820	–2.1
Other S&E-related occupations (not included above)	7,317,320	2.9
Healthcare practitioner/ technical workers	7,160,310	2.8
Other	157,010	4.4

SOURCE: Bureau of Labor Statistics, Occupational Employment Statistics Survey, May 2004 and May 2006. See appendix tables 3-1 to 3-3.

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Science and Technology Occupations

Discussions of the S&E labor force sometimes use broader definitions, referring to the S&T or the STEM labor force. These broader definitions usually include technicians, computer programmers, and technical managers, along with those occupations that NSF considers to be S&E. The broader aggregate may thus be thought of as S&E occupations plus individuals who directly manage S&E activities and the technical workers who support those in S&E occupations. Total employment in this broader set of S&T occupations was 7.4 million in May 2006. The distribution of employment across S&T occupations is shown in figure 3-15. In contrast to S&E occupations, S&T employment grew only slightly faster than the labor market as a whole (1.9% versus 1.7% average annual growth) because of a declining number of technicians and programmers as well as technical managers.

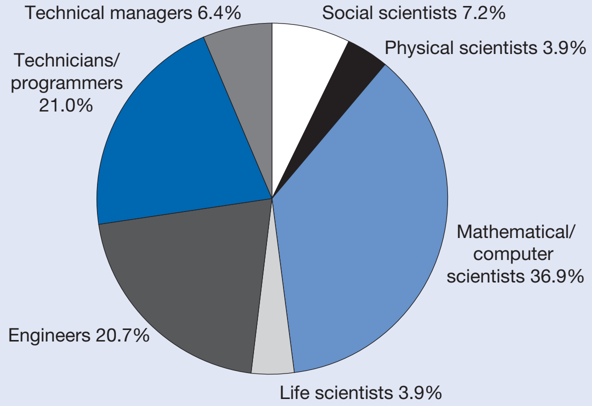
A number of occupations may be considered related to this broader set of S&T occupations. They include healthcare occupations and a number of technical occupations such as actuary and architect. Overall, the more than 7 million people in these additional occupations increased by an average annual rate of 2.9%.

Annual Earnings From OES Data

Median annual earnings (regardless of education) in S&E occupations were $67,780, more than double the median ($30,400) for all occupations (table 3-7). The spread in average (mean) earnings was less dramatic but still quite wide, with individuals in S&E occupations earning considerably more on average than workers in all occupations: $71,150 versus $39,190 for all occupations. Average earnings ranged from a mean of $64,570 for social science occupations to $77,910 for engineering occupations. Mean annual earnings for S&E-related

Figure 3-15

Employment distribution across science and technology or STEM occupations: May 2006



STEM = science, technology, engineering, and mathematics

NOTE: As generally used in policy discussions and as used in this chapter, STEM and science and technology have identical meaning.

SOURCE: Bureau of Labor Statistics, Occupational and Employment Statistics Survey, May 2006.

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Table 3-7
Annual earnings and earnings growth in science and technology and related occupations: May 2004–May 2006

Occupation	Mean: 2006 annual earnings ($)	Mean: Average annual growth rate (%)	Median: 2006 annual earnings ($)	Median: Average annual growth rate (%)
All U.S. employment	39,190	2.9	30,400	2.8
Science and technology occupations	68,940	2.9	64,160	2.8
S&E occupations	71,150	3.1	67,780	3.0
Social scientists	64,570	3.2	58,310	3.0
Physical scientists	70,870	3.6	64,520	3.7
Mathematical/computer scientists	68,910	2.9	65,900	3.0
Life scientists	68,760	2.9	60,750	2.6
Engineers	77,910	3.5	74,800	3.3
Technology occupations	64,700	2.9	NA	NA
Technicians/programmers	51,440	2.6	47,350	2.7
Technical managers	108,390	4.3	103,020	4.5
Other S&E-related occupations (not included above)	63,130	3.8	53,050	4.4
Healthcare practitioner/technical workers	62,990	4.1	52,830	4.9
Other	69,450	2.3	62,960	3.0

NA = not available

SOURCE: Bureau of Labor Statistics, Occupational Employment Statistics Survey, May 2004 and May 2006. See appendix tables 3-1 to 3-3.

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technical occupations ranged from $51,440 for technicians and programmers to $108,390 for technical managers.

The growth in mean earnings was slightly greater for all S&E and S&E-related occupation groups than for the total of all occupations included in OES, an average annual rate of 3.1% in S&E occupations, 2.9% in technology occupations, and 3.8% in other S&E-related occupations, compared with 2.9% for all occupations. Technicians and programmers experienced a slower than average 2.6% average annual growth in earnings.

Metropolitan Areas

United States metropolitan areas are ranked in table 3-8 according to the proportion of the entire metropolitan area workforce that is employed in S&E occupations, and in table 3-9 by the total number of workers employed in S&E occupations. The Boulder-Longmont, Colorado, metropolitan area had the highest percentage of its workforce employed in S&E occupations in May 2006, at 14.3%. The New York metropolitan area has the greatest total number of individuals employed in S&E occupations at 309,000, while having a slightly below average 3.8% of workers in S&E occupations. Although the top-20 list for proportion of S&E employment consists mainly of smaller and perhaps less economically diverse metropolitan areas, Washington, DC, Seattle, Boston, San Francisco, and San Jose appear in both top-20 lists.

S&E Occupation Density by Industry

Individuals in S&E occupations are not just employed by "high-technology" employers. S&E knowledge is necessary in a variety of different industries, and as shown in table 3-10, workers with such knowledge are found in industries with very different percentages of S&E occupations as a portion of total employment. More than 1 million in S&E occupations are employed in industries with less than the average 4% of S&E occupations. These industries, with a below average density of S&E occupations, employ 75% of all workers and 19% of all workers in S&E occupations. Industries with a low density of S&E occupations include a wide variety of activities, such as local government (2.9% with 158,000 in S&E occupations), hospitals (1.3% with 63,000 in S&E occupations), and plastic parts manufacturing (2.4% with 15,000 in S&E occupations).

In general, industries with higher proportions of individuals in S&E occupations pay higher average salaries to both S&E and non-S&E workers. The average salary of workers in non-S&E occupations who are in industries with more than 40% S&E occupations is nearly double the average salary of workers in non-S&E occupations in industries with below average density of S&E occupations ($68,600 versus $34,600).

Employment Sectors

Industry is the largest provider of employment for individuals with S&E degrees (figure 3-16), 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 doctoral degree holders (44%). This 44% includes a variety of employment types other than the tenured and tenure-track employment that is still sometimes referred to as the "traditional" doctoral career path, including many younger doctorate holders in postdoc positions and other temporary employment situations, as well as individuals with a variety of research and administrative functions.

Table 3-8
Top-ranked metropolitan areas for employment in S&E occupations, by S&E percentage of total employment: 2006

Rank	Metropolitan area	Workforce (%)	S&E employees (*n*)
na	United States	4.1	5,407,710
1	Boulder, CO	14.3	22,520
2	San Jose-Sunnyvale-Santa Clara, CA	14.1	126,090
3	Huntsville, AL	12.2	24,030
4	Durham, NC	10.7	27,770
5	Corvallis, OR	10.7	4,150
6	Washington-Arlington-Alexandria, DC-VA-MD-WV	10.5	297,670
7	Kennewick-Richland-Pasco, WA	9.3	7,880
8	Ames, IA	8.4	3,440
9	Palm Bay-Melbourne-Titusville, FL	7.9	16,490
10	Olympia, WA	7.9	7,440
11	Austin-Round Rock, TX	7.9	56,100
12	Seattle-Tacoma-Bellevue, WA	7.8	127,070
13	Ann Arbor, MI	7.6	14,950
14	Boston-Cambridge-Quincy, MA-NH	7.4	180,110
15	Portsmouth, NH-ME	7.3	4,140
16	Colorado Springs, CO	7.0	17,610
17	Fort Walton Beach-Crestview-Destin, FL	6.9	5,970
18	Madison, WI	6.9	22,640
19	Raleigh-Cary, NC	6.9	32,920
20	San Francisco-Oakland-Fremont, CA	6.9	137,150

na = not applicable

SOURCE: Bureau of Labor Statistics, Occupational Employment Statistics Survey, May 2006. See appendix table 3-6.

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Table 3-9
Top-ranked metropolitan areas for employment in S&E occupations, by total number of individuals employed in S&E occupations: 2006

Rank	Metropolitan area	S&E employees (*n*)	Workforce (%)
na	United States	5,407,710	4.1
1	New York-Northern New Jersey-Long Island, NY-NJ-PA	308,860	3.8
2	Washington-Arlington-Alexandria, DC-VA-MD-WV	297,670	10.5
3	Los Angeles-Long Beach-Santa Ana, CA	231,900	4.1
4	Boston-Cambridge-Quincy, MA-NH	180,110	7.4
5	Chicago-Naperville-Joilet, IL-IN-WI	179,560	4.1
6	Dallas-Fort Worth-Arlington, TX	140,140	5.0
7	San Francisco-Oakland-Fremont, CA	137,150	6.9
8	Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	134,980	4.9
9	Detroit-Warren-Livonia, MI	128,430	6.4
10	Seattle-Tacoma-Bellevue, WA	127,070	7.8
11	San Jose-Sunnyvale-Santa Clara, CA	126,090	14.1
12	Houston-Sugar Land-Baytown, TX	117,310	4.9
13	Atlanta-Sandy Springs-Marietta, GA	100,560	4.3
14	Minneapolis-St. Paul-Bloomington, MN-WI	100,540	5.7
15	San Diego-Carlsbad-San Marcos, CA	76,830	5.9
16	Denver-Aurora, CO	75,690	6.3
17	Phoenix-Mesa-Scottsdale, AZ	70,070	3.8
18	Baltimore-Towson, MD	67,930	5.3
19	Miami-Fort Lauderdale-Miami Beach, FL	65,940	2.8
20	St. Louis, MO-IL	56,520	4.3

na = not applicable

NOTE: Values for New York-Northern New Jersey-Long Island, NY-NJ-PA are for 2005.

SOURCE: Bureau of Labor Statistics, Occupational Employment Statistics Survey, May 2006. See appendix table 3-6.

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Industry also dominates employment in S&E occupations in the BLS's OES survey (figure 3-17). Government and educational services sectors each had less than 11% of total employment in S&E occupations in 2006. The largest sector of employment for S&E occupations was "professional, scientific, and technical services" with 28%, followed by manufacturing with 17%.

Employer Size

Small firms are important employers of scientists and engineers, particularly at the doctoral degree level. For individuals whose highest degree is in S&E and who are employed in business/industry, the distribution of employer size is shown in figure 3-18. Across all degree levels, 37% of S&E degree holders are employed in companies with fewer than 100 employees. In general, there is a similar pattern of employment across employer size by degree levels, but

Table 3-10

Employment distribution and average earnings of 4-digit NAICS industry classifications, by proportion of employment in S&E occupations: 2006

Workers in S&E occupations (%)	All occupations	All S&E occupations	Average worker salary ($) Non-S&E occupations	Average worker salary ($) S&E occupations
>40	2,080,670	973,160	68,600	77,100
20-40	3,483,360	984,060	52,800	78,000
10–20	10,491,600	1,504,350	53,900	72,000
4–10	13,045,120	835,750	46,000	65,900
<4	99,710,090	1,049,190	34,600	61,600

NAICS = North American Industry Classification System

NOTES: NAICS has a hierarchal structure that uses 2 to 4 digits; 4-digit NAICS industries are subsets of 3-digit industries, which are subsets of 2-digit sectors. For data by individual 4-digit NAICS industries, see appendix tables 3-4 and 3-5.

SOURCE: Bureau of Labor Statistics, Occupational Employment Statistics Survey, May 2006.

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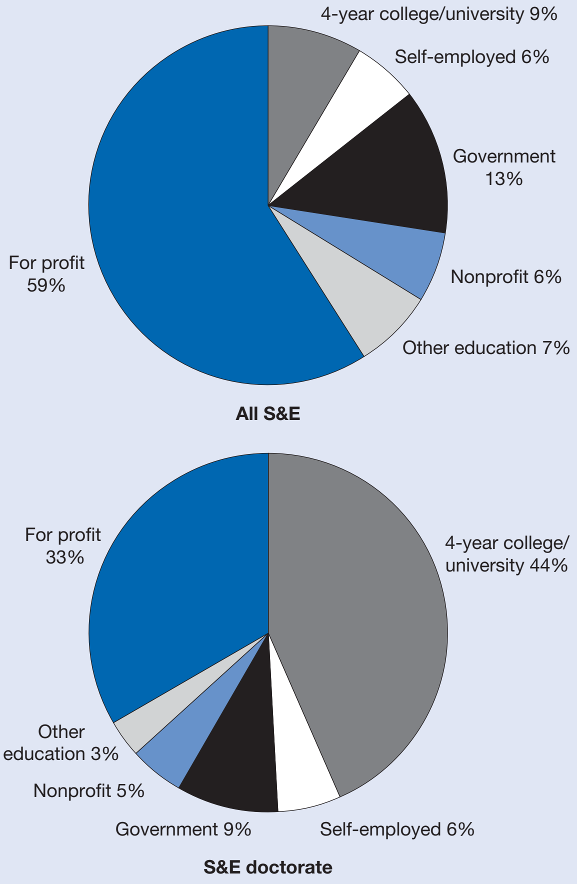
Figure 3-16

Employment sector for individuals with highest degree in S&E: 2003



SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), 2003, http://sestat.nsf.gov.

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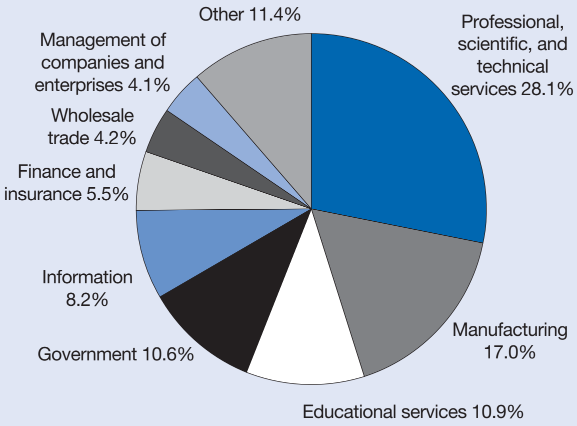
Figure 3-17

Largest sectors of employment for individuals in S&E occupations, by NAICS sectors: May 2006



NAICS = North American Industry Classification System

SOURCE: Bureau of Labor Statistics, Occupational Employment Statistics Survey, May 2006.

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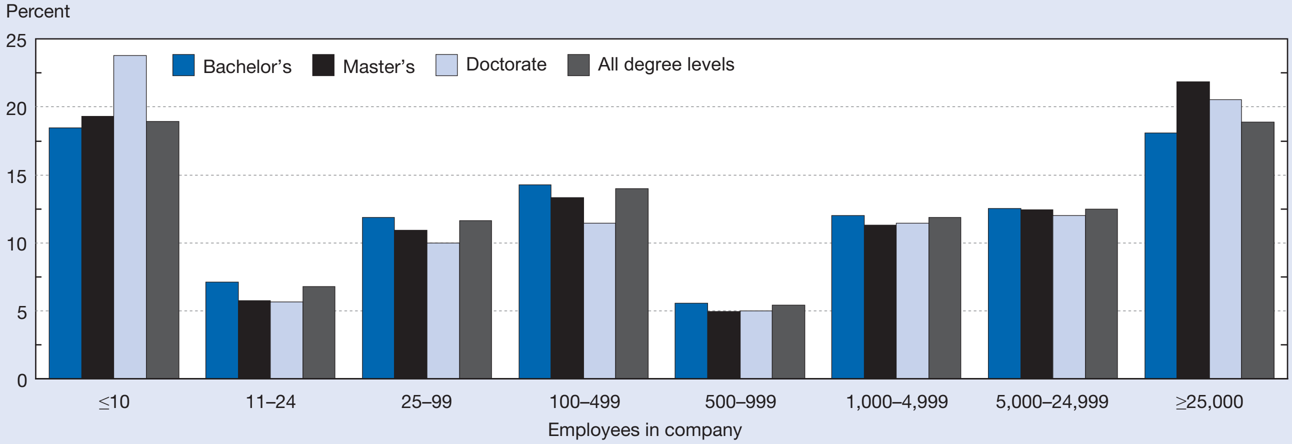
Figure 3-18
Individuals with highest degree in S&E employed in private business, by employer size: 2003



SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), 2003, http://sestat.nsf.gov.

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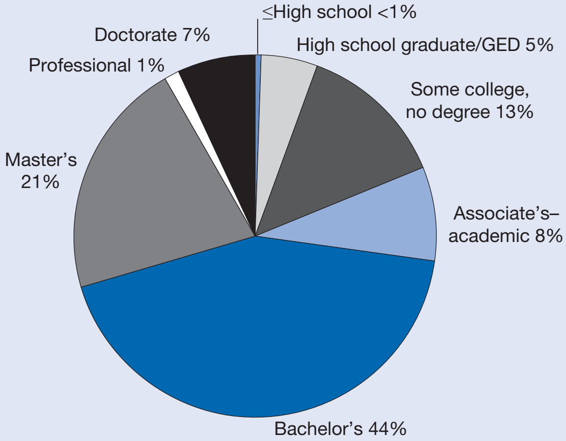
S&E doctorate holders are somewhat more concentrated at very small and very large firms. Conversely, although 18% of S&E bachelor's degree holders in business and industry are employed in firms with fewer than 10 employees, this figure is 19% at the master's degree and 24% at the doctoral degree level.

Educational Distribution of S&E Workers

Discussions of the S&E workforce often focus on individuals who hold doctoral degrees. However, American Community Survey data on the educational achievement of individuals working in S&E occupations outside academia in 2005 indicate that only 7% had doctorates (figure 3-19). In 2005, about two-thirds of individuals working in nonacademic S&E occupations had bachelor's degrees (44%) or master's degrees (21%).[5] Slightly more than one-quarter 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 sidebar "Who Performs R&D?" and discussion in chapter 2.)

Figure 3-19
Educational distribution, by nonacademic S&E occupations: 2005



GED = General Equivalency Diploma

SOURCE: Census Bureau, American Community Survey, 2005.

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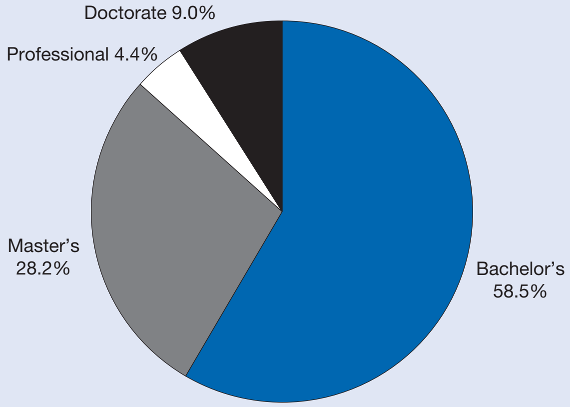
Who Performs R&D?

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 3-20 shows the distribution of individuals with S&E degrees 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), by level of degree. Individuals with doctoral 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 3-21 shows the distribution of individuals with S&E degrees who reported R&D as a major work activity, by field of highest degree. Individuals with engineering degrees constitute more than one-third (36%) of the total.

Individuals who are in non-S&E occupations do much R&D. Table 3-11 shows the occupational distribution of S&E degree holders who report R&D as a major work activity, as well as those reporting that at least 10% of their time involves R&D. Forty percent of those for whom R&D is a major work activity are in non-S&E occupations (and two-thirds of these are also outside of the occupations that NSF classifies as "S&E related"). Among those S&E degree holders whose jobs involve at least 10% R&D, 55% are in non-S&E occupations.

Figure 3-22 shows the percentages of S&E doctoral 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 doctoral 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 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 3-20
Distribution of S&E degree holders 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), 2003, http://sestat.nsf.gov.

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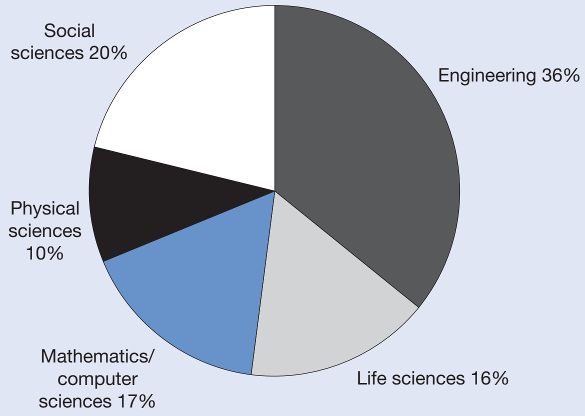
Figure 3-21
Distribution of S&E degree holders with R&D as major work activity, by field of highest degree: 2003



SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), 2003, http://sestat.nsf.gov.

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Table 3-11
Occupations of S&E degree holders with R&D work activities: 2003
(Percent)

Occupation	R&D as major work activity	R&D at least 10% of work time
S&E occupations	60.5	45.0
Engineering occupations	24.4	17.7
Life sciences	7.9	5.1
Mathematics/computer science occupations	18.1	14.8
Physical science occupations	5.5	3.7
Social science occupations	4.8	3.8
Non-S&E occupations	39.5	55.0
S&E-related occupations	13.2	15.1
Other non-S&E occupations	26.3	39.9

SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), 2003, http://sestat.nsf.gov.

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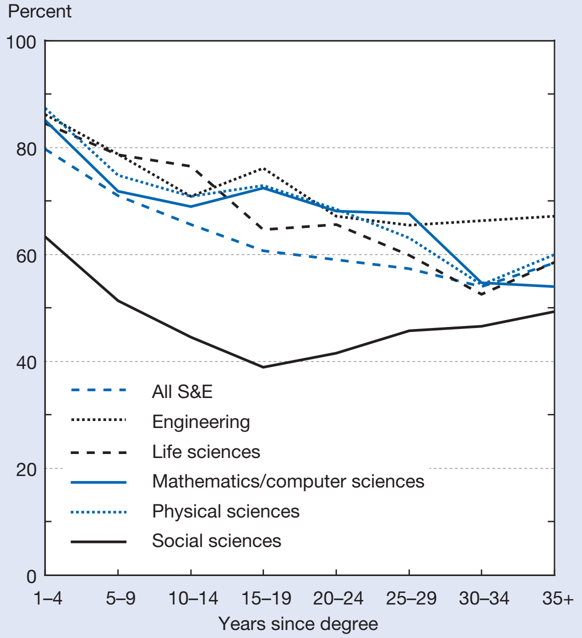
Figure 3-22
S&E doctorate holders with R&D as major work activity, by field and years since degree: 2003



SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), 2003, http://sestat.nsf.gov.

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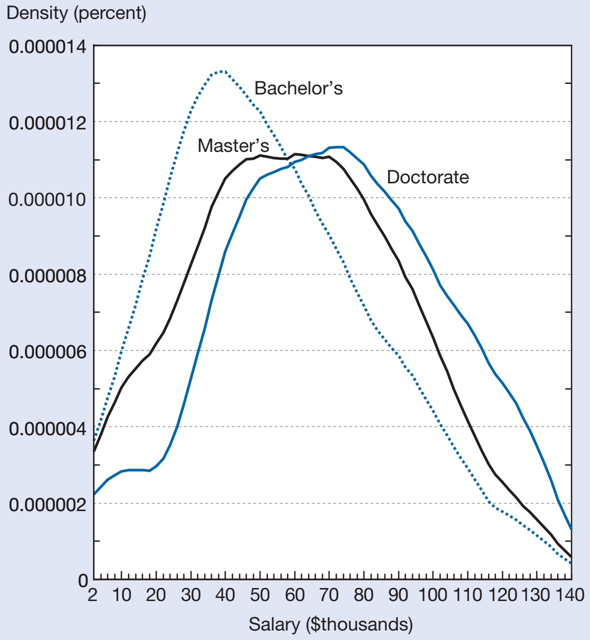
Salaries

Figure 3-23 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 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 doctoral degree holders. Similarly, 22% of bachelor's degree holders earned less than $30,000, compared with 8% of doctoral degree holders. The latter figure reflects the inclusion of postdoc appointees. (The Survey of Doctorate Recipients defines postdoc appointments 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 3-24. 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 doctoral degree holders' 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 doctoral degree holders.

Figure 3-23
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), 2003, http://sestat.nsf.gov.

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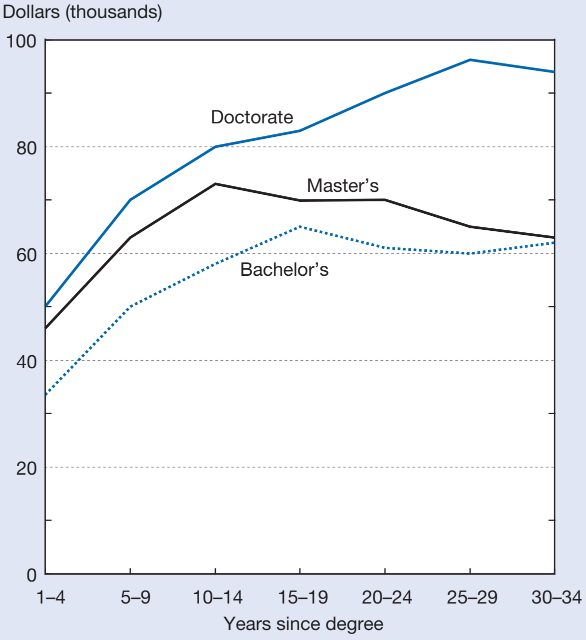
Figure 3-24
Median salaries of S&E graduates, by degree level and years since degree: 2003



SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), 2003, http://sestat.nsf.gov.

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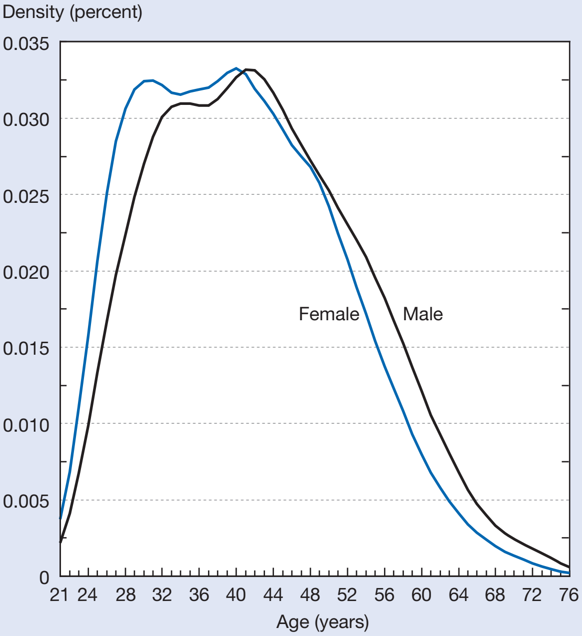
Figure 3-25
Age distribution of individuals in S&E occupations, by sex: 2003



NOTE: Age distribution smoothed with kernel density techniques.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), 2003, http://sestat.nsf.gov.

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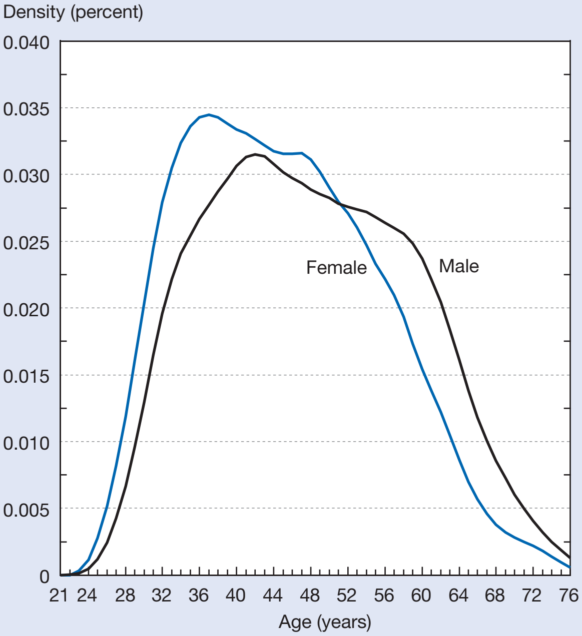
Figure 3-26
Age distribution of doctorate holders in S&E occupations, by sex: 2003



NOTE: Age distribution smoothed with kernel density techniques.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), 2003, http://sestat.nsf.gov.

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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 and Ethnic Minorities 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.

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 (47%) of the total U.S. college-educated labor force in 2005.

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 3-25 and 3-26): 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 doctoral level, which has a much greater concentration of female doctoral degree holders in their late 30s. One consequence of this age distribution is that a much larger proportion of male scientists and engineers at all degree levels, but particularly at the doctoral level, will reach traditional retirement age during the next decade. This alone will have a significant effect on sex

Growth of Representation of Women and Ethnic Minorities in S&E Occupations

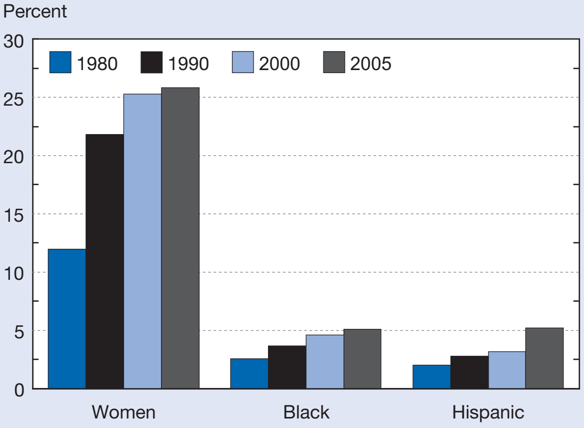
A view of changes in the gender and ethnic composition of the S&E workforce can be achieved by examining data on college-educated individuals in nonacademic S&E occupations from the 1980–2000 censuses and the 2005 American Community Survey* (figures 3-27 and 3-28).

In 2005, 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 25.8% of college-degreed individuals in S&E occupations and 47.2% of the college-degreed workforce. Among doctorate holders working in S&E occupations in 2005, women were 30.6% of the total, while representing 34.1% of doctorate holders in the labor force.
- Blacks made up 5.1% of the S&E workforce and 7.5% of the college-degreed workforce.
- Hispanics made up 5.2% of the S&E workforce and 5.8% of the college-degreed workforce.
- Among doctorate holders working in S&E occupations in 2005, all underrepresented ethnic groups combined† (blacks, Hispanics, and American Indians/Alaska Natives) were 6.1%, while representing 9.1% of doctorate holders in the labor force.

However, since 1980, the share of S&E occupations has almost doubled for blacks (2.6% to 5.1%) and more than doubled for women (12.0% to 25.8%) and Hispanics (2.0% to 5.2%). Among doctorate holders (measured only since 1990), women increased in representation from 22.8% to 30.6%; and blacks, Hispanics, and American Indians/Alaska Natives increased from 4.4% to 6.1%.

Figure 3-27
College-educated women and ethnic minorities in nonacademic S&E occupations: 1980, 1990, 2000, and 2005



SOURCE: National Science Foundation, Division of Science Resources Statistics, Decennial Census Public Use Microdata Sample (PUMS), 1980–2000; and Census Bureau, American Community Survey, 2005.

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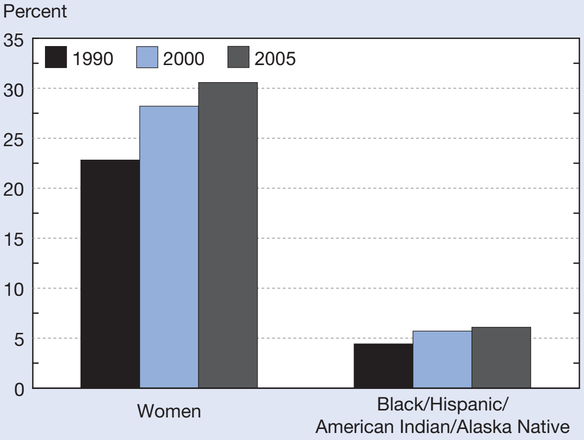
Figure 3-28
Women and ethnic minority doctorate holders in nonacademic S&E occupations: 1990, 2000, and 2005



SOURCE: National Science Foundation, Division of Science Resources Statistics, Decennial Census Public Use Microdata Sample (PUMS), 1990–2000; and Census Bureau, American Community Survey, 2005.

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*The Census Bureau no longer reports postsecondary teaching occupations by field of instruction, so it is not possible to identify S&E professors from the decennial Public Use Microdata Sample, the American Community Survey, or the Current Population Survey. Postsecondary teachers of S&E subjects are identified in NSF's own labor force surveys.

†Different ethnic groups were combined to maintain sufficient sample size for this estimate.

ratios, and also perhaps on the numbers of female scientists in senior-level positions as the many female doctoral degree holders in their late 30s move 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 3-29). Since 1993, the percentage of women in most S&E occupations in NSF's labor force surveys has gradually increased from 23% to 27% across all S&E occupations. However, in mathematics and computer sciences, 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 3-12).

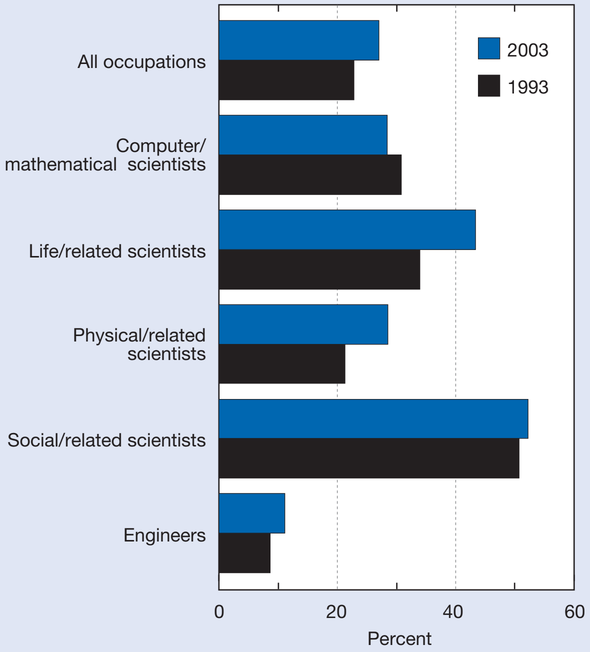
Representation of Racial and Ethnic Minorities in S&E

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) constitute 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 Islanders are more highly represented in S&E than in the workforce as a whole.

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 (figure 3-30), and this is even truer for doctoral degree holders in S&E occupations (figure 3-31). In the near future, a much greater proportion of non-Hispanic white doctoral degree holders in S&E occupations will be reaching traditional retirement ages compared with underrepresented racial and ethnic minority doctoral degree holders. Indeed, unlike the distribution of ages of male and female doctoral 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 doctoral degree holders in S&E occupations (measured by race and not by place of birth) are on average the youngest racial/ethnic group.

Figure 3-29
Women as proportion of S&E workforce, by broad field of occupation: 1993 and 2003



SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT),1993 and 2003, http://sestat.nsf.gov.

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Table 3-12
Unemployment rate for individuals in S&E occupations, by sex, race/ethnicity, and visa status: 1993 and 2003
(Percent)

Characteristic	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, Scientists and Engineers Statistical Data System (SESTAT), 1993 and 2003, http://sestat.nsf.gov.

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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 2003, they constituted 4% of social scientists but more than 11% of engineers and more than 13% of individuals working in mathematics and computer sciences. More black scientists and engineers work in social sciences and in computer sciences and mathematics than in other fields. In 2003, 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 include 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 2003. Hispanics appear to have a more even representation across all fields, constituting approximately 2.5%–4.5% of scientists and engineers in each field.

Salary Differentials

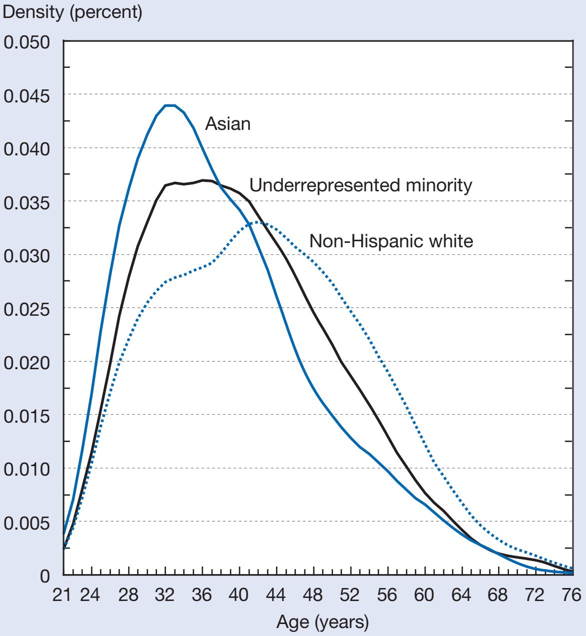
Trends in Median Salaries. In 2003, female scientists and engineers earned a median annual salary of $53,000, about 25% less than the median annual salary of $70,000 earned by male scientists and engineers (table 3-13). Several factors may contribute to these salary differentials. Women more often work in educational institutions, in social science occupations, and in nonmanagerial positions; they also tend to have fewer years of experience.

Between 1993 and 2003, median annual salaries for women in S&E occupations increased by 33%, compared with an increase of 40% for male median salaries (table 3-13). This may be because relatively more women than men have recently entered these occupations.

Salaries for individuals in S&E occupations also 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 3-13). 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, but the absolute salary differential actually rose.

Analysis of Salary Differentials. It is often difficult to use gross differences in the salaries of women and ethnic minorities in S&E as indicators of the progress of individuals in those groups in S&E employment. Differences in average age, work experience, fields of degree, and other characteristics can make direct comparison of salary and earnings statistics

Figure 3-30
Age distribution of individuals in S&E occupations, by race/ethnicity: 2003



NOTES: Age distribution smoothed with kernel density techniques. Underrepresented minority includes blacks, Hispanics, and American Indians/Alaska Natives.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), 2003, http://sestat.nsf.gov.

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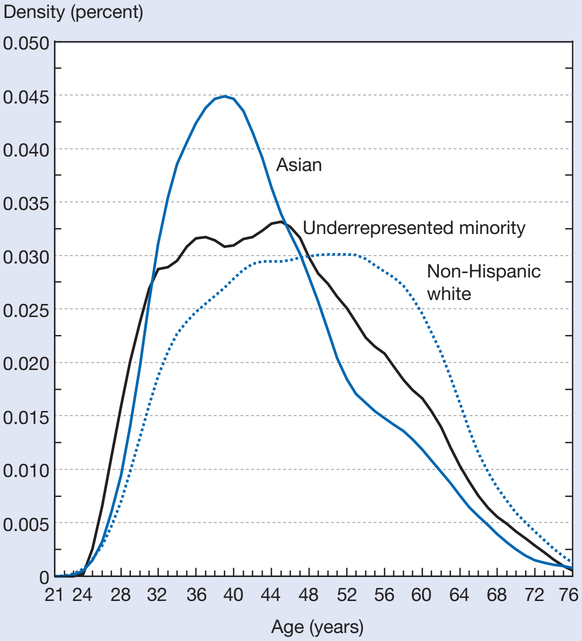
Figure 3-31
Age distribution of S&E doctorate holders in S&E occupations, by race/ethnicity: 2003



NOTES: Age distribution smoothed with kernel density techniques. Underrepresented minority includes blacks, Hispanics, and American Indians/Alaska Natives.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), 2003, http://sestat.nsf.gov.

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Table 3-13
Median annual salary of individuals in S&E occupations, by sex, race/ethnicity, and visa status: Selected years, 1993–2003
(Dollars)

Characteristic	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), 1993–2003, http://sestat.nsf.gov.

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misleading. 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.[6] Table 3-14 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 information on all individual skill sets, personal background and attributes, or other characteristics that may affect compensation.

Differences in mean annual salary are substantial when comparing all individuals with S&E degrees only by level of degree, with no other statistical controls: in 2003, women with S&E bachelor's degrees had full-time mean salaries that were 34.2% 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 18.8% less than those of non-Hispanic whites and Asians/Pacific Islanders with S&E bachelor's degrees.[7]

Table 3-14
Estimated salary differentials of individuals with S&E degrees, by individual characteristics: 2003
(Percent)

Variable	Bachelor's	Master's	Doctorate
Female vs. male	–34.2	–31.7	–18.5
Controlling for age and years since degree	–33.2	–30.6	–11.1
Plus field of degree	–25.4	–24.9	–7.9
Plus occupation and employer characteristics	–20.1	–17.3	–6.1
Plus family and personal characteristics	–18.2	–15.2	–5.0
Plus sex–specific marriage and child effects	–7.8	–5.8	NS
Black, Hispanic, and other vs. white and Asian/Pacific Islander	–18.8	–14.2	–13.2
Controlling for age and years since degree	–17.9	–12.1	–6.6
Plus field of degree	–13.6	–8.9	–5.2
Plus occupation and employer characteristics	–10.7	–5.9	–1.9
Plus family and personal characteristics	–7.6	–3.4	–1.4
Foreign born with U.S. degree vs. native born	–2.7	10.0	–1.8
Controlling for age and years since degree	NS	9.6	2.7
Plus field of degree	–6.3	NS	NS
Plus occupation and employer characteristics	–9.7	–5.8	–3.8
Plus family and personal characteristics	–6.8	NS	NS

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), 2003, http://sestat.nsf.gov.

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These differentials are somewhat lower than those shown in a similar analysis using 1999 data (see *Science and Engineering Indicators 2006* [NSB 2006]). These raw differences in salary are lower but still large at the doctoral level (–18.5% for women and –13.2% for underrepresented ethnic groups). Foreign-born individuals with U.S. S&E degrees have slightly lower salaries than U.S. natives (–2.7% at the bachelor's and –1.8% at the doctoral levels), but at the master's degree level earn 10.0% more than U.S. natives.

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 receipt of degree reduces salary differentials for women compared with men by only about 1 percentage point at the bachelor's (to –33.2%) and master's (to –30.6), but by two-fifths at the doctoral level (to –11.1%).[8] Two factors may explain why statistical controls make less difference at lower degree levels: a similar proportion of men and women with S&E degrees are in midcareer, but a larger proportion of men are at older ages where salaries begin to decline.

Similar small 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 only 1 or 2 percentage points at the bachelor's and master's degree levels, but by half at the doctoral level (to –6.6%).

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 –25.4% at the bachelor's level and to –7.9% at the doctoral level.[9] 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 differences exist between men and women in field of degree or whether salaries are affected by the percentage of women with degrees in each field.

Field of degree is associated with significant estimated salary differentials for underrepresented ethnic groups relative to all other ethnic groups. Controlling for field of degree further reduces salary differentials to –13.6% for those individuals with S&E bachelor's degrees and to –5.2% for those individuals with S&E doctorates. Thus, age, years since degree, and field of degree are associated with two-thirds of doctoral-level salary differentials for underrepresented ethnic groups.

Compared with natives, foreign-born individuals with advanced S&E degrees show no statistically significant salary differences when controlling for age, years since degree, and field of degree. At the bachelor's degree level, foreign-born S&E degree holders still had a –6.3% salary differential.

Effects of Occupation and Employer Characteristics on Salary Differentials. Occupation and employer characteristics affect compensation.[10] 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 or 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 somewhat beyond what is found when controlling for age, years since degree, and field of degree. At the doctoral level, the addition of occupation leaves no statistically significant difference between the salaries of underrepresented ethnic groups, compared with whites and Asians. For the foreign born, controlling for occupational characteristics actually moves differentials in a negative direction, suggesting that the foreign born generally have better-paying occupations than natives.

Effects of Family and Personal Characteristics on Salary Differentials. Marital status, the presence of children, parental education, and other personal characteristics are often associated with differences in compensation. Although these differences may involve discrimination, they may also reflect many subtle individual differences that might affect work productivity.[11] For example, having highly educated parents is associated with higher salaries for individuals of all ethnicities and genders, and may well be associated with greater academic achievement not directly measured in these data. However, for many individuals in many ethnic groups, historical discrimination probably affected parents' educational opportunities and achievement.

As with occupation and employer characteristics, controlling for these characteristics changes salary differentials only slightly for each group and degree level. However, it does have enough of an effect to eliminate the rest of the estimated salary differentials for both underrepresented ethnic groups with advanced S&E degrees vis-à-vis all others, and for foreign-born individuals vis-à-vis native-born individuals.

An additional issue for the wage differentials of women, however, is that family and child variables often have different effects for men and women. Marriage is associated with higher salaries for both men and women with S&E degrees, 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, except at the doctoral level, where children have no statistically significant effect. Allowing for these differences in gender effects in the model reduces the salary differential at the bachelor's degree level by 10.4 percentage points (to –7.8%) and at the master's level by 9.4 percentage points (to 5.8%), and leaves no statistical significant difference in earnings at the doctoral level.

Labor Market Conditions for Recent S&E Graduates

Compared with experienced S&E workers, recent S&E graduates more often bring newly acquired skills to the labor market and have relatively few work or family commitments that limit their job mobility. As a result, measures of the success of recent graduates in securing good jobs can be sensitive indicators of changes in the S&E labor market.

This section looks at a number of standard labor market indicators for recent S&E degree recipients at all degree levels, and 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 reflect 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.

General Labor Market Indicators for Recent Graduates

Some basic labor market statistics are summarized for recent (defined here as those between 1 and 5 years since degree) recipients of S&E degrees in table 3-15. Across all fields of S&E degrees in 2003, there was a 4.7% unemployment rate for bachelor's degree holders who received their degrees in the previous 1–5 years. This ranged from 4.0% for physical sciences degree recipients to 5.1% for social science degree recipients. Although individuals often change jobs more often and have higher unemployment early in their careers, all of these values are less than the unemployment rate for the full labor force in 2003 of 6.0%. For doctorate recipients across all fields of degree, the unemployment rate was 2.8%.

A more subjective indicator of labor market conditions is the percentage of recent graduates who report that they sought, but could not find, full-time employment related to their field of degree. The IOF employment rate is a measure unique to NSF's labor force surveys. Because highly educated people are usually able to find employment of some kind, the IOF rate is sometimes a more sensitive indicator of changing conditions in the S&E labor market than the unemployment rate. At the bachelor's degree level, across all S&E fields, the IOF rate was 11.5%, but ranged from 3.6% for recent engineering bachelor's graduates to 15.7% in the social sciences. In all fields of degree, the IOF rate decreases with level of education, reaching 2.9% for recent doctorate recipients.

Average salary for recent S&E bachelor's degree recipients in 2003 was $40,900, ranging from $34,300 in the life sciences to $53,500 in engineering. Recent master's recipients had average salaries of $55,200 and recent doctorate recipients only about $5,000 more at $60,300. This reflects in part the relatively low postdoc salaries of some recent doctorate recipients (see discussion in next section) and the greater employment of doctorate holders in academia.

Employment and Career Paths for Recent Bachelor's and Master's Recipients

Although 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

Table 3-15
Labor market indicators for recent S&E degree recipients 1–5 years after receiving degree, by field: 2003
(Percent)

Indicator	All S&E fields	Computer/ mathematical sciences	Life sciences	Physical sciences	Social sciences	Engineering
Unemployment rate						
Bachelor's	4.7	4.5	4.1	4.0	5.1	4.4
Master's	4.4	5.4	2.9	2.6	4.6	4.5
Doctorate	2.8	2.1	4.6	1.1	1.9	3.3
Involuntary out-of-field rate						
Bachelor's	11.5	9.2	10.9	9.4	15.7	3.6
Master's	5.5	3.4	3.0	6.4	9.5	2.9
Doctorate	2.9	3.0	1.4	4.1	4.0	2.5
Average salary ($)						
Bachelor's	40,900	49,600	34,300	37,500	35,400	53,500
Master's	55,200	65,100	45,000	45,900	43,600	67,600
Doctorate	60,300	65,200	48,500	61,800	59,600	74,100

NOTE: Average salary rounded to nearest $100.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), 2003, http://sestat.nsf.gov.

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bachelor's and master's degree recipients whether they had obtained employment in a career path 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 (figure 3-32). 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.

Recent 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 opens 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. Some doctoral degree holders also face an additional period of low earnings while in a postdoc position. In addition, some doctoral degree holders do not obtain the jobs they desire after completing their education.

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 highly trained and motivated graduate students to aid university-based research. These programs have not only provided individuals with detailed, highly specialized training in particular areas of research, they have also cultivated a general ability to perform self-initiated research in more diverse areas.

The career rewards of highly skilled individuals in general, and doctoral 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 reflect the state of the doctoral S&E labor market. Some of the available labor market indicators, such as unemployment rates, IOF employment, satisfaction with field of study, employment in academia versus other sectors, postdoc positions, and salaries, are discussed below.

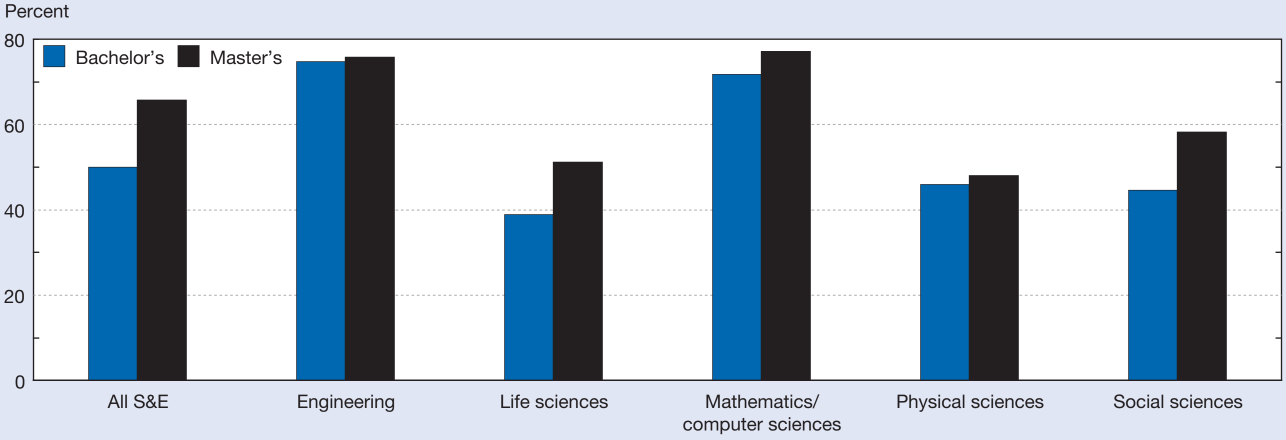
Aggregate measures of labor market conditions for recent (1–3 years after receipt of degree) U.S. S&E doctoral degree recipients in 2006 show improvement from the already generally good rates found when last measured in 2003: unemployment fell from 2.3% to 1.3% and IOF rates fell from 3.3% to 1.3% (table 3-16). There was also an increase in the percentage of the most recent graduates entering tenure-track programs at 4-year institutions—from 17.8% in 2003 to 19.2% in 2006.

Unemployment

The 1.3% unemployment rate for recent S&E doctoral degree recipients as of April 2006 was even lower than other generally low 2006 unemployment rates. The 2006 unemployment rate for all civilian workers was 4.6%, with lower rates of 2.2% for those with a bachelor's degree or above and 1.6% for those in S&E occupations.

The highest unemployment rates were for recent doctoral degree recipients in mechanical engineering (3.0%) and sociology/anthropology (2.4%). Unemployment in both fields (which also had the highest unemployment rates in 2003) fell from 5.8% and 5.0%, respectively, in 2003.

Figure 3-32
Recent S&E recipients in career-path jobs within 3 months of degree, by field: 1999



SOURCE: National Science Foundation, Division of Science Resources Statistics, National Survey of Recent College Graduates,1999.

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Table 3-16
Labor market rates for recent doctorate recipients 1–3 years after receiving doctorate, by field: 2001, 2003, and 2006
(Percent)

Field	Unemployment rate			Involuntary out-of-field rate		
	2001	2003	2006	2001	2003	2006
All S&E	1.3	2.3	1.3	3.4	3.3	1.3
Engineering	1.8	2.3	1.9	1.7	3.0	1.5
Chemical	1.6	2.1	0.7	2.0	8.9	9.8
Electrical	0.9	2.3	0.3	1.5	0.8	1.0
Mechanical	3.2	5.8	3.0	1.7	2.6	0.0
Life sciences	1.1	2.5	0.9	2.5	1.5	0.3
Agriculture	0.3	3.1	0.0	4.1	2.9	1.7
Biological sciences	1.0	2.6	1.0	2.4	1.3	0.2
Mathematics/computer sciences	0.3	4.2	0.7	2.4	3.6	2.2
Computer sciences	0.4	4.4	1.7	2.3	1.4	2.3
Mathematics	0.3	4.0	0.0	2.4	5.6	2.1
Physical sciences	1.3	0.9	1.6	5.0	3.6	2.3
Chemistry	0.8	1.2	1.9	3.2	4.3	0.9
Geosciences	1.9	1.5	1.9	3.0	0.0	0.0
Physics/astronomy	1.9	0.0	1.0	8.2	4.3	5.9
Social sciences	1.3	2.5	1.2	5.1	5.0	1.5
Economics	2.2	0.3	0.0	2.1	1.9	0.0
Political science	0.8	0.0	0.0	8.7	9.0	0.6
Psychology	1.4	2.8	1.2	3.8	5.2	1.3
Sociology/anthropology	1.2	5.0	2.4	6.3	4.5	4.8

NOTES: Two-year institutions not included. Doctorate recipients in health fields included in life sciences for consistency with prior years. Rates of 0.0, like other rates in this table, are rounded estimates and do not preclude possibility that some individuals in that field may be unemployed or working involuntarily out of field.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, 2001, 2003, and 2006 (preliminary data for 2006).

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The unemployment rate for recent S&E doctoral degree recipients in computer sciences, the field with the third highest unemployment rate in 2003, fell from 4.4% to 1.7% in 2006.

Involuntarily Working Outside Field

In addition to unemployment, another 1.3% of recent S&E doctoral degree recipients in the labor force reported in 2006 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 and 3.3% in 2003. 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 chemical engineering (9.8%), physics/astronomy (5.9%) and sociology/anthropology (4.8%).

Tenure-Track Positions

Most S&E doctoral degree holders ultimately do not work in academia, and there has been a long-term decline in this proportion, as academic opportunities grew slower than those in other sectors of the economy. In recent years, however, the proportion of all recent doctorate recipients in the labor force who are in tenure-track academic jobs (the tenure-track rate) has increased. Increases in the rate of new doctorate holders entering tenure-track positions at 4-year academic institutions were observed in NSF surveys between 2001 and 2003, and again between 2003 and 2006. As a result, in 2006, tenure-track rates for both those 1–3 years after degree and 4–6 years after degree returned roughly to the same rates found in 1993 (figure 3-33 and table 3-17). The rate for those 1–3 years since degree rose from 17.8% to 19.2% and the rate for those 4–6 years since degree increased from 23.5% to 25.8%. (See chapter 5 for a discussion of trends in tenure-track positions as a proportion of all academic positions.)

Academia is just one possible sector of employment for S&E doctorate holders, but the availability of tenure-track positions is an important aspect of the job market for individuals who seek academic careers. Changes over time in tenure-track employment reflect availability of tenure-track job opportunities in academia and the availability of nonacademic employment opportunities. For example, one of the quickest declines in tenure-track employment occurred in computer sciences, from 51.5% in 1993 to 23.6% in 2001, despite many discussions about difficulties that computer science departments were having finding faculty (figure 3-33).

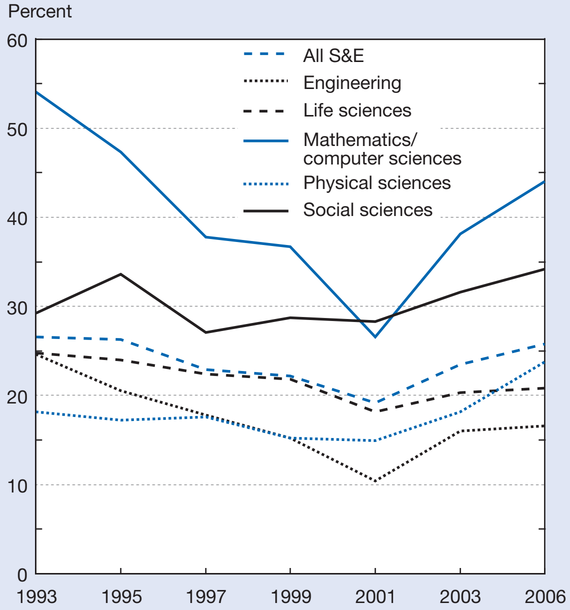
Salaries for Recent S&E Doctoral Degree Recipients

In 2006 for all fields of degree the median annual salary for recent S&E doctoral degree recipients 1–5 years after their degrees was $52,000. Across various S&E fields of degree, median annual salaries ranged from a low of $46,000 in the life sciences to a high of $70,000 in engineering (table 3-18).

By type of employment, salaries for recent doctoral degree recipients range from $40,000 for postdoc positions to $80,000 for those employed by private for-profit business (table 3-19).

Figure 3-33

Doctorate recipients holding tenure and tenure-track appointments at academic institutions 4–6 years after degree, by field: 1993–2006



NOTE: Two-year institutions not included. Doctorate recipients in health fields included in life sciences for consistency with prior years.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, 1993, 2003, and 2006 (preliminary data for 2006).

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Postdoc Positions

The growing number of recent doctoral graduates in postdoctoral appointments, generally known as postdocs,[12] has become a major issue and concern in science policy. Neither the reasons for its growth, nor the effect of the growth on the health of science, are well understood. Are new doctoral degree recipients more likely to enter postdoc positions because of increased competition for tenure-track academic research jobs? Are postdoc positions needed more than in the past because of the increasing team nature of research and the increased need for training?

Although individuals in postdoc positions perform much cutting-edge research, there is a concern that time spent in a postdoc position is time added onto the already long time spent earning a doctorate, thereby delaying their career advancement. Because postdoc positions usually pay much less than these highly educated individuals could make in other employment, forgone earnings add significantly to the costs of a doctoral education and may discourage doctoral-level careers in S&E.

Postdocs by Academic Discipline

Around half (49%) of U.S.-educated S&E doctorate recipients in postdoc positions in April 2006 had doctorates in the biological sciences, well above the 23% they represented of all S&E doctorates awarded in 2005 (figure 3-34). The high representation among postdocs of biological sciences doctorates reflects both the field's high rate of entering postdocs (about three-fifths of the 2002–05 graduation cohort) and the relatively long periods these individuals spent in postdoc positions. Other fields with high rates of entering postdocs (psychology, chemistry, and physics) make up another one-quarter of postdocs. The remaining quarter come from all other fields of S&E, most of which do not have strong traditions of a postdoc position being a normal part of a doctoral career path.

How Many Postdocs Are There?

No single data source measures the entire population of postdocs, and some parts of the population are not systematically measured at all. Two NSF surveys, the Survey of Doctorate Recipients and the Survey of Graduate Students and Postdoctorates in Science and Engineering (GSS), include data bearing on the number of postdocs in the United States.

SDR covers U.S. residents who have earned S&E and health doctorates from U.S. schools (MDs and other types of degrees with "doctor" in the name are not included). Thus, postdocs who received doctorate degrees from foreign institutions are not included in SDR. In 2006, SDR collected data on the dates of current and past postdoc positions, allowing an estimate to be made of the number of postdocs in fall 2005, the same period as the most recent GSS data. Unlike SDR, which collects data from individuals, GSS surveys academic departments. GSS asks departments that offer graduate programs in S&E and specific health-related

Table 3-17

Doctorate recipients holding tenure and tenure-track appointments at academic institutions, by years since receipt of doctorate: 1993, 2003, and 2006

(Percent)

	1993		2003		2006	
Field	1–3	4–6	1–3	4–6	1–3	4–6
All S&E	18.4	26.6	17.8	23.5	19.2	25.8
Engineering	16.0	24.6	12.2	16.0	14.7	16.6
Chemical	8.1	14.0	4.9	6.0	8.2	9.4
Electrical	17.6	26.9	11.6	15.3	18.6	15.4
Mechanical	13.5	29.5	11.1	16.0	16.5	14.6
Life sciences	12.6	24.8	8.0	20.3	13.4	20.8
Agriculture	15.6	27.0	23.7	35.1	18.9	30.0
Biological sciences	12.1	24.8	6.5	18.6	13.2	20.6
Mathematics/computer sciences	39.7	54.1	34.5	38.1	36.1	44.0
Computer sciences	37.1	51.5	30.9	30.3	37.8	36.4
Mathematics	41.8	56.0	37.7	43.8	34.7	50.6
Physical sciences	9.7	18.2	13.7	18.2	10.7	23.8
Chemistry	7.7	16.3	14.5	16.0	11.0	22.2
Geosciences	12.7	26.2	21.6	35.1	13.9	30.5
Physics/astronomy	12.0	17.7	9.4	14.5	8.7	22.5
Social sciences	26.4	29.2	28.3	31.6	29.6	34.2
Economics	46.6	48.6	43.7	32.2	37.4	39.4
Political science	53.9	47.1	45.0	50.6	45.0	51.3
Psychology	12.7	15.5	14.5	21.1	18.7	21.9
Sociology/anthropology	37.9	46.9	43.3	48.0	62.1	65.0

NOTE: Two-year institutions not included. Doctorate recipients in health fields included in life sciences for consistency with prior years.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, 1993, 2003, and 2006 (preliminary data for 2006).

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Table 3-18

Salary of recent doctorate recipients 1–5 years after receiving degree, by percentile: 2006

(Dollars)

Field	25th	50th	75th
All fields	40,000	52,000	74,000
Engineering	41,000	70,000	87,500
Life sciences	38,000	46,000	65,000
Mathematics/ computer sciences	43,500	64,000	84,000
Physical sciences	40,000	53,000	75,600
Social sciences	40,000	51,300	65,000

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, 2006 (preliminary data).

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fields for counts of all of their postdocs, regardless of whether their degrees were earned in the United States or abroad. However, unlike SDR, it does not gather data on people in nonacademic positions or academic units that lack graduate programs, including many academic research organizations and affiliated nonprofit research centers.

Table 3-20 shows the estimates that SDR and GSS provide for those parts of the U.S. postdoc population that they measure. Estimates for many, but not all, parts of the postdoc population can be derived from these data sources and used to piece together an overall national estimate for fall 2005. However, any overall estimate involves numerous uncertainties and assumptions.

Academic Postdocs. SDR estimates that 22,900 U.S. citizens and permanent residents were in academic postdoc positions in the fall of 2005.[13] The 2005 GSS estimate (16,200) is substantially lower, in part because postdocs affiliated with some non-degree-granting academic departments and research centers are not captured on GSS. In addition, the individuals surveyed by SDR and the departments surveyed by GSS may have somewhat different views on whether an individual should be classified as a postdoc.

Not surprisingly, GSS reports a much larger number of academic postdocs with temporary visas (26,600) than SDR (7,700). The most likely explanation for this gap is that GSS, unlike SDR, includes people with doctorates from non-U.S. universities in its counts.[14]

Other Postdocs. Neither survey includes data on the number of foreign-educated postdocs. SDR estimates that 29% of U.S.-educated postdocs, 13,000 total, are in industry, nonprofits, government, and other types of educational institutions. There is no reason to believe that the proportions of U.S. and foreign-educated postdocs in nonacademic positions are similar.

Table 3-19
Median annual salary of recent doctorate recipients 1–5 years after receiving degree, by type of employment: 2006
(Dollars)

Field	All sectors	Private	Tenure track	Postdoc	Other education	Nonprofit/ government
All S&E fields	52,000	80,000	53,000	40,000	48,500	68,000
Computer/mathematical sciences	64,000	90,000	62,000	48,500	48,000	S
Engineering	70,000	80,000	71,000	40,000	56,000	80,000
Life sciences	42,600	74,000	57,000	40,000	48,000	60,000
Physical sciences	53,000	78,000	50,500	42,000	48,000	76,000
Social sciences	51,300	65,000	52,000	39,600	50,000	62,000

S = data suppressed for reasons of reliability

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, 2006 (preliminary data).

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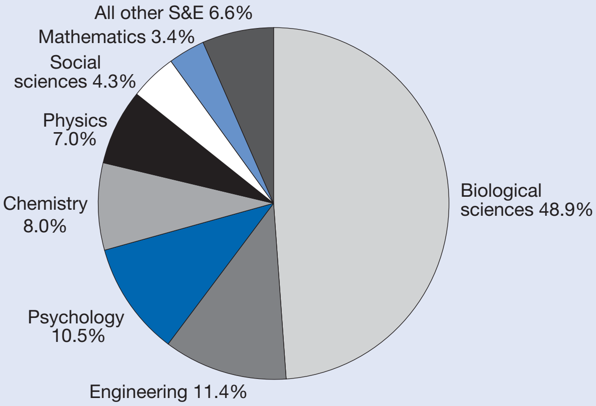
Figure 3-34
Field of doctorate of U.S.-educated S&E doctorate recipients in postdoc positions: 2006



NOTES: Social sciences exclude psychology. Detail does not add to 100% because of rounding.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, 2006 (preliminary data).

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Using these data, one might, for example, estimate as follows:

- 22,900 U.S. citizens and permanent residents in academic postdoc positions (SDR estimate).
- 26,600 persons on temporary visas in academic postdoc positions (GSS estimate).
- 13,000 U.S.-educated persons in postdoc positions not covered by GSS (SDR estimate).
- 26,500 postdocs on temporary visas and in positions not covered by GSS (estimate derived by assuming that the proportion of temporary visa postdocs in other sectors and other parts of academia is the same as in the portion covered by GSS).

This estimate yields a total of 89,000 postdocs but other, comparably plausible assumptions lead to a substantially different total.

Increase in the Likelihood and Length of Postdoc Positions

Among holders of U.S. S&E doctorates received before 1972, 31% reported having had a postdoc position earlier in their careers (figure 3-35).[15] This proportion has risen over time to 46% among 2002–05 graduates. This increase over time occurred both in fields in which postdocs have been traditionally important and in those in which only a small number of doctoral degree recipients went on to postdoc positions. In the high postdoc fields such as the life sciences (from 46%–60%) and the physical sciences (from 41%–61%), a majority of doctoral degree recipients now have a postdoc position as part of their career path. Similar increases were found in mathematical and computer sciences (19%–31%), social sciences (18%–30%), and engineering (14%–38%). The increasing use of postdoc positions in engineering is particularly noteworthy, with recent engineering doctoral degree recipients now being almost as likely to take a postdoc position as physical sciences doctoral degree recipients were 35 years ago.

There have also been increases in the average length of time spent in a postdoc position, most notably in the life sciences (figure 3-36). The median length of time spent in postdoc positions for life science doctoral degree recipients grew from 24 months for pre-1972 graduates to 46 months for 1992–96 graduates. Although the median length of time in a postdoc position for those who completed postdoc positions falls for later graduation cohorts, this in part reflects some individuals who did not enter a postdoc position immediately after graduation and were still in the position in April 2006. The increase in the time spent in postdoc positions in the physical sciences was more modest, rising from a median of 21 months to 30 months for 1992–96 graduates. In contrast, in psychology, which is a high-postdoc rate discipline, median months in postdoc positions has remained

Table 3-20

Postdoc estimates from two NSF surveys, by place of employment and citizen/visa status: Fall 2005

	SDR		GSS	
Place of employment and citizen/visa status	Estimate	Percent	Estimate	Percent
All places of employment				
All postdocs	43,400	100.0	43,100	100.0
U.S. citizens/permanent residents	33,400	77.0	16,200	37.5
Temporary visa	10,000	23.0	27,000	62.5
Higher education institutions[a]				
All postdocs	30,500	100.0	26,900	100.0
U.S. citizens/permanent residents	22,900	74.8	16,200	37.6
Temporary visa	7,700	25.2	26,900	62.4
All other educational institutions				
All postdocs	1,900	100.0	NA	NA
U.S. citizens/permanent residents	1,600	85.5	NA	NA
Temporary visa	300	14.5	NA	NA
Nonprofits/government/industry/all other institutions				
All postdocs	11,100	100.0	NA	NA
U.S. citizens/permanent residents	9,000	81.2	NA	NA
Temporary visa	2,100	18.8	NA	NA

NA = not available

GSS = Survey of Graduate Students and Postdoctorates in Science and Engineering; NSF = National Science Foundation; SDR = Survey of Doctorate Recipients

[a] For SDR, individuals reporting postdoc in 4-year U.S. educational institutions/medical schools/affiliated research institutes (includes those whose institution type in fall 2005 unknown); for GSS, postdocs in graduate S&E/health departments in U.S. graduate schools (excludes holders of medical and other professional degrees, some of whom may also hold doctorates).

NOTES: SDR gathers information from individuals with research doctorate in S&E/health field from U.S. educational institution. GSS gathers information from institutional coordinators at U.S. educational institutions with programs leading to graduate degrees in S&E/health fields, i.e., GSS includes postdocs with doctorates/equivalent degrees from foreign institutions. Estimates of postdoc status from 2006 SDR constructed from postdoc history module; fall 2005 used rather than April 2006 for comparability with GSS data and to capture those who may have left a postdoc position early. Detail may not add to total because of rounding.

SOURCES: National Science Foundation, Division of Science Resources Statistics, SDR, 2006 (preliminary data); and GSS, 2005.

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essentially the same for the 20 years from the 1972–76 graduation cohort (23 months) to the 1992–96 graduation cohort (22 months). In all other areas of S&E taken together, the estimated median months in postdoc positions has also shown little growth, and is never higher than the 23 months estimated for the 1972–76 cohort. In these nontraditional postdoc fields, the growing importance of postdoc positions is driven by the increased rate of entering postdocs, and not by the length of the postdoc appointment.

Postdoc Pay and Benefits

Low pay and fewer benefits for postdocs are frequently raised as concerns by those worried about the effect of the increasing use of postdocs on the attractiveness of science careers. The median academic postdoc salary is one-third less than the median salary for nonpostdocs 1–3 years after receiving their doctorates, as shown in table 3-21. By broad field, this ranges from a 44% pay gap with recent engineering doctoral degree recipients to a 25% gap for doctorate holders in the social sciences. Nonacademic postdocs have better pay than academic postdocs, but the medium salary is still 20% less than for nonpostdocs.

Most individuals in postdoc positions in 2006 did have employment benefits. Indeed, across all S&E fields, 90% of postdocs reported having medical benefits and 49% reported having retirement benefits. It is not possible to know from the survey how extensive medical benefits may be, or how transferable retirement benefits are. In the social sciences, medical benefits are somewhat less available, with only 75% of postdocs reporting that they had medical benefits.

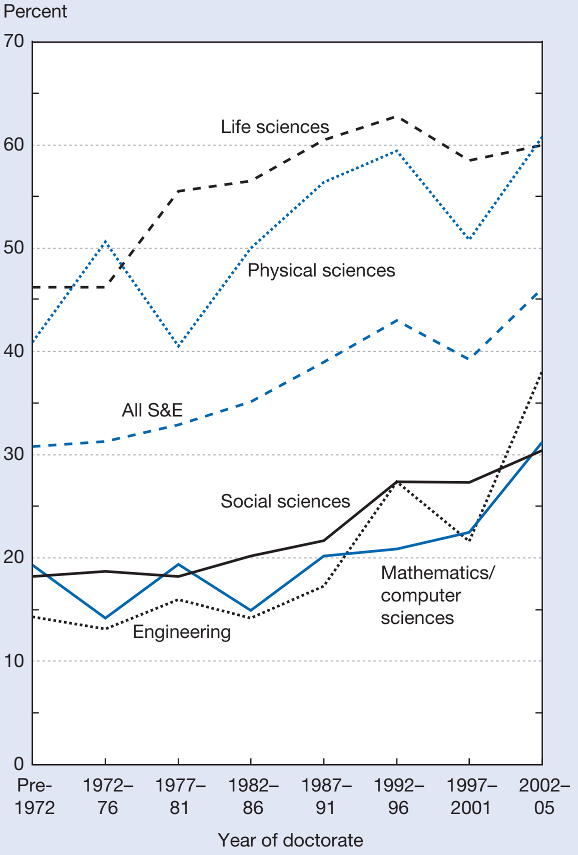
The perception that postdocs do not receive employee benefits does have a historical basis. As shown in figure 3-37, among former postdocs who received their S&E doctorates before 1972, only 59% of biological science postdocs and 60% of postdocs in all other fields reported having medical benefits, and only 16% and 18%, respectively, reported having retirement benefits. The prevalence of both types of employment benefits for postdocs has risen fairly steadily over time.

Postdocs as a Sign of Labor Market Distress for Recent Doctoral Degree Recipients

Former postdoc position holders were asked about the reason they accepted a postdoc appointment. Most respondents reported reasons consistent with the traditional view

Figure 3-35

Proportion ever holding a postdoc among S&E doctorate holders, by field and year of doctorate: 2006



SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, 2006 (preliminary data).

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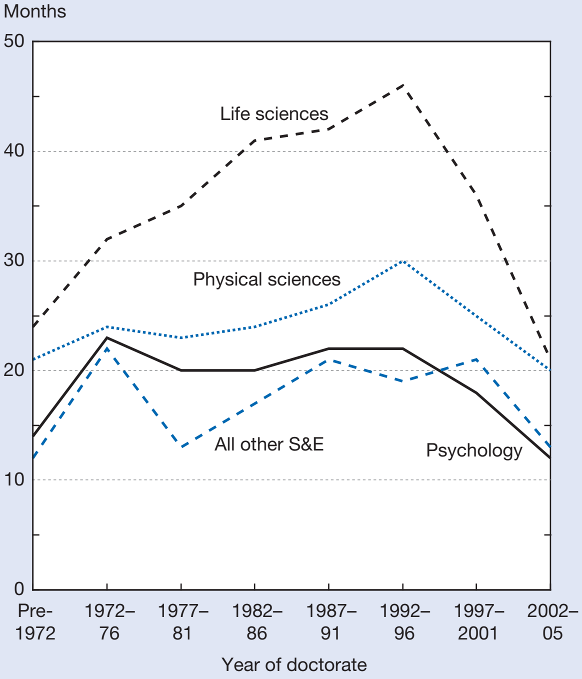
Figure 3-36

Median time spent in postdoc postions for S&E doctorate recipients completing postdocs, by field and year of doctorate: 2006



NOTE: Excludes those currently in postdoc position.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, 2006 (preliminary data).

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of postdoc appointments as a type of apprenticeship, such as seeking “additional training in doctorate field” or “training in an area outside of doctorate field.” However, 9% of respondents in a postdoc position in April 2006 reported that they took their current postdoc position because “other employment not available.” This reason was given by 5% of postdocs in the life science; 8% in computer and mathematical sciences; 10% in the physical sciences; 14% in the social sciences; and 16% in engineering.

A cohort trend for former and current postdocs who reported taking their first postdoc position because no other employment was available is shown in figure 3-38. Across all S&E fields, this proportion has a peak at 12% for both the 1972–76 and the 1992–96 graduation cohorts (5% in 1992–96 if looked at as a proportion of all doctorate holders). Both peaks roughly coincide with periods of relative difficulty for S&E doctorate holders, in the first case following an oil crisis and recession, and in the second following the end of the Cold War.

Postdoc Outcomes

There are several differences in the career patterns of former postdocs and nonpostdocs. However, available data do not permit definitive judgments about whether the experience gained in a postdoc position produced these differences. For example, those who entered postdoc positions may have already been more interested in research careers, and may have already given employers a reason to believe they have the ability and aptitude for such a career.

Most former postdocs report that the postdoc experience was helpful to their career, and the proportion of former postdocs saying this is remarkably constant over different doctorate graduation cohorts (figure 3-39). Across all S&E fields and cohorts, 53%–56% of former postdocs said that their postdoc experience “greatly helped” their careers. Across all cohorts, an additional 33%–38% said that their postdoc experience “somewhat helped” their careers. The proportion of those completing postdoc positions who said that it was no help to their careers ranged from only 8% for the 2002–05 graduation cohort to 12% for the 1987–2001 cohort.

Nonetheless, there are only modest differences in many measures of the career status of former postdocs and nonpostdocs in 2006. For example, among 1997–2001 recipients of U.S. S&E doctorates, 31% of those who had a postdoc

Table 3-21
Salary and benefits of U.S. S&E doctorate holders in postdoc positions: 2006

S&E field	Median salary ($) Academic postdoc	Median salary ($) Nonacademic postdoc	Median salary ($) Nonpostdocs 1–3 years after degree	Benefits (%) Medical	Benefits (%) Retirement
All fields	40,000	48,000	60,000	90.1	48.9
Engineering	40,000	60,000	71,400	92.4	56.2
Life sciences	40,000	44,000	55,000	92.9	47.7
Mathematics/computer sciences	47,000	55,000	72,000	93.0	69.1
Physical sciences	40,000	55,000	63,000	92.7	54.7
Social sciences	40,000	50,000	53,000	75.0	44.8

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, 2006 (preliminary data).

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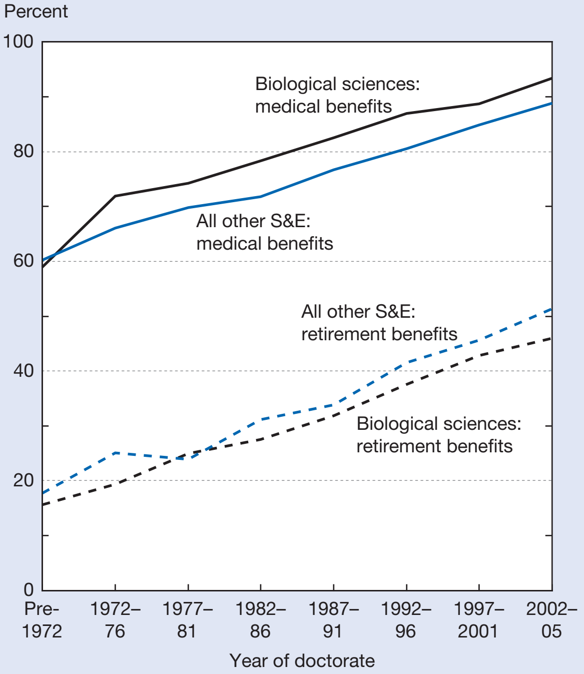
Figure 3-37
Growth of job benefits for S&E doctorate holders in postdoc positions, by field and year of doctorate: 2006



NOTE: Percentage currently or formerly in postdoc position who reported receiving medical or retirement benefits.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, 2006 (preliminary data).

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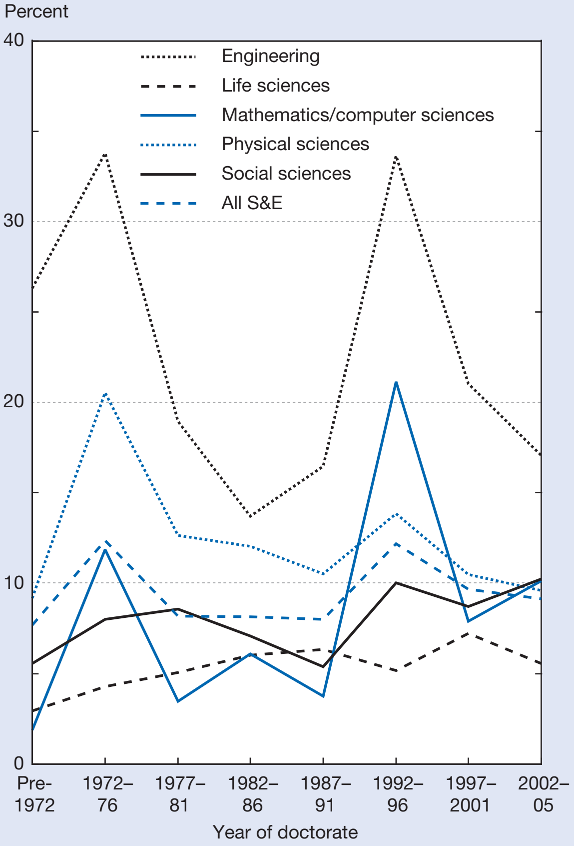
Figure 3-38
Former or current postdocs who took first postdoc position because other employment not available, by field and year of doctorate: 2006



SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, 2006 (preliminary data).

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position were in tenured or tenure-track positions at a 4-year postsecondary institution, compared with 25% of those not in postdoc positions. The differences between the tenure-track rates were larger for computer and mathematical sciences (a 21 percentage point difference), and for engineering and the physical sciences (each with a 14 percentage point difference between former postdocs and nonpostdocs in the proportion in tenure track). However, in the life sciences, where it is often said that a postdoc position is a requirement for an academic career, there is only a 5 percentage point difference between former postdocs and nonpostdocs in tenure-track employment. In the social sciences, nonpostdocs are actually slightly more likely to be in a tenure-track position, but this may be because many postdoc positions in psychology provide primarily clinical training.

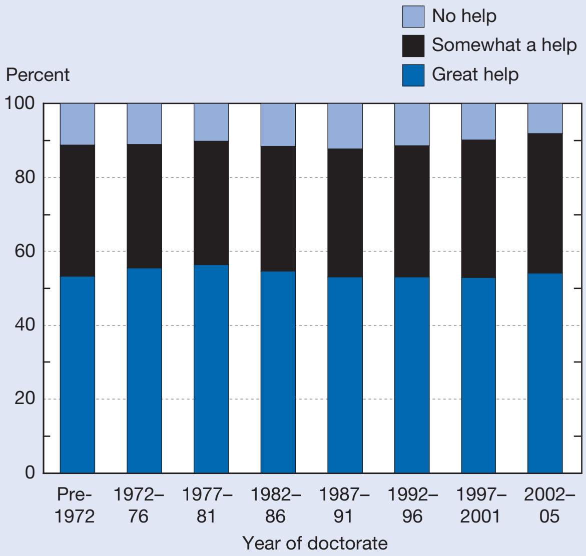
Changes in the proportion in 2006 tenured or tenure-track positions can be seen in figure 3-40. In the life sciences, the tenure-track rate has generally declined for more recent graduation cohorts for both former postdocs and nonpostdocs, with the largest gap of 12 percentage points occurring in the oldest graduation cohort, those receiving their doctorate prior to 1972. In contrast, in the physical sciences, the tenure-track rate is relatively constant across graduation cohorts for former postdocs, with former postdocs being 18 percentage points more likely than nonpostdocs to be in a tenure-track position among the newest, not the oldest, cohort. In psychology, there is a similar proportion going into tenure-track positions among most graduation cohorts. In all other S&E fields, there is a higher tenure-track rate for former postdocs that varies greatly by graduation cohort and ranges from 3 to 18 percentage points above the rate for nonpostdocs.

The 1997–2001 graduation cohort is the most recent to be almost entirely finished with postdoc experiences. In this cohort, the additional proportion in tenure-track positions for former postdocs ranged from 21 percentage points in the mathematical and computer sciences to minus 5 percentage points in the social sciences, where nonpostdocs have higher tenure-track rates (figure 3-41).

Former postdocs are also more likely than nonpostdocs to have R&D as a major work activity, defined here as reporting that basic research, applied research, design, or development is the work activity on which they spend the greatest, or second greatest amount of time. In the 1997–2001 graduation cohort, 73% of former postdocs had R&D as a major work activity in 2006, compared with 59% among those who

Figure 3-39

Former postdocs' evaluation of degree to which postdoc position helped career, by year of doctorate: 2006



SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, 2006 (preliminary data).

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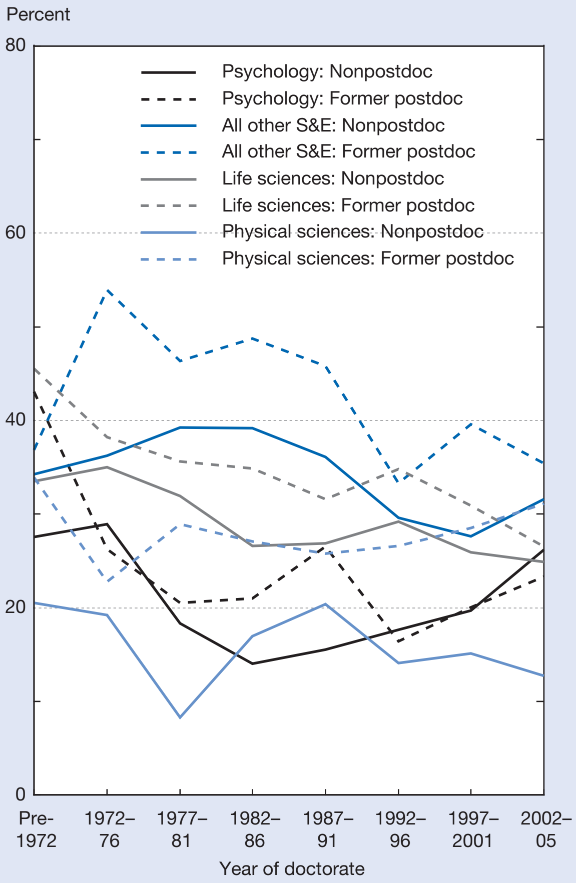
Figure 3-40

S&E doctorate holders in tenured or tenure-track positions in 2006, by field, postdoc status, and year of doctorate: 2006



NOTES: Excludes those still in postdoc position in April 2006. All other S&E fields include engineering, mathematics/computer sciences, and all other social sciences.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, 2006 (preliminary data).

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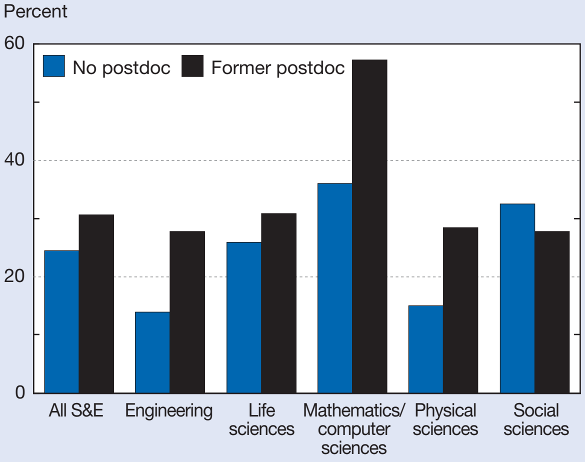
Figure 3-41
S&E doctorate holders in 1997–2001 graduation cohort in tenured or tenure-track positions, by degree field and postdoc status: 2006



NOTE: Excludes those currently in postdoc position.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, 2006 (preliminary data).

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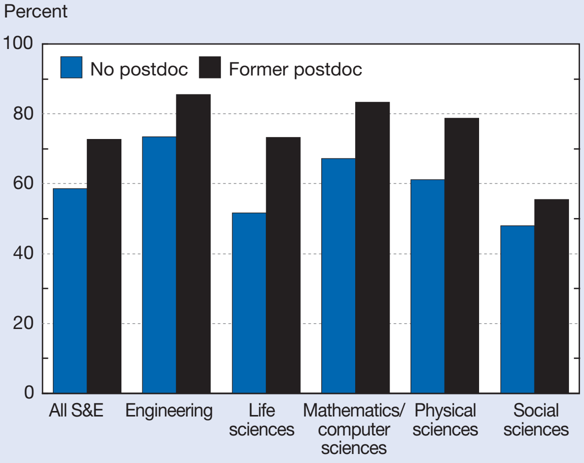
Figure 3-42
S&E doctorate holders in 1997–2001 graduation cohort with R&D as primary or secondary work activity, by degree field and postdoc status: 2006



NOTE: Excludes those currently in postdoc position.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, 2006 (preliminary data).

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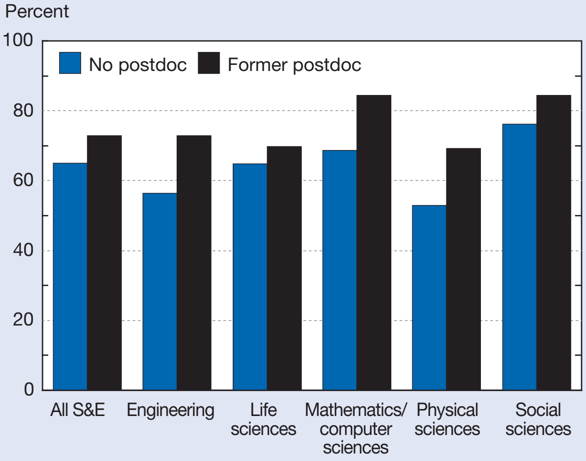
never has a postdoc position (figure 3-42). This increased likelihood to do R&D exists for all broad S&E fields of degree, and ranges from 7 percentage points in the social sciences to 21 percentage points in the life sciences.

Former postdocs are also somewhat more likely to report that their job is closely related to their degree. Although over 90% of S&E doctorate holders report that their job is at least somewhat related to their degree, smaller proportions report that it is closely related. In the 1997–2001 graduation cohort, 73% of former postdocs reported that their job was closely related to their degree in 2006, compared with 65% among those who never had a postdoc position (figure 3-43). The difference in reporting of a job closely related to degree ranged from 5 percentage points in the life sciences to 17 percentage points in engineering and the physical sciences.

Taking a postdoc position delays an individual's entry into a career path with a more permanent employer, but also may provide the individual with valuable experience and skills. Figure 3-44 shows the difference in the 2006 salary of former postdocs and nonpostdocs by field of degree and sector of employment. For this purpose, an older cohort, 1992–96 doctoral degree graduates, is used for comparison to allow somewhat more time for former postdocs to demonstrate their performance with an employer. In all fields of degree, former postdocs working for a private noneducational employer earned less than nonpostdocs in the same sector. In mathematical and computer sciences, former postdocs earned 8% less, and in all other fields former postdocs earned 10% less in the private sector. In the three fields in which enough postdocs enter government service to allow measurement—the physical sciences, life sciences, and engineering—a positive salary differential is associated with having been a postdoc, ranging from 3% in engineering to 9% in the life sciences. A more ambiguous salary differential appears among former postdocs in the educational sector, who earn more than nonpostdocs in the physical sciences, computer and mathematical sciences, and engineering, but earn less in the social sciences and life sciences.

Figure 3-43
S&E doctorate holders in 1997–2001 graduation cohort with job closely related to degree field, by degree field and postdoc status: 2006



NOTE: Excludes those currently in postdoc position.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, 2006 (preliminary data).

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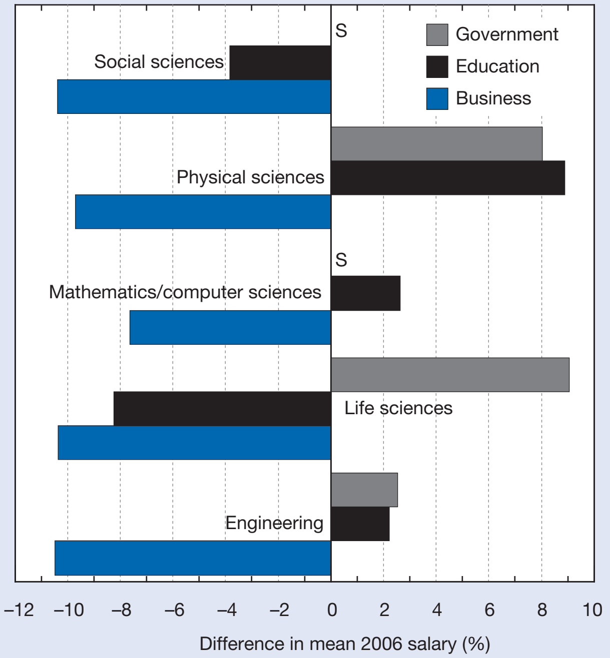
Figure 3-44
Salary of former postdocs relative to nonpostdocs for S&E doctorate holders in 1992–96 graduation cohort, by degree field and sector of employment: 2006



S = suppressed for reliability

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, 2006 (preliminary data).

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In summary, postdocs in S&E fields are associated with a greater likelihood to be engaged in research, hold a tenure-track position, and report that their job is closely related to their degree. Having had a postdoc position is associated with a moderate disadvantage in salary within private non-educational employment, and a moderate advantage in government employment. A majority of former postdocs from all graduation cohorts said that their postdoc positions were a great help to their career, and only about one-tenth said that a postdoc position was of no help to their careers.

Age and Retirement

The age distribution and retirement patterns of the S&E labor force affect its size, 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 picture is changing as individuals who earned S&E degrees in the late 1960s and early 1970s move into the latter part of their careers.

Increasing average age may mean increased experience and greater productivity among scientific workers. However, it could also reduce opportunities for younger researchers to make productive contributions by working independently. In many fields, scientific folklore and empirical evidence indicate that the most creative research comes from younger people (Stephan and Levin 1992).

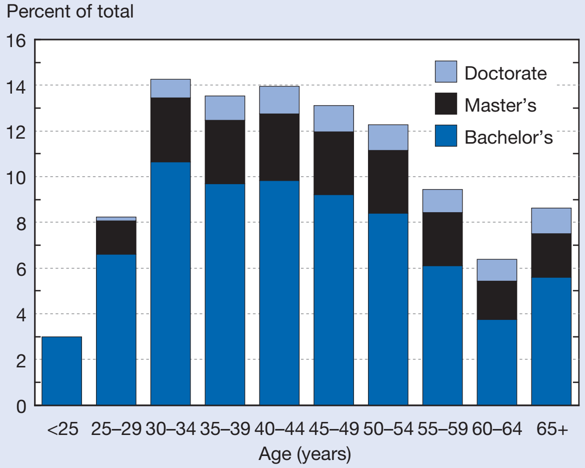
This section does not attempt to project future S&E labor market trends; however, some general conclusions can be made. Absent changes in degree production, retirement patterns, or immigration, the number of S&E-trained workers in the labor force will continue to grow for some time, but the growth rate 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.

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 30 and 49. (Figure 3-45 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 doctoral degrees. Because of the long time needed

Figure 3-45
Age distribution of individuals in labor force with highest degree in S&E: 2003



SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), 2003, http://sestat.nsf.gov.

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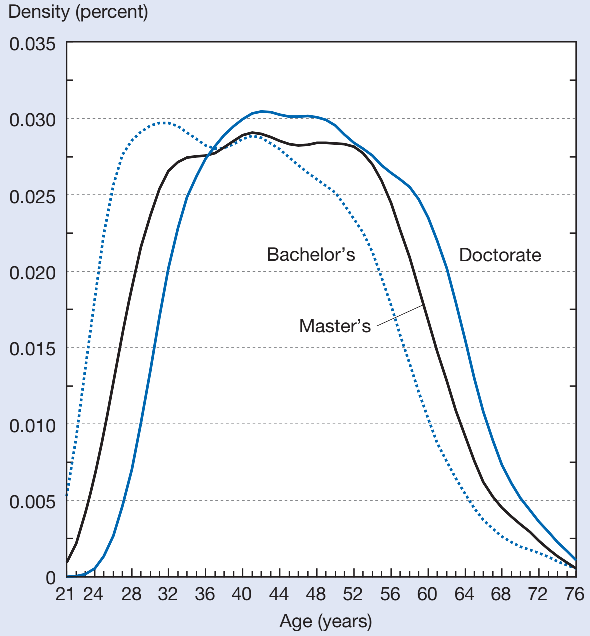
to obtain a doctorate, doctoral degree holders are somewhat older than individuals who have less-advanced S&E degrees. The greatest population density of S&E doctoral degree holders occurs between the ages of 40 and 54. This can be most easily seen in figure 3-46, which compares the age distribution of S&E degree holders in the labor force at each level of degree, and in figure 3-47, which shows the cumulative age distribution for individuals at each degree level. Even if one takes into account the somewhat older retirement ages of doctoral 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 3-48, 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 doctoral-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 doctoral-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 10.8% of individuals with their highest degree in computer sciences to 38.0% of individuals with their highest degree in physics (figure 3-49).

Figure 3-46

Age distribution of individuals in labor force with highest degree in 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), 2003, http://sestat.nsf.gov.

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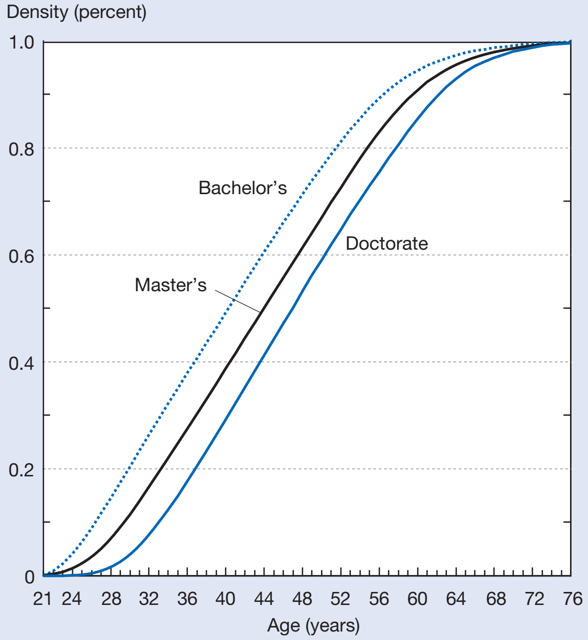
Figure 3-47

Cumulative age distribution of individuals in labor force with highest degree in 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), 2003, http://sestat.nsf.gov.

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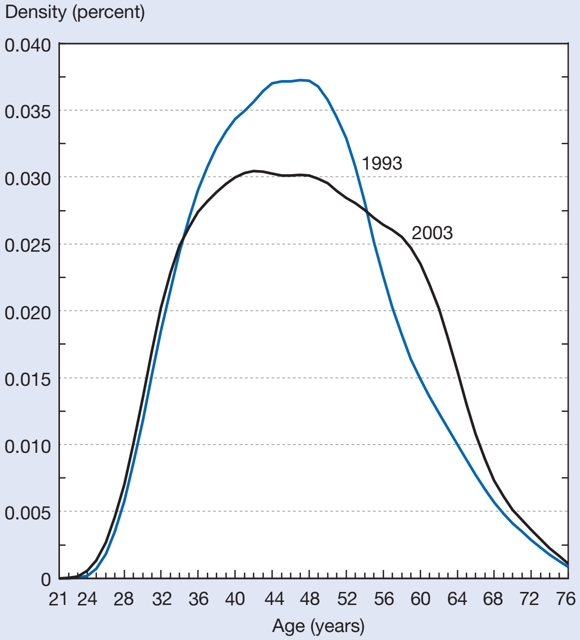
Taken as a whole, the age distribution of S&E-educated individuals suggests several likely important effects on the future S&E labor force:

- 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.
- 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 doctoral 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 2003 report of the

Figure 3-48
Age distribution of S&E doctorate holders in 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 2003, http://sestat.nsf.gov.

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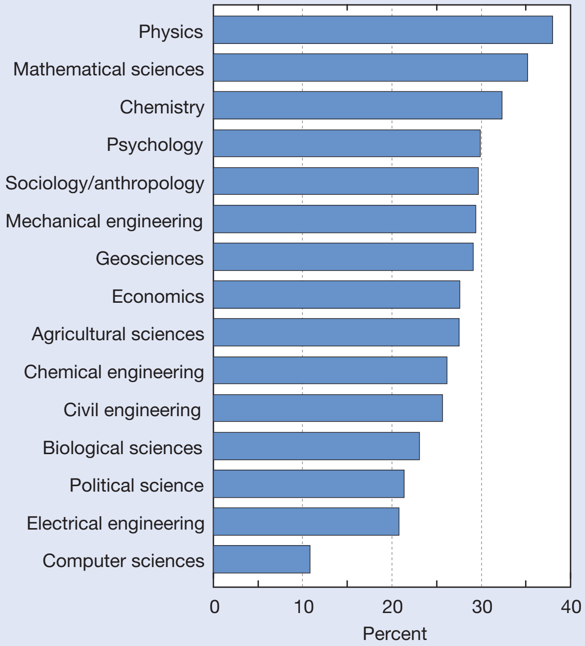
Figure 3-49
Employed S&E degree holders older than 50, by selected field: 2003



SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), 2003, http://sestat.nsf.gov.

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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 3-22 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, only at age 66 do S&E doctoral degree holders reach the 50% not working full-time. 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 doctoral degree holders did not do so until ages 66 and 70, respectively. Formal retirement also occurs at somewhat higher ages for doctoral 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 doctoral degree holders.

Figure 3-50 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 doctoral degree holders becomes significantly greater than for bachelor's and master's degree holders. At age 69, 21% of doctoral degree holders work full-time, compared with 16% of bachelor's or master's degree recipients.

Table 3-22
Retirement age for individuals with highest degree in S&E, by education level and age: 2003

	First age at which >50% were—		
Highest degree	Not working full time	Not in labor force	Retired from any job
Bachelor's...........	61	65	62
Master's..............	62	66	62
Doctorate............	66	70	65

SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), 2003, http://sestat.nsf.gov.

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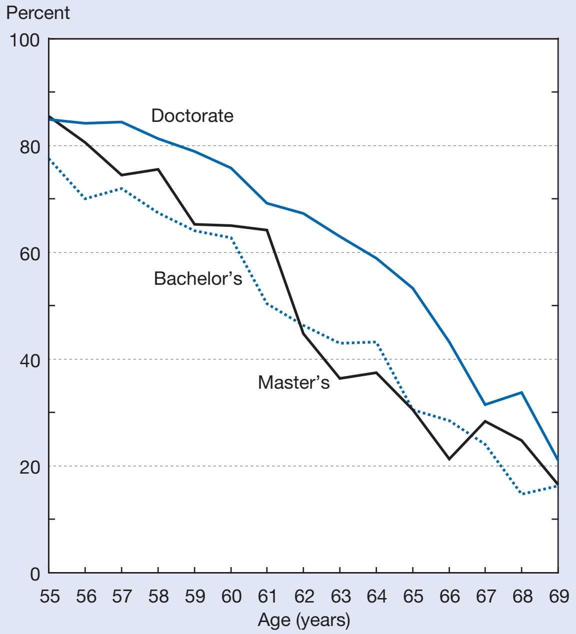
Table 3-23 shows rates at which doctoral degree holders left full-time employment, by sector of employment, between 1999 and 2001 and 2001 and 2003. At nearly every age and sector of employment, a smaller proportion of doctoral degree holders left full-time employment in the more recent period than between 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 3-24). However, among "retired" individuals ages 71–75, 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.

Figure 3-50
Older S&E degree holders working full time, by degree level: 2003



SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), 2003, http://sestat.nsf.gov.

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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 rapid development of the capacity to make scientific and technical innovations is creating a new competitive environment. New ways of doing business and performing R&D take advantage of gains from new knowledge discovered anywhere, from

Table 3-24
Retired individuals with highest degree in S&E who continue to work, by education level and age: 2003
(Percent)

	Bachelor's		Master's		Doctorate	
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 those 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), 2003, http://sestat.nsf.gov.

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Table 3-23
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 = data suppressed for reasons of reliability

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, 1999, 2001, and 2003.

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increases in foreign economic development, and from expanding international migration of highly trained scientists and engineers.

Other chapters in *Science and Engineering Indicators 2008* provide indirect indicators on the global S&E labor force. Production of new scientists and engineers through university degree programs is reported in chapter 2 (Higher Education in Science and Engineering). Indicators of R&D performed by the global S&E labor force are provided in chapter 4 (in sections on R&D expenditures and alliances), chapter 5 (in sections on publications output and international collaborations), and chapter 6 (in section on patenting activity).

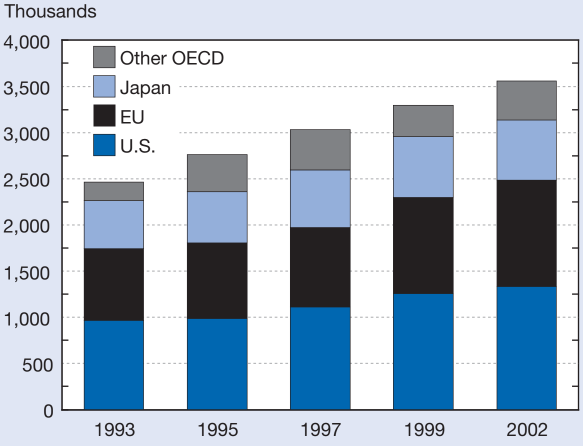
Section Overview

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 doctoral degree labor force, and are even more prevalent 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 Global S&E Labor Force

Few direct measures of the global S&E labor force exist; however, reports on the number of researchers in OECD member countries constitute one source of data. From 1993 to 2002, the number of researchers reported in OECD countries increased by 33.3% (a 4.2% average annual rate of increase) from approximately 2.5 million to 3.6 million (figure 3-51). During this same period, approximately comparable U.S. estimates increased 38.3% (a 3.7% average annual rate of increase) from about 1.0 million to 1.3 million. Of course, many scientists and engineers are in non-OECD countries, and counts of these individuals are harder to obtain. Figure 3-52, based on estimates by Robert Barro and Jong-Wha Lee (Barro and Lee 2000), 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.

Figure 3-51
Researchers in OECD countries: Selected years, 1993–2002



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

NOTE: 1999 and 2002 numbers reflect EU-25 membership.

SOURCE: OECD, Main Science and Engineering Indicators (2006).

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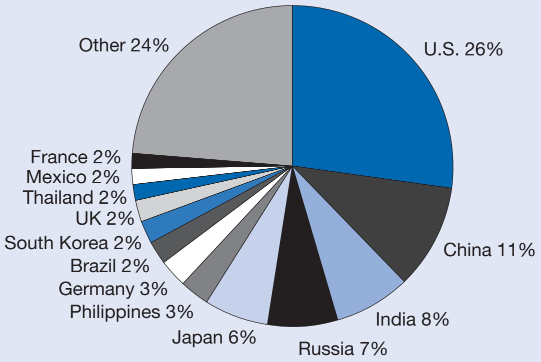
Figure 3-52
Tertiary-educated population more than 15 years old: 2000 or most recent year



UK = United Kingdom

SOURCE: Adapted from Barro RJ, Lee J, International Data on Educational Attainment: Updates and Implication, Center for International Development (2000).

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R&D Employment by Multinational Corporations

R&D is often done for companies that are based outside the country in which the researcher resides. Comparable data is available every 5 years on two aspects of this common phenomenon: the employment of R&D workers by U.S. firms at their foreign subsidiaries and by foreign firms at their subsidiaries in the United States.[16] This information is derived from the Bureau of Economic Analysis surveys that are discussed in more detail in chapter 4.

It is worthwhile noting that these measures capture only some parts of industrial R&D employment for global economic purposes. R&D is often done by a company in one country under contract to a company in another country, in arrangements that range from simple consulting work to strategic collaborations. R&D is also done to develop products and services for specific foreign markets. Neither work is captured by measures that only look at a company's own subsidiaries. Nevertheless, R&D work by subsidiaries is important in itself, and may be an indicator of other international R&D activity.

R&D employment in the United States by U.S. subsidiaries of foreign firms rose from 105,100 in 1994 to a peak of 135,300 in 1999, then declined to 123,900 in 2004, for an 18% net increase over the decade (figure 3-53). Over the same 10 years, R&D employment by U.S. firms at their foreign subsidiaries grew 75.8%, from 102,000 to 179,300. Most of the R&D employment at foreign subsidiaries of U.S. firms is in Europe (63.5%), followed by Asia (17.8%) and Canada (10.3%).

Although the growth in R&D employment abroad by U.S. firms from 1994 to 2004 was fairly rapid (a 5.8% average annual growth rate), it does not represent a very large shift in the location of R&D employment by U.S. multinational corporations (MNCs). Over the same 10 years, domestic R&D employment of the same corporations increased by 31.0% (a 2.7% average annual rate) to 818,700 in 2004 (figure 3-54). The proportion of the total R&D employment of U.S. MNCs that is abroad increased from 14.0% in 1994 to 18.0% in 2004.

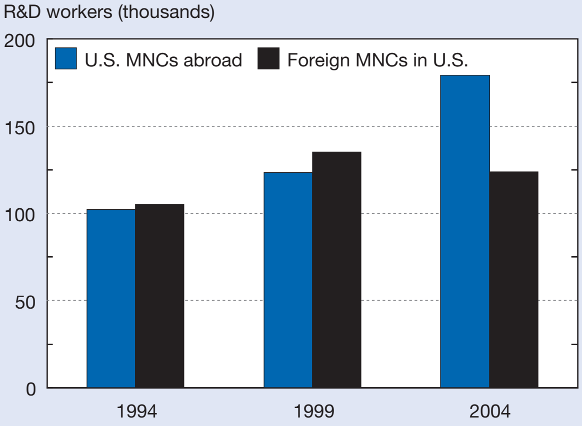
The data in both figures 3-53 and 3-54 are consistent with two trends discussed in this chapter: rapid growth in S&T employment in the United States occurring at the same time as a general expansion of the ability to do S&T work throughout the world.

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 that "[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 Canada and Japan.")

The nature of high-skilled migration makes it difficult to count foreign-born scientists and engineers working in the United States. According to an estimate based on data from the Census Bureau's American Community Survey, slightly over one million individuals in S&E occupations (26% of all college-educated workers in these occupations)

Figure 3-53
R&D employment of U.S. MNCs at their foreign affiliates and foreign MNCs at their U.S. affiliates: 1994, 1999, and 2004



MNC = multinational corporation

SOURCE: Bureau of Economic Analysis, Survey of Foreign Direct Investment in the United States, and Survey of U.S. Direct Investment Abroad, 2004 (preliminary data).

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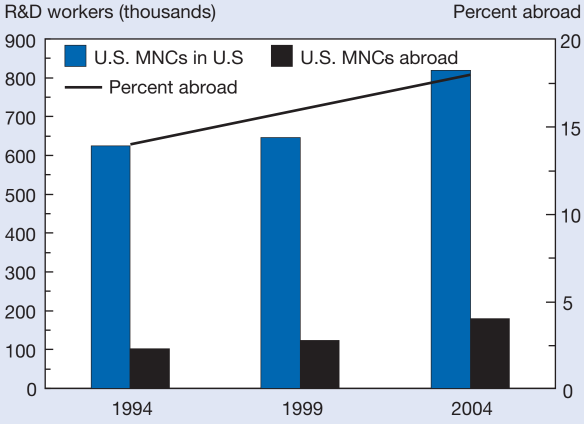
Figure 3-54
R&D employment of U.S. MNCs in United States and at their foreign affiliates: 1994, 1999, and 2004



MNC = multinational corporation

SOURCE: Bureau of Economic Analysis, Survey of Foreign Direct Investment in the United States, and Survey of U.S. Direct Investment Abroad, 2004 (preliminary data).

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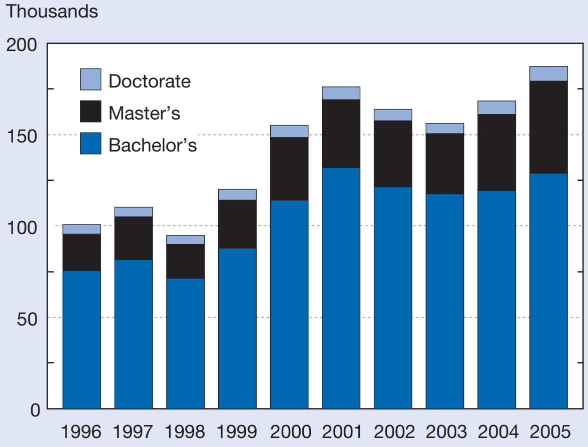
High-Skill Migration to Canada and Japan

Recent debates and legislative changes in many developed (and sometimes less developed) countries have focused on visa programs for temporary high-skilled workers. Canada and Japan are just two examples of countries that have made temporary high-skilled migration important parts of national economic policies.

In 2005, Canada issued permanent visas to 189,000 immigrants with university degrees (figure 3-55). The ratio of such visas to the total Canadian population far exceeded the comparable ratio in the United States. For the U.S. ratio to reach the Canadian level, the United States would have had to grant 1.7 million permanent visas to college graduates in 2005; in fact, it issued only 891,000 permanent visas to adults at all education levels. The Canadian government estimated the number of workers in Canada with high-skilled temporary visas (44,000) had increased by 63% during the 1995–2005 decade (figure 3-56). This number of temporary workers is particularly notable since Canada also has relatively quick and easy pathways for those on temporary visas to obtain permanent visas. In addition, many types of workers who would need temporary work visas in the United States, such as advanced degree recipients from U.S. graduate schools, would usually be able to bypass temporary visas and qualify for a "skilled worker" permanent visa based upon Canada's point system.*

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). In 2003, 268,045 workers entered Japan in high-skilled temporary visa categories, a 93% increase compared with 1992 (figure 3-57). 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 3-55
Canadian awards of permanent residency to university graduates, by degree level: 1996–2005



SOURCE: Citizenship and Immigration Canada, Facts and Figures 2005 (2006).

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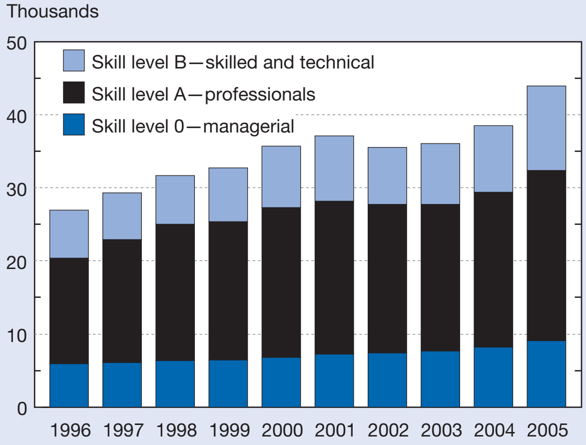
Figure 3-56
Stock of workers in Canada on high-skilled temporary work visas, by skill level: 1996–2005



SOURCE: Citizenship and Immigration Canada, Facts and Figures 2005 (2006).

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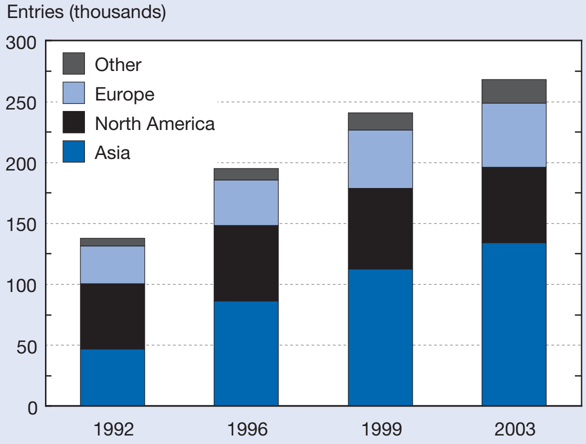
Figure 3-57
High-skilled workers with visas in Japan, by region of origin: Selected years, 1992–2003



SOURCES: Fuess SM 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).

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* See http://www.cic.gc.ca/english/immigrate/skilled/assess/index.asp, accessed 11 June 2007.

were foreign born (table 3-25). The proportions ranged from 19% among bachelor's degree holders to 41% at the doctorate level. However, these estimates are likely to be on the low side, because census occupational classifications miss many individuals who use S&E knowledge extensively in their jobs. For example, most university professors teaching in S&E fields are excluded from census S&E occupational counts, because they are classified as "postsecondary teacher." NSF 2003 SESTAT data, on the other hand, show 4.9 million college graduates in S&E occupations but 12.9 million who said they needed at least a bachelor's level of S&E knowledge in their jobs.

NSF's labor force surveys (SESTAT) gather information on education and workplace activities that can be used to identify the broader S&E labor force and that goes beyond the data in the decennial census or the American Community Survey. However, SESTAT data also have important limitations. SESTAT excludes individuals with foreign degrees who were not in the United States for the previous decennial census. As a result, SESTAT surveys miss foreign-educated S&E workers who have entered the country since the most recent census. Because high-skilled migrants often come to the United States for just a few years to pursue training or work, this can be a serious limitation. For example, the 1999 SESTAT survey provided an estimate of 15% foreign-born among college-educated individuals in S&E occupations; the corresponding census estimate is about 22% (table 3-25). In the 2000 census, about 43% of all college-educated, foreign-born individuals in S&E occupations (62% of doctorate holders) reported arriving in the United States after 1990. The 1999 NSF/SRS SESTAT estimates in table 3-25 include these post-1990 arrivals only if their degrees are from a U.S. institution.

In contrast, 2003 SESTAT estimates of the foreign born in S&E occupations are quite close to estimates from the 2000 census (table 3-25). By level of degree, SESTAT estimates are only 1 to 2 percentage points different from comparable census estimates.

The 2003 SESTAT survey also provides an estimate of foreign-born S&E degree holders by field of degree (table 3-26). 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 individuals in sociology/anthropology to 27% of those 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 3-58 shows country-of-birth for the 2.2 million foreign-born S&E degree holders in the United States, 276,000 of whom have doctorates. Although no one source country dominates, 16% came from India and 11% came from China. Source countries for foreign-born holders of S&E doctorates are somewhat more concentrated, with China providing 22% and India 14%.

Although many foreign-born scientists and engineers in the United States first came to the United States to study, many other individuals came to the United States after receiving their university training abroad (table 3-27). This fact is important both to understanding the various ways that the United States recruits highly skilled workers from around the world, but also to understanding how these workers help to connect the United States to universities and research institutions around the world. (See sidebar "Foreign Scientists at the Max Planck Society" for a discussion of the importance of foreign scientists in Germany's research system).

Table 3-25

NSF and Census Bureau estimates of foreign-born individuals in S&E occupations, by education level: Selected years, 1999–2005

(Percent)

			2003		2005
Education	1999 NSF/SRS SESTAT	2000 Census 5% PUMS	NSF/SRS SESTAT	Census American Community Survey	Census American Community Survey
All college educated	15.0	22.4	22.5	25.0	25.5
Bachelor's	11.3	16.5	16.3	18.8	19.1
Master's	19.4	29.0	29.0	32.0	32.7
Doctorate	28.7	37.6	35.6	39.5	41.1

NSF/SRS = National Science Foundation, Division of Science Resources Statistics; PUMS = Public Use Microdata Sample; SESTAT = Scientists and Engineers Statistical Data System

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. NSF/SRS SESTAT S&E occupations adjusted to be compatible with Census and American Community Survey occupations. All college educated includes those with professional degrees.

SOURCES: NSF/SRS, SESTAT database, 1999 and 2003, http://sestat.nsf.gov; Census Bureau, PUMS, 2000; and American Community Survey, 2003, 2005.

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Table 3-26
Foreign-born proportion of total with highest degree in S&E, by field and education level: 2003
(Percent)

Field	All degree levels	Highest degree		
		Bachelor's	Master's	Doctorate
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), 2003, http://sestat.nsf.gov.

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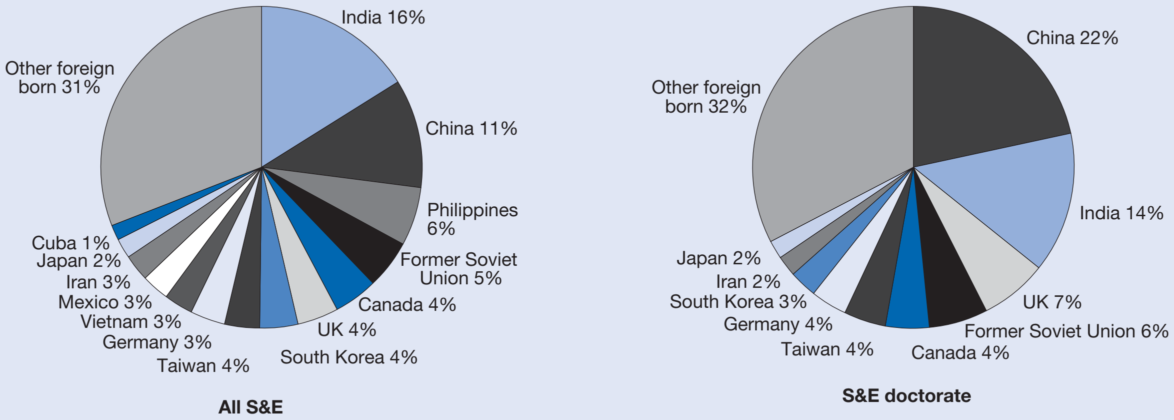
Across all levels of degree, 41% of the university-educated foreign born in the United States had their highest degree from a foreign educational institution and 55% had at least one foreign degree. At the highest level of education, 36% of foreign-born doctorate holders earned their doctorates from a foreign school.

The prevalence of foreign degrees among foreign-born S&E degree holders has been increasing over time (figure

Figure 3-58
Foreign-born individuals with highest degree in S&E living in United States, by place of birth: 2003



UK = United Kingdom

SOURCE: National Science Foundation, Division of Science Resources Statistics, SESTAT database, 2003, http://sestat.nsf.gov. See appendix table 3-8.

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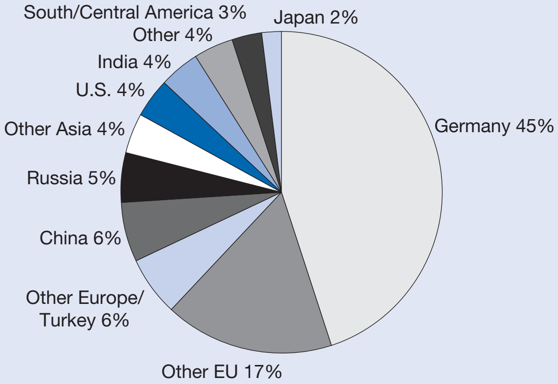
Foreign Scientists at the Max Planck Society

In many European countries, research institutes that are outside of formal universities play a very large role in basic research and graduate training. Research institutes often also have a major role in recruiting international scientists and engineers, very often to work in laboratories and classrooms where English is the working language. Germany's Max Planck Society is an example of this phenomenon.

The Max Planck Society is a nonprofit research organization mostly funded by the German government. It is a notable part of both German and global science, with a budget of just under $2 billion in 2006, and with research performed at 78 separate Max Planck Institutes. The 78 institutes are run by 260 Scientific Directors, 28% of whom (in October 2006) are foreign citizens. Hierarchically just below the Scientific Directors are approximately 4,300 staff scientists, 27% of whom are foreign citizens. However, at the junior and guest scientist level, over half of the 10,900 are foreign citizens (54%, see figure 3-59). Less than one-third of these foreign citizens are from other European Union countries, with China, Russia, the United States, and India the largest non-EU countries of citizenship.

Figure 3-59
Citizenship of junior and guest scientists at Max Planck Institutes: 2005



EU = European Union

SOURCE: Max Planck Society, Division of International Relations.

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3-60). Among foreign-born S&E degree holders who entered the United States before 1980, only 20% of doctorate holders and 23% of bachelor's degree holders had their highest degree from a foreign school. These percentages increase for more recent entry cohorts of immigrants. It should be noted that some portion of the increase in the most recent entry years reflects immigrants who entered during those years but have not yet had sufficient time to complete an American degree.

Table 3-27
Share of college-educated, foreign-born individuals in United States holding foreign degrees, by education level: 2003
(Percent)

Highest degree	Highest degree from foreign school	Any foreign university degree	Foreign secondary school
All degree levels ...	41.4	54.8	69.2
Bachelor's	47.9	49.7	65.8
Master's	26.8	58.6	74.2
Professional	49.5	58.5	63.3
Doctorate	36.3	78.6	93.0

SOURCE: National Science Foundation, Division of Science Resources Statistics, National Survey of College Graduates, 2003, Scientists and Engineers Statistical Data System (SESTAT), http://sestat.nsf.gov.

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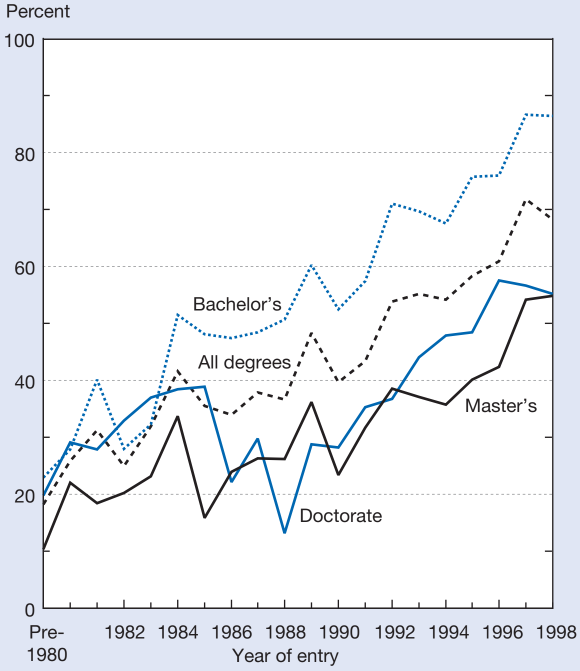
Citizenship and Visa Status of Foreign-Born Scientists and Engineers in the United States

The length of time for foreign scientists and engineers to earn U.S. citizenship affects both their decision to come to the United States and their subsequent decision to stay. As shown in figure 3-61, only about half of foreign S&E degree holders who entered the United States in 1991 and remained in 2003 had obtained citizenship. Citizenship status may particularly affect the supply of S&T talent available to segments of the U.S. economy that can hire only citizens: the federal government and private companies engaged in defense and other classified research.

The length of time before acquiring citizenship is not necessarily because of a lack of interest on the part of the foreign-born scientists and engineers. Consider a hypothetical case of a bachelor's-level engineer who enters the United States with a student F visa to pursue a doctorate, who spends 6 years completing the doctorate, followed by 2 years in a postdoc position, and then is hired by an employer for a permanent job on a temporary work visa. The employer applies for a permanent work visa for their new worker, who receives it 2 years after starting work. Now, 10 years after entering the United States, a 5-year waiting period begins after receiving a permanent visa, before the engineer can apply for citizenship. The engineer applies soon after becoming eligible, and after 1 year, becomes a U.S. citizen, 16 years after entry to the United States.

Figure 3-60

Foreign-born S&E degree holders with highest degree from foreign institution, by year of entry to United States: 2003



SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), 2003, http://sestat.nsf.gov.

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The importance of temporary visas is also shown in figure 3-60. Five years after entry to the United States, half of the foreign born with S&E degrees are still on temporary visas. Among those who have been in the United States for 10 years, 12% are on some form of temporary visa.

Temporary Work Visas

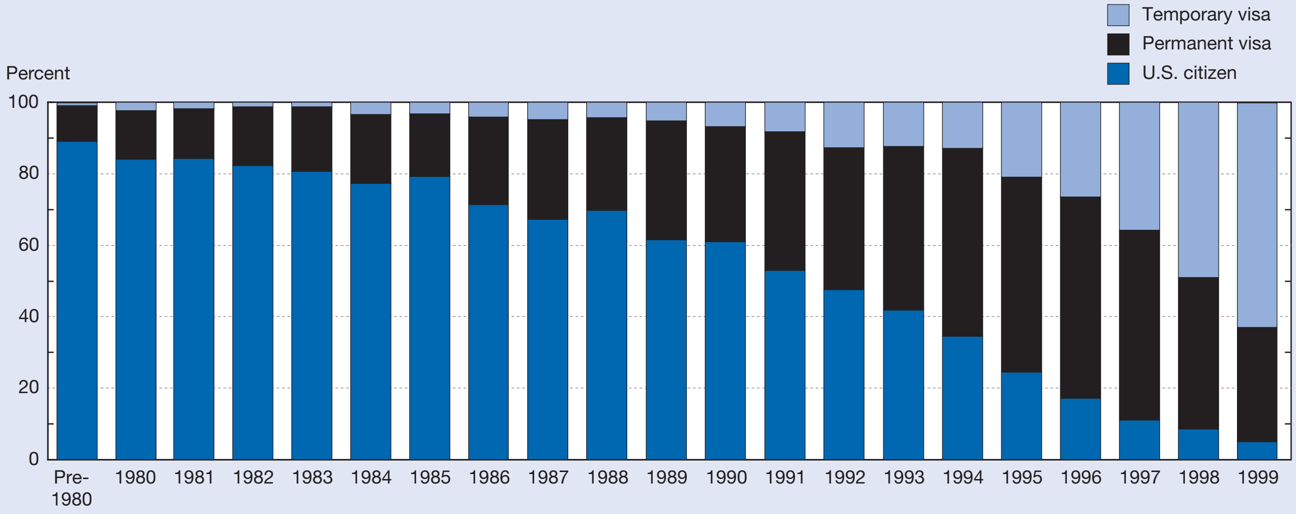
In recent years, policy discussion has focused on the use of various forms of temporary work visas by foreign-born scientists. Many newspaper and magazine stories have been written about the H-1B visa program, which provides visas for up to 6 years for individuals to work in occupations mostly requiring at least a bachelor's degree. A wide variety of skilled workers use H-1B visas; those in computer occupations have represented at peak levels a little over half, and at lowest level a little less than one-quarter, of new H-1B visas issued.

Over two-thirds of the slightly more than 110,000 recipients of H-1B visas in 2006 are in S&T occupations (figure 3-62). A large portion of the remainder are either in closely related fields such as medicine and health (5%) or have occupational titles that often mask the S&T expertise required, such as college and university education (8%) and various managerial, administrative, and professional and technical occupations (13%).

In 2006, 51% of new H-1B recipients were in computer-related occupations, including 48% in the United States Citizenship and Immigration Services occupational category of "occupations in systems analysis and programming," which includes many S&E occupations, such as computer scientist,

Figure 3-61

Distribution of foreign-born S&E degree holders, by citizenship/visa status and year of entry to United States: 2003



NOTE: Although some data on foreign-born S&E degree holders available through 2003, data after 1999 exclude many individuals with foreign degrees.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), 2003, http://sestat.nsf.gov.

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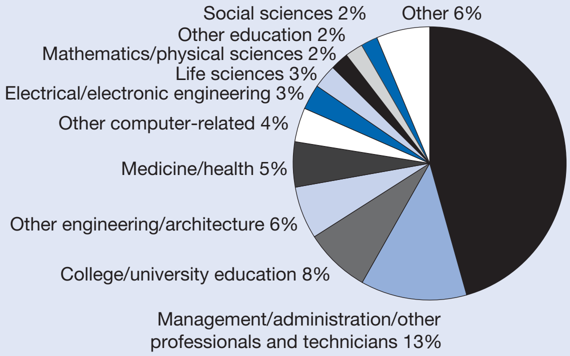
Figure 3-62
Distribution of occupations of new recipients of U.S. H-1B temporary work visas: FY 2006



NOTE: Total 2006 new H-1B visas approved: 113,593.

SOURCE: Citizenship and Immigration Services, special tabulations.

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and technician occupations, such as programmer. This actually represents an increase in recent years (from a low of 25% in 2002) in the proportion of new H-1B visas going to computer-related occupations. In 2006, 44% of those receiving new H-1B visas in computer-related occupations had master's degrees, and a little more than 1% had doctoral degrees.

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. Universities and academic research institutions are exempt from this ceiling in their own hiring, and 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. However, even with these extra allowances, the H-1B visa ceiling constrains the use of foreign scientists and engineers by private industry for R&D located in the United States. It also makes it more difficult for foreign students to stay in the United States after their studies, because long delays in the visa process usually makes it impractical to be directly hired with a permanent work visa without first being a temporary worker. For FY 2008, the ceiling on H-1B visas was reached in the first day that applications were accepted.

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, which 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). State Department counts of visas issued for each of these categories are shown in table 3-28. For all types of visas, the actual number of individuals using them is less than the number issued for any number of reasons. For example, some individuals may have job offers from employers in more than one country, and choose not to foreclose any options until a visa is certain.

Table 3-28
Temporary visas issued in categories likely to include scientists and engineers, by visa type: FY 2006

Visa type	Category	Visas
Work		
H-1B	Specialty occupations requiring bachelor's equivalent	135,421
L-1.....................	Intracompany transfers	72,613
O-1....................	People of extraordinary ability	6,961
O-2....................	Workers assisting O-1	3,726
TN	NAFTA high-skilled visa (most from Canada)	2,972
Student/exchange		
F-1	Students	273,870
J-1.....................	Exchange visitors	309,951

NAFTA = North American Free Trade Agreement

NOTES: Actual numbers of individuals entering United States likely to be lower, and H-1B numbers in particular include some visa reissuances. U.S. Citizenship and Immigration Services numbers show 109,614 new H-1B issuances in FY 2006.

SOURCE: Department of State, Immigrant Visa Control and Reporting Division, administrative data (2007).

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Characteristics of Workers Issued New H-1B Visas

Education Levels. In FY 2006, 57% of new H-1B visa recipients had advanced degrees, including 41% with master's degrees, 5% with professional degree, and 11% with doctorates. This degree distribution differs by occupation, with 87% holding advanced degrees in math and physical sciences occupations (47% with doctorates) and 89% in life science occupations (61% with doctorates).

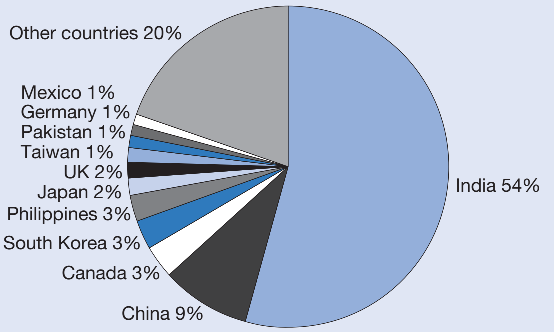
For those with advanced degrees, it may be possible to infer the proportion without prior U.S. education by examining the number seeking to be counted against the larger quota for those with advanced degrees from U.S. schools. In FY 2006, 59% of doctorate holders, 21% of professional degree holders, and 52% of master's degree holders indicated on their H-1B applications that their degree was from a U.S. school. This both documents the use of the H-1B visa as a way for graduates of U.S. schools to continue their careers in the United States, and the importance of the H-1B in bringing the foreign educated to the United States.

H-1B Country of Citizenship. H1-B visa recipients have a diverse set of citizenships, with a large representation of Indian citizens overall and Chinese citizens among those holding doctorates (figures 3-63 and 3-64). Across all recipients of new H-1B visas in FY 2006, 54% were Indian citizens, followed by 9% for China, and 3% each for Canada,[17] South Korea, and the Philippines. Among the 12,500 doctorate holders receiving new H-1B visas, 32% were Chinese citizens, followed by 13% for India, 7% for South Korea, 5% for Canada, and 3% each for Germany, the United Kingdom, and Japan. Most doctorate holders coming from countries with large university systems had low rates of claiming a U.S. degree, for example, the United Kingdom (21%), Germany (28%), Canada (29%), France (30%), and Japan (31%). In contrast, 71% of doctorate holders from China and 59% of doctorate holders from India claimed advanced U.S. degrees on their visa applications.

H-1B Salaries. Salaries paid to new recipients of H-1B temporary work visas are shown in table 3-29 by occupation group and level of degree. These starting salary figures, taken from final visa application forms sent to U.S. Citizenship and Immigration Services, are different from, and generally higher than, H-1B salaries that have been previously reported based on applications from firms to the Department of Labor,

Figure 3-63

Country of citizenship for new recipients of U.S. H-1B temporary work visas: 2006



UK = United Kingdom

SOURCE: Citizenship and Immigration Services, special tabulations.

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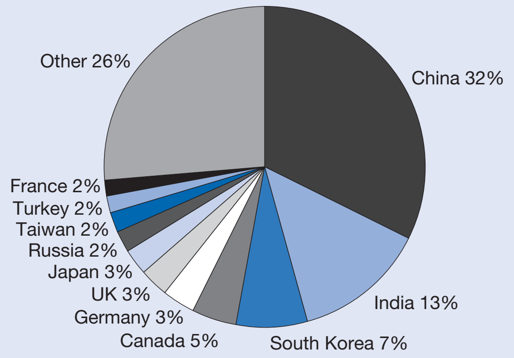
Figure 3-64

Country of citizenship for new recipients of U.S. H-1B temporary work visas holding doctorates: FY 2006



UK = United Kingdom

SOURCE: Citizenship and Immigration Services, special tabulations.

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Table 3-29

Average annual salary of new recipients of H-1b temporary work visas, by occupation and degree: FY 2006

(Dollars)

Occupation	All degree levels	Bachelor's	Master's	Professional	Doctorate
Computer-related occupations	56,200	56,000	55,600	71,200	80,400
Managers/officials nec	78,000	70,800	81,500	107,500	105,300
Miscellaneous professional/technical/managerial	64,400	54,800	68,800	na	84,500
Administrative specializations	53,500	49,600	56,200	70,100	85,100
Architecture/engineering/surveying	61,600	58,400	60,000	73,700	73,000
Art	44,800	44,500	44,400	na	na
Education	48,500	36,700	43,800	67,000	51,900
Entertainment/recreation	38,900	38,000	40,700	na	na
Law/jurisprudence	100,100	63,200	83,200	114,600	na
Life sciences	45,600	40,400	43,900	47,700	46,700
Mathematics/physical sciences	60,400	58,500	59,800	60,900	61,400
Medicine/health	72,300	48,100	51,700	86,800	62,700
Museum/library/archival sciences	41,800	39,500	41,300	na	na
Religion/theology	37,400	NA	38,500	na	na
Social sciences	60,900	54,100	64,000	na	77,600
Writing	38,200	37,900	37,500	na	na

na = not applicable; NA = not available

nec = not elsewhere classified

SOURCE: Department of Homeland Security, U.S. Citizenship and Immigration Services, special tabulations.

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which are filed much earlier in the H-1B process. The relatively low average salaries for doctorate holders in the life sciences may reflect the common use of H-1B visas to hire for relatively low-paid postdoc fellowships.

Visa Applications and Rejections for Students and Exchange Visitors

The F-1 and J-1 visas used by students and exchange visitors have recovered from the decline experienced after FY 2001 (which ended on 30 September 2001). In FY 2006, student visa applications for the first time exceeded the previous 2001 high, and visa-rejection rates were below those experienced by applicants in FY 2001 (20.1% versus 22.9% rejections in 2001) (table 3-30). Relatively few potential students are 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. In addition to reductions in the rejection rate, applications for student visas are likely to have been favorably affected by the rapid growth of demand for university education elsewhere in the world, by rising incomes in East and South Asia, and by the declines in the value of the U.S. dollar (which reduces the cost of a U.S. education for foreign students).

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 (2007) of the Oak Ridge Institute for Science and Education, 65% of 2000 U.S. S&E doctoral degree recipients with temporary visas remained in the United States in 2005. This is up from a 61% 5-year stay rate found in 2003 (figure 3-65). The 5-year stay rate has been increasing for S&E doctorate recipients from a wide number of countries.

Table 3-30
Initial applications for student/exchange visitor visas: FY 2001–06

Year	Student (F-1) Applications	Student (F-1) Refused (%)	Exchange visitor (J-1) Applications	Exchange visitor (J-1) 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
2004	282,662	22.6	274,789	7.4
2005	333,161	19.8	311,728	5.8
2006	385,596	20.1	349,598	5.9

NOTE: Application counts and refusal rates adjusted for reapplications and appeals by same individual.

SOURCE: Department of State, Immigrant Visa Control and Reporting Division, administrative data.

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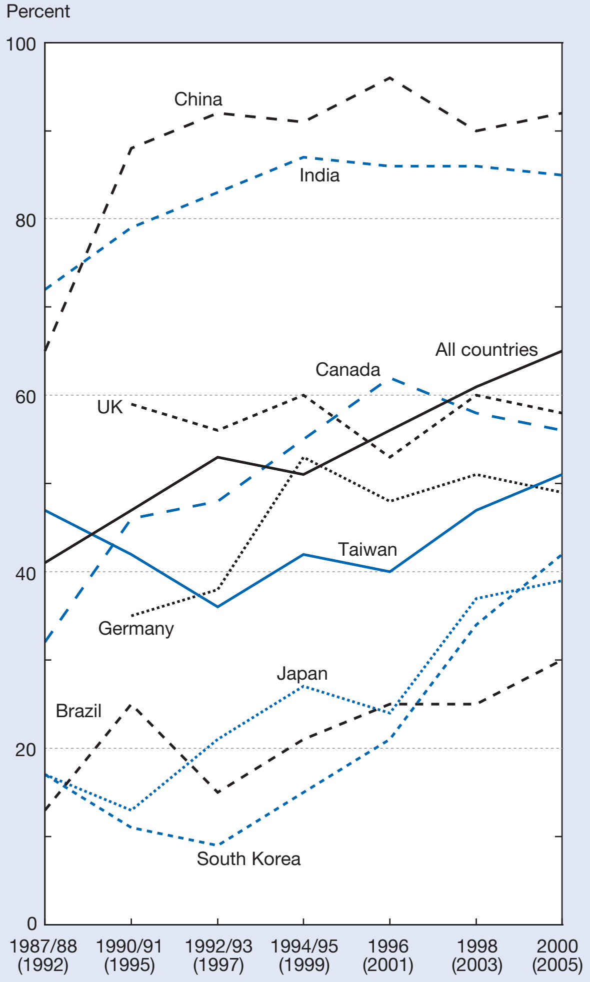
Figure 3-65
Five-year stay rates for U.S. S&E doctorate recipients with temporary visas, by place of origin: 1992–2005



UK = United Kingdom

NOTE: Year of observation in parentheses.

SOURCE: Finn M, Stay Rates of Foreign Doctorate Recipients from U.S. Universities: 2005, Oak Ridge Institute for Science and Education (2007).

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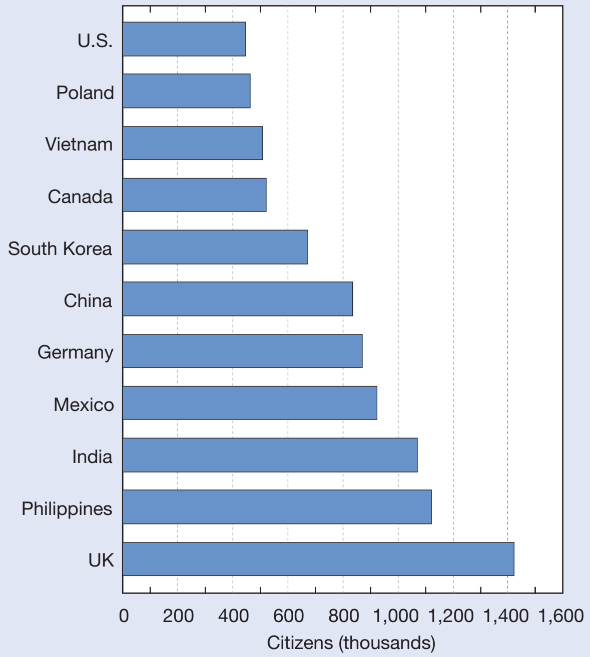
Highly Skilled Migrants in OECD Countries

Estimates of international migrants residing in OECD countries were made by Docquier and Marfouk (2004) using data from the various national censuses. Based on their data, figure 3-66 shows the 11 countries with the largest number of citizens found residing abroad 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

Figure 3-66
Top countries of origin of persons with tertiary-level education or better who reside abroad in OECD countries: 2000



OECD = Organisation for Economic Co-operation and Development; UK = United Kingdom

SOURCE: Docquier F, Marfouk A, International Migration by Educational Attainment (1990–2000), Institute for the Study of Labor (2004).

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provide advantages for a country that help to mitigate the 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.

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 doctoral 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 S&T 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. Despite this, many recent statistics suggest that the United States is still an attractive destination for many foreign scientists and engineers.

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.

Notes

1. Once a decade, NSF's surveys include non-S&E degree holders, and this was true in 2003.

2. Although BLS labor force projections do a reasonable job of forecasting employment in many occupations (see Alpert and Auyer 2003), the mean absolute percentage error in the 1988 forecast of employment in detailed occupations in 2000 was 23.2%.

3. Since their growth rate projection is near the overall average, engineers and physical scientists are classified as having average growth by BLS.

4. Not all analyses of changes in earnings are able to control for level of skill. For example, data on average earnings within occupation over time may not be a good indicator of labor market conditions if the average experience level was to fall for workers in a rapidly growing occupation.

5. Many comparisons using Census Bureau data on occupations are limited to looking at "nonacademic S&E occupations" because the occupation of "postsecondary teacher" has not been broken out into subjects in most recent census surveys.

6. Specifically presented here are coefficients from linear regressions using the 2003 Scientists and Engineers Statistical Data System (SESTAT) data file of individual characteristics on the natural log of reported full-time annual salary as of October 2003.

7. "Underrepresented ethnic group" as used here includes individuals who reported their race as black, American Indian/Alaska Native, or other, or who reported Hispanic ethnicity.

8. 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.

9. 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").

10. 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.

11. 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.

12. Although the formal job title is often postdoctoral fellowship or research associate, many different titles are used. This chapter will generally use the shorter, more commonly used, and best understood name, "postdoc." A postdoc has traditionally been defined as a temporary position, after completion of a doctorate, taken primarily for additional training—a period of advanced professional apprenticeship.

13. Some part of the citizen and permanent resident postdoc population in the fall of 2005 will not be counted even in SDR. Excluded are summer 2005 graduates who may be in postdoc positions in the fall of 2005, doctorate holders who may have left the country before April 2006, and those who have foreign doctorates.

14. A 2003 survey conducted by the Sigma Xi honor society, which was nonrepresentative and likely to undercount foreign postdocs, found that 46% of responding postdocs had received their doctorate from a non-U.S. institution.

15. Respondents also had to be under age 76 and resident in the United States in April 2006. In a similar retrospective question on the 1995 SDR, 25% of those earning their doctorates before 1964 reported having had postdocs.

16. Bureau of Economic Analysis R&D employment data are counts of full-time and part-time employees that devote the majority of their time to R&D activities.

17. Although Canadians with university degrees can use the easier-to-obtain TN visa to work in the United States, many prefer to seek H-1Bs, perhaps in part because TN visa holders are not permitted to apply for permanent resident ("green card") status. There is no preferential path to a permanent work visa for H-1B holders; they are not forbidden to seek a green card.

Glossary

EU-25: Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, and the UK.

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. These networks can provide advantages for a country that help to mitigate any loss of human capital through migration.

Involuntary employment outside of field: Those either employed outside their field because a job in that field was not available or employed part time in their field because full-time work was not available.

Stay rate: The proportion of students on temporary visas who have stayed in the United States 1–5 years after doctoral degree conferral.

Tertiary educated: Roughly equivalent in U.S. terms to individuals who have earned at least technical school or associate's degrees and including all degrees up to doctorate.

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Chapter 4

Research and Development: National Trends and International Linkages

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Highlights

National R&D Trends

U.S. R&D expenditures have continued to rise steadily since 2002, reaching an estimated $340 billion in 2006.

- After having declined in nominal terms in 2002 for the first time since 1953 to $277 billion, U.S. R&D surpassed $300 billion in 2004 and is projected to increase further to $340 billion in 2006.
- In inflation-adjusted terms, this increase represents a 2.5% average annual change over the past 4 years.

The business sector accounts for the largest share of R&D performance in the United States and provides most of the nation's R&D funding.

- The business sector's share of U.S. R&D performance peaked in 2000 at 75%, but following the economic slowdown of 2001 and 2002, the business activities of many R&D-performing firms were curtailed, with the result that the industry share fell to 69% of the U.S. R&D total, until rising again to 71% in 2006.
- In terms of funding, the business sector's share peaked at 70% of total also in 2000 but has since dipped somewhat to 64% in 2004 before inching back up to 66% of the 2006 R&D total.
- The federal share of R&D funding first fell below 50% in 1979 and dropped to a low of 25% in 2000. Reflecting initially and primarily increased research spending on health and more recently development spending in the areas of defense and counterterrorism, the federal share of R&D funding is projected at 28% of the R&D funding total in 2006.

U.S. R&D is dominated by development expenditures, largely performed by the business sector, with most basic research conducted at universities and colleges.

- In 2006, the United States performed an estimated $62 billion of basic research, $75 billion of applied research, and $204 billion of development.
- Universities and colleges historically have been the largest performers of basic research in the United States and now account for more than half (56% in 2006) of the nation's basic research. Most (59%) of the nation's basic research is federally funded.
- The development of new and improved goods, services, and processes is dominated by the business sector, which funded 83% and performed 90% of all U.S. development in 2006. The federal government funded most of the remaining development performed in the United States, mostly on defense-related activities.

Location of R&D Performance

R&D is geographically concentrated, and states vary significantly in the types of research performed within their borders.

- In 2004, more than three-fifths of U.S. R&D took place in 10 states. California alone accounted for more than one-fifth of the $300 billion of R&D that could be attributed to one of the 50 states or the District of Columbia.
- Federal R&D accounts for 85% 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.
- More than 70% of all R&D performed in the United States by computer and electronic products manufacturers is located in California, Massachusetts, Texas, and Illinois.
- The R&D of chemicals manufacturing companies is particularly prominent in three states, accounting for 66% of New Jersey's, 54% of Pennsylvania's, and 50% of Connecticut's business R&D. Together these states represent more than 40% of the nation's R&D in this sector.

Business R&D

Business sector R&D reached a new high in 2005.

- R&D performed by the business sector in the United States reached $226.2 billion in 2005 and is projected to have increased to $242 billion in 2006.
- Since a peak of 4.2% in 2001, the average R&D-to-sales intensity of companies performing R&D in the United States has varied between 3.5% and 3.9%; in 2005 it was 3.7%.
- Six industrial sectors account for more than three-fourths of all industrial R&D. The aggregate R&D intensity for these industries was 7.7% in 2005; for all other industries, the aggregate R&D intensity was 1.3%.

Federal R&D

In the president's 2008 budget submission, the federal government is slated to set aside $138 billion for R&D, amounting to 12.8% of its discretionary budget.

- Federal agencies are expected to obligate $113 billion for R&D support in FY 2007. The seven largest R&D-funding agencies (each with expected R&D obligations of more than $1 billion) account for 96% of total federal R&D.

Defense-related R&D dominates the federal R&D portfolio.

- The largest R&D activity in the FY 2008 budget is defense, with a proposed budget authority of more than $82 billion (mostly on development), or about 60% of the entire federal R&D budget ($138 billion).
- In FY 2008, the Department of Defense (DOD) requested a research, development, testing, and evaluation budget of $78 billion.
- Health accounts for the largest share of nondefense R&D support; 52% of the proposed FY 2008 nondefense R&D budget was for health-related programs.

Federal and State R&D Tax Credits

Both the federal and state governments use business tax credits to promote R&D.

- Federal R&D tax credit claims reached an estimated $5.5 billion in 2003, involving just under 10,400 corporate tax returns, compared with the all-time high of $7.1 billion in 2000.
- At least 32 states offered credits for company-funded R&D in 2006. The first such credit was enacted by Minnesota in 1982, only a year after the federal research and experimentation credit was enacted. Since then, the number of states offering a research credit has increased gradually.

International R&D Comparisons

R&D is performed and funded primarily by a small number of developed nations.

- In 2002 (the latest year of available data), global R&D expenditures totaled at least $813 billion, of which 45% 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, which accounted for $657 billion in 2002, grew to $726 billion in 2004. The G-7 countries performed more than 83% of OECD R&D in 2004. Outside of the G-7 countries, South Korea is the only country that accounted for a substantial share of the OECD total.
- More money was spent on R&D activities in the United States in 2004 than in the rest of the G-7 countries combined.
- In 2004, Brazil performed an estimated $14 billion of R&D, and India performed an estimated $21 billion in 2000, making it the seventh largest country in terms of R&D in that year, ahead of South Korea.
- China had the fourth largest expenditures on R&D in 2000 ($45 billion), which increased in 2005 to an estimated $115 billion. Given the lack of R&D-specific exchange rates, it is difficult to draw conclusions from these absolute R&D figures, but the country's nearly decade-long, steep ramp-up of R&D expenditures appears unprecedented in the recent past.

Industrial firms account for the largest share of total R&D performance in each of the G-8 countries and most OECD countries.

- No one industry accounted for more than 16% of total business R&D in the United States; most other countries display much higher industry concentrations.
- The pharmaceuticals industry accounts for 20% or more of business R&D in Denmark, the United Kingdom, Belgium, and Sweden. Among OECD countries, only the Netherlands and Japan report double-digit concentration of business R&D in the office, accounting, and computing machine industry.
- Service-sector R&D has risen from 9% of all business R&D in 1993 to 15% in 2003 for European Union countries.

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 seventh among OECD countries in terms of reported R&D/GDP ratios. Israel (not an OECD country), devoting 4.7% of its GDP to R&D, led all countries, followed by Sweden (3.9%), Finland (3.5%), and Japan (3.2%).
- 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/GDP ratios of 2.7% in 2001 (a recent high) and 2.6% in 2002 and thereafter. The U.S. R&D/GDP ratio was an estimated 2.57% in 2006.
- Most non-European (non-OECD) countries invest a smaller share of their economic output in R&D than do OECD members. For example, all Latin American countries for which such data exist have R&D/GDP ratios at or below 1%.
- Despite its growing investment in R&D, China reports an R&D/GDP ratio of just 1.3% for 2005.

R&D by Multinational Corporations

R&D by affiliates of foreign companies located in the United States increased faster than overall U.S. industrial R&D.

- Affiliates of foreign companies located in the United States performed $29.9 billion in R&D expenditures in 2004, little changed from 2003. However, between 1999 and 2004, R&D by these affiliates increased faster than overall industrial R&D in the United States (2.1% on an annual average rate basis after adjusting for inflation, compared with 0.2%).

Major developed economies accounted for the majority of overseas R&D expenditures by U.S. multinational corporations (MNCs), although certain Asian emerging markets increased their share.

- Foreign affiliates of U.S. MNCs performed $27.5 billion in R&D abroad in 2004 after adjusting for inflation, up $4.7 billion, or 17.4%, from 2003. Affiliates located in Europe represented slightly more than two-thirds of the 2004 increase. Indeed, the share of this region rebounded from an all-time low of 61% in 2001 to 66% in 2004.
- Concurrently, foreign affiliates of U.S. MNCs have increasingly engaged in R&D activities in Asian emerging markets. Within the Asia-Pacific region, Japan's share decreased from 64% in 1994 to 35% in 2004, even though it remains the largest host of U.S.-owned R&D in the region. By contrast, the R&D shares of foreign affiliates located in China and Singapore increased over this period.
- R&D expenditures by affiliates located in India doubled from $81 million in 2003 to $163 million in 2004, pushing their share within this region to 3.3%.

International Trade in R&D-Related Services

Trade in research, development, and testing (RDT) services is a relatively new indicator of international knowledge and technology flows.

- In 2005, exports of RDT services reached $10.1 billion, compared with imports of $6.7 billion, resulting in a trade surplus of $3.4 billion.
- International transactions in RDT services are available for two major categories: trade among independent or unaffiliated companies and trade among affiliates of MNCs (affiliated trade). Affiliated RDT trade has been larger than unaffiliated trade since 2001, when the former became available for the first time. The prominence of affiliated trade in business services, particularly R&D-related services, may reflect advantages of internally managing, exploiting, and protecting complex or strategic transactions involving proprietary technical information.

Federal Technology Transfer

R&D performed at federal laboratories, whether run by federal agencies themselves or by contractors, represents a key source for knowledge and technologies.

- Federal technology transfer activities and metrics reflect the variety of agency missions, R&D organization and funding structures (e.g., intramural versus extramural laboratories), the character of R&D activities, and the characteristics of potential downstream technologies or industrial users.
- The Department of Energy and DOD had the largest shares of inventions disclosed and patents, whereas the National Institutes of Health/Food and Drug Administration had the largest share of new invention licenses, according to available data for FY 2005.

Introduction

Chapter Overview

As nations seek to develop knowledge-based aspects of their economies, science, engineering, and related technological activities are recognized as key drivers. Furthermore, industrial R&D has become increasingly interconnected financially, geographically, and functionally across a number of dimensions, including performing, funding, and user sectors; scientific disciplines; and business functions.

Innovation—the introduction of new goods, services, or processes in the marketplace—builds on new knowledge and technologies, contributes to national competitiveness and government agencies' missions, and furthers social welfare. A distinction is made between R&D and the implementation or commercialization of the resulting knowledge. R&D expenditures indicate the priority given to advancing science and technology (S&T) relative to other public and private goals. For example, R&D must compete for funding with other activities supported by discretionary government spending, from education to energy to national defense. In the private sector, R&D and other innovation investments are also subject to cost-benefit analyses, including productivity and organizational issues, and are increasingly linked to broader strategic business goals.

The continued policy relevance of the national innovation landscape, which includes, for example, R&D, education, tax incentives, and intellectual property protection, is reflected in the American Competitiveness Initiative (OSTP 2006) and in the recently enacted America COMPETES Act (Public Law 110–69). In support of these efforts, Dr. John H. Marburger III, the president's S&T adviser, has challenged the policy, research, and statistical community to develop better data, models, and tools for understanding the U.S. scientific and engineering enterprise in its global context by advancing the science of science policy. Concurrently, international bodies such as the Organisation for Economic Co-operation and Development's (OECD) Working Party of National Experts on Science and Technology Indicators and the United Nations Statistical Commission have engaged in several research and methodological activities to improve metrics, including work leading to new or updated statistical manuals on innovation, globalization, national economic accounts, and services trade.

Because the organizations that fund R&D shape how it is performed and what kinds of innovations nations ultimately produce, this chapter focuses on financial inputs and flows. The chapter also presents trends in R&D performance, notably R&D by industry and the federal government. Where data permit, the chapter includes comparisons with other countries. Analyses of the R&D activities of multinational corporations (MNCs) point out the importance of this growing interconnectedness. Global R&D and related international investments still are concentrated in a few developed countries or regions. However, during the past decade, certain developing markets have increased their national R&D expenditures and have become hosts of R&D by MNCs from the United States and other advanced economies.

The chapter also introduces new indicators of industrial knowledge flows in terms of U.S. international trade in R&D-related services. Transactions in these services represent the convergence of two recent trends in industrial S&T: an increase in R&D performance in the service sector and an increase in external and overseas links in innovation activities.

Chapter Organization

This chapter is organized into seven sections that examine trends in R&D domestic and international 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 latter section also includes indicators on federal and state tax incentives for industrial R&D.

International R&D trends within nations and MNCs are discussed in the fifth and sixth sections, respectively. The former includes 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; the allocation of R&D efforts among components (basic research, applied research, and development); and international comparisons of government R&D priorities. The sixth 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.

The last section summarizes available information on external technology sourcing and collaborative R&D activities across R&D-performing sectors, including domestic contract R&D, international trade in R&D services, business technology alliances, and federal technology transfer.

National R&D Trends

The National Science Foundation (NSF) estimated that expenditures for R&D conducted in the United States would grow to $340 billion in 2006, continuing a pattern of growth largely uninterrupted since 1953, when these data were first collected (see sidebar, "Definitions of R&D"). As points of reference, U.S. R&D first exceeded $100 billion in 1984, $200 billion in 1997, and $300 billion in 2004. After adjusting for inflation, total R&D increased a projected 2.3% between 2005 and 2006, following an increase of 4.5% between 2004 and 2005.[1] These recent growth rates in R&D are in line with the average annual growth rates over the past two decades and are largely driven by increases in R&D expenditures in the business sector (figure 4-1).

Official U.S. R&D data are derived by adding up the R&D expenditures for all sectors of the economy for which

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 2002, 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. Although basic research may not have specific applications as its goal, it can be directed in fields of present or potential interest. This is often the case with basic research performed by industry or mission-driven federal agencies.

Applied research. The objective of applied research is to gain 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. U.S. statistics include separate tabulations for R&D plant (NSF/SRS 2007b), which are not generally available in comparable international R&D statistics.

Budget authority. Budget authority is the authority provided by federal law to incur financial obligations that will result in outlays.

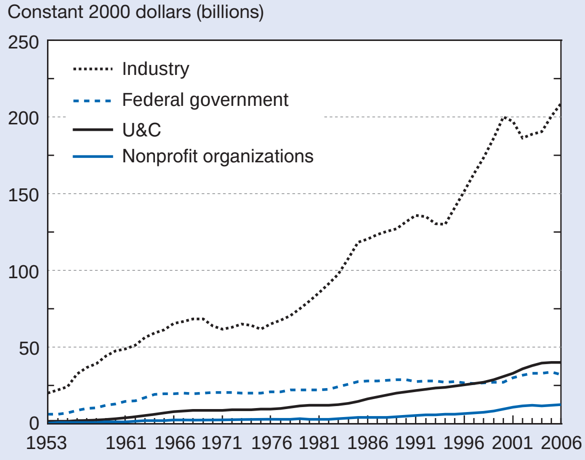
Obligations. Federal obligations represent the dollar amounts for orders placed, contracts and grants awarded, services received, and similar transactions during a given period, regardless of when funds were appropriated or payment was required.

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.

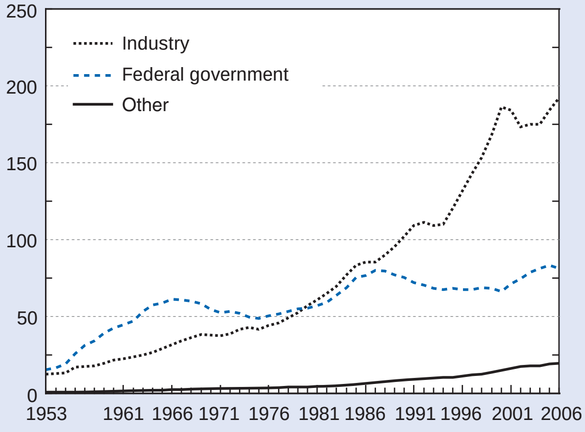
For an annotated compilation of definitions of R&D by U.S. statistical agencies, tax statutes, accounting bodies, and other official sources, see NSF/SRS (2006b).

expenditures can be reasonably estimated. Generally these figures only include expenditures on projects that are recognized as R&D and that are separately budgeted and tracked by organizations, and therefore they do not represent the total expenditures on R&D and innovation in the economy. For example, the General Electric Company notes in its 2005 annual report that its R&D expenditures for 2005 were $3.4 billion, according to the definition of R&D required by generally accepted accounting principles in the United States. However, the report goes on to state, "For operating and management purposes, we consider amounts spent on product and services technology to include our reported R&D expenditures, but also amounts for improving our existing products and services, and the productivity of our

Figure 4-1
National R&D, by performing and funding sectors, 1953–2006



Performing sector



Funding sector

U&C = universities and colleges

NOTE: Federal performers of R&D include federal agencies and federally funded research and development centers. Other includes U&C, nonprofit, and state and local governments.

SOURCE: National Science Foundation, Division of Science Resources Statistics, National Patterns of R&D Resources (annual series). See appendix tables 4-4 and 4-6.

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Unmeasured R&D

The estimates of U.S. R&D presented in this volume are derived from surveys of organizations 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.
- 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.
- Social science 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 estimated for national statistics. A new survey of state R&D is currently being collected by NSF and the Census Bureau.

Although NSF estimates the R&D performance of nonprofit organizations, a nonprofit R&D survey has not been fielded since 1998.

Recent Developments in Innovation-Related Metrics

This sidebar reports on recent or ongoing initiatives aimed at advancing innovation-related measures. As noted earlier, a distinction is made between R&D and the subsequent implementation or commercialization of the resulting knowledge.

NSF Workshop: Advancing Measures of Innovation

NSF held a workshop focused on innovation metrics during the summer of 2006, “Advancing Measures of Innovation: Knowledge Flows, Business Metrics, and Measurement Strategies.” The workshop was driven by several considerations, including the challenge by Dr. John H. Marburger III, the president’s S&T adviser, for better data, models, and tools for understanding the U.S. S&E enterprise (Marburger 2005a, b). A number of strategies for data development were discussed at the workshop: survey-based methods, data linking and data integration, nonsurvey-based methods (such as mining of administrative data), and using case studies and qualitative data. The sense of the workshop was that these diverse strategies are not mutually exclusive and can be pursued productively in parallel or in combination. For workshop presentations and a summary report, see NSF/SRS (2006a).The OECD’s Blue Sky Forum, which followed the NSF workshop, discussed the development of new and better indicators of science, technology, and innovation and developed a synthesis of findings toward an agenda for the next decade. For more information about the Blue Sky Forum, see OECD (2006a).

Federal Initiatives Supporting New Metrics

Science of Science and Innovation Policy (SciSIP) is an NSF research initiative started in the fall of 2006. The initiative is expected to develop the foundations of an evidence-based platform from which policymakers and researchers may assess the nation’s S&E enterprise, improve their understanding of its dynamics, and predict its outcomes. The research, data collection, and community development components of SciSIP’s activities will: (1) develop theories of creative processes and their transformation into social and economic outcomes; (2) improve and expand science metrics, datasets, and analytical tools; and (3) develop a community of experts on SciSIP. Additional information is available at NSF/SBE (2007).

In addition to the OSTP interagency taskforce described on page 4-11, the Department of Commerce (DOC) established the Measuring Innovation in the 21st Century Economy Advisory Committee to “study metrics on effectiveness of innovation in various businesses and sectors, and work to identify which data can be used to develop a broader measure of innovation’s impact on the economy.” The committee held its first public meeting in February 2007. See DOC (2007) for further details.

Lastly, the America COMPETES Act (Public Law 110–69) enacted in the summer of 2007 establishes, among other measures, a President’s Council on Innovation and Competitiveness. In addition to policy monitoring and advice, the Council’s duties include “developing a process for using metrics to assess the impact of existing and proposed policies and rules that affect innovation capabilities in the United States” as well as “developing metrics for measuring the progress of the Federal government with respect to improving conditions for innovation, including through talent development, investment, and infrastructure development. . . .” For the complete text of the America Competes Act, see Library of Congress (2007).

plant, equipment, and processes. On this basis, our technology expenditures in 2005 were $5.2 billion” (GE 2006). For a description of other activities not captured in official U.S. R&D statistics, see sidebar, “Unmeasured R&D.”

The U.S. innovation system comprises a diverse set of organizations, each with its own goals, priorities, and capabilities. These organizations include small businesses, MNCs, federal and state agencies, universities and colleges, research hospitals, and others. Because R&D often involves significant transfers of resources between organizations and sectors, the sections below analyze R&D both in the context of who is performing the R&D as well as in the context of who is funding the R&D.

Innovation—the introduction of new goods, services, or business processes in the marketplace—builds on new knowledge and technologies and contributes to national competitiveness and other social goals (NRC 2005b; OECD 2005; OSTP 2006). However, technology-based innovation activities include, but are not limited to, R&D. In response to the growing importance and complexity of these issues, the National Science and Technology Council, under the auspices of the White House Office of Science and Technology Policy (OSTP), has formed an Interagency Task Group on Science of Science Policy. The task group is analyzing federal and international efforts in science and innovation policy, identifying tools needed for new indicators and charting a strategic road map to improve theoretical frameworks, data, models, and methodologies. See also sidebar, “Recent Developments in Innovation-Related Metrics.”

Performers of R&D

Expenditures on R&D reported by R&D-performing organizations reflect the level of effort, in financial terms, expended on the creation of new knowledge and the use of that knowledge to devise new and improved S&T applications. However, these data in and of themselves do not indicate how successful or effective these efforts are, only how much money is spent on them. For a methodology to measure the role of R&D in economic growth, see sidebar, “The BEA/NSF R&D Satellite Account.”

Business Sector

In dollar terms, the business sector performed an estimated 71% ($242 billion of a total of $340 billion) of U.S. R&D in 2006 (figure 4-2). 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 declined by 2% per year in real terms between 2000 and 2003, and the industry share fell to 69% of the U.S. R&D total. Subsequently, R&D expenditures in the business sector grew by more than 3% per year in real terms between 2003 and 2006 and now account for 71% of the U.S. R&D total.

Of the estimated $242 billion of business sector R&D expenditures in 2006, $23 billion was funded by the federal government (table 4-1). Before the late 1960s, the federal government was the primary source of funding for business R&D, but it now accounts for less than 10% of all R&D performed by businesses in the United States. This decline in

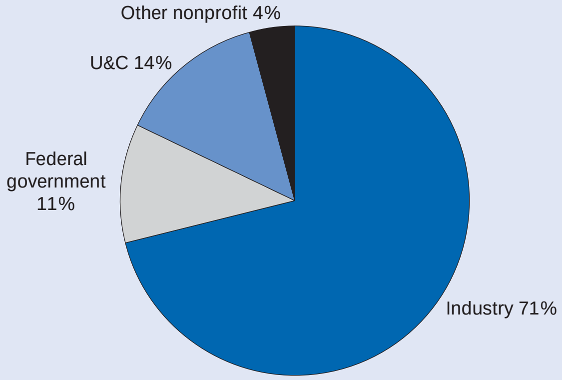
The BEA/NSF R&D Satellite Account: R&D and Economic Growth

Satellite accounts are supplementary estimates of the GDP and related measures that provide greater detail or alternative measurement concepts without changing the core accounts. In particular, the purpose of the R&D satellite account is to consider R&D as an economic investment or capital (i.e., capitalizing R&D). This is an ongoing project involving NSF’s Division of Science Resources Statistics, the agency responsible for official U.S. statistics on R&D expenditures, and the Bureau of Economic Analysis (BEA), the agency responsible for the U.S. national economic accounts. This activity is one of several interagency efforts aimed at improved measures of intangibles and their economic role (Jorgensen, Landefeld, and Nordhaus [2006]; Okubo et al. [2006]). Current plans call for the incorporation of R&D capital into the National Income and Product Accounts’ core accounts in 2013, based on the concepts developed in the satellite account.

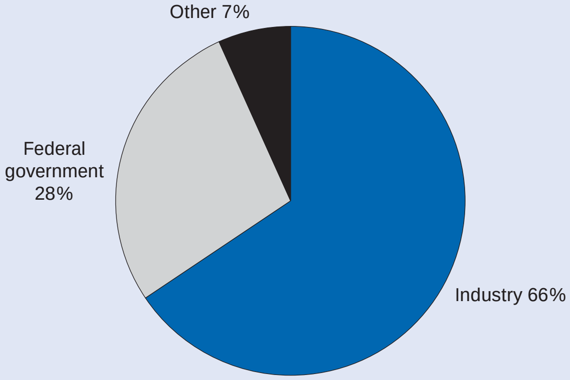
Measuring R&D as capital investment recognizes its long-term benefits much as investments in physical assets such as highways and machinery. As a newly recognized component of investment, R&D has a direct impact on GDP because business expenditures for R&D become part of economic output, instead of being treated as an expense. According to these estimates, capitalizing R&D increases the level of GDP in current dollars by an average of 2.5% per year from 1959 to 2002 (Okubo et al. 2006). In terms of GDP growth, R&D capital would account for about 4.5% of real GDP growth during that same period. During the more recent period 1995–2002, R&D investment would account for about 6.5% of growth. By comparison, according to BEA, business investment in commercial and all other types of buildings accounted for slightly more than 2% of real GDP growth between 1959 and 2002.

Further research topics include the measurement of the overall impact, both direct and indirect, of R&D activity on productivity. The indirect effects of R&D activity on productivity include spillovers that accrue when the benefits to the economy as a whole are larger than the benefits to the private owners of R&D. Additional research topics include the incorporation of international R&D flows and several methodological improvements. For more information, see BEA (2007a).

Figure 4-2
Shares of national R&D expenditures, by performing and funding sectors: 2006



Performing sector



Funding sector

U&C = universities and colleges

NOTES: National R&D expenditures projected at $340 billion in 2006. Federal performing sector includes federal agencies and federally funded research and development centers. Values rounded to nearest whole number.

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.

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federal R&D funding as reported by businesses differs from the trend in R&D data collected from federal agencies. (For details on this discrepancy, see sidebar, “Tracking R&D: Gap Between Performer- and Source-Reported Expenditures” later in the chapter.)

Universities and Colleges

The next largest sector in terms of R&D performance is the academic sector. Universities and colleges performed almost $47 billion of R&D in 2006, one-fifth the amount performed by businesses in the United States. However, universities and colleges perform more than half (56%) the nation’s basic research. (See the discussion of R&D by character of work that appears later in this chapter.) Universities and colleges rely much more than businesses on external sources of R&D funding. In 2006, slightly less than 20% of university and college R&D was funded by institutional funds, and more than 61% was funded by the federal government (table 4-1). In recent years, the amount of R&D performed by universities and colleges has grown faster than in any other sector of the U.S. economy. Academic R&D grew at an average annual 7.4% real rate between 2000 and 2003, but more recently this growth slowed to 1.9% per year in real terms between 2003 and 2006. See chapter 5 for a more detailed discussion of trends in academic R&D expenditures.

Federal Agencies and FFRDCs

Federal agencies and federally funded research and development centers (FFRDCs) accounted for an estimated 11% of the R&D performed in the U.S. in 2006.[2] Although the amount of R&D performed by these organizations is small compared to the U.S. business sector, the $37 billion in R&D expenditures at these organizations exceeds the total national R&D expenditures of every country in the world other than China, Germany, and Japan. These expenditures also do not include the sizable investments the U.S. government has made in R&D infrastructure and equipment. The federal government often maintains research facilities and conducts research projects that would be too costly or risky for a single company or university to undertake. Largely as a result of increased defense spending following the terrorist attacks of September 11, 2001, expenditures for R&D conducted by federal agencies and FFRDCs grew at the rapid rate of almost 6.6% per year in real terms between 2000 and 2003. In terms of total U.S. R&D, this growth helped offset the decline in business sector R&D during that period. Since 2003, the real R&D expenditures at federal agencies and FFRDCs have remained basically flat. Federal R&D is discussed in more detail later in this chapter.

R&D Funding

The funding for R&D conducted by organizations in the United States can come from a variety of sources, including the organizations’ own funds as well as contracts and grants from other organizations. Although data on the flows of R&D funding within sectors (such as between two companies) is limited, data on the flows of R&D between sectors indicate that financial relationships between organizations play a significant role in the U.S. R&D system. In 2006, an estimated 20% of U.S. R&D ($67 billion) was funded by an organization in a different sector than the performing sector. Most of this intrasector R&D funding comes from the federal government, which funds significantly more R&D than it conducts in its own laboratories and FFRDCs (table 4-1). Unlike the federal government, most businesses spend their R&D budgets on either internal R&D projects or for contract R&D performed by other businesses (see the section entitled “Technology Linkages”). Less than 2% of business R&D funding flows to universities and other nonprofit organizations, although industry funded approximately 5% of all universities’ 2006 R&D.

Table 4-1
U.S. R&D expenditures, by funding and performing sectors: 2006
(Millions of current dollars)

Performing sector	Source of funds					All expenditures (% distribution)
	All sources	Industry	Federal government	U&C	Other nonprofit institutions	
R&D	340,429	223,370	94,217	12,354	10,488	100.0
Industry	242,129	219,569	22,560	NA	NA	71.1
Industry-administered FFRDCs	2,426	NA	2,426	NA	NA	0.7
Federal government	24,408	NA	24,408	NA	NA	7.2
U&C	46,642	2,452	28,548	12,354	3,288	13.7
U&C-administered FFRDCs	7,720	NA	7,720	NA	NA	2.3
Other nonprofit institutions	14,270	1,349	5,721	NA	7,200	4.2
Nonprofit-administered FFRDCs	2,834	NA	2,834	NA	NA	0.8
Percent distribution by source	100.0	65.6	27.7	3.6	3.1	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 ($3,057 million in total R&D) included in U&C support for U&C performance.

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

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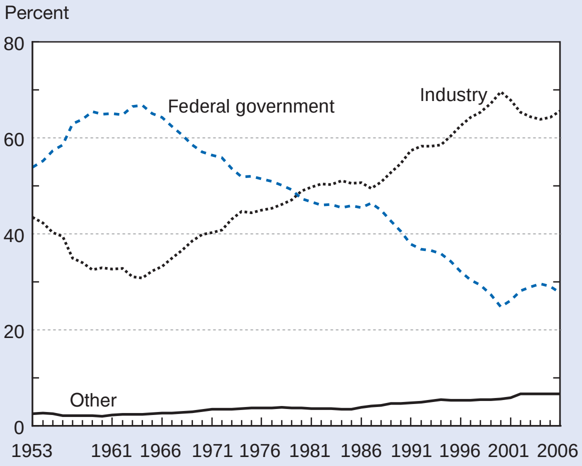
Federal R&D Funding

In 2006, the federal government is projected to have funded $94 billion of R&D as reported by performers of R&D, accounting for 28% of all R&D funding in the United States (figure 4-2). The federal government was once the foremost sponsor of the nation's R&D, funding as much as 67% 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 25% in 2000. The declining share of federal R&D funding is most evident in the business sector. In the late 1950s and early 1960s, more than 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. The decades-long trend of federal R&D funding shrinking as a share of the nation's total R&D reversed between 2000 and 2004. During this period, private investment slowed and federal spending on R&D expanded, reflecting initially and primarily increased research spending on health, and, more recently, development spending in the areas of defense and counterterrorism. By 2004, the federal share of the nation's R&D funding had increased to 30%. The federal share of R&D funding has since declined to an estimated 28% in 2006, as noted earlier.

Nonfederal R&D Funding

R&D funding from nonfederal sources reached an estimated $246 billion in 2006. Business sector funding dominates nonfederal R&D support. Besides performing the majority of U.S. R&D, the business sector also is the largest source of R&D funding in the United States, providing 66% ($223 billion) of total R&D funding in 2006 (figure 4-2). 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 almost 8%. This growth was maintained 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% per year in real terms. However, from 1994 to 2000, industrial R&D support grew in real terms by more than 9% per year. This rapid growth rate came to a halt following the downturn in both the market valuation and economic demand for new technology during the first years of the 21st century. Between 2000 and 2002, industrial R&D support declined by more than 3% per year in real terms, but

Figure 4-3
National R&D expenditures, by funding sector: 1953–2006



SOURCE: National Science Foundation, Division of Science Resources Statistics, National Patterns of R&D Resources (annual series). See appendix table 4-5.

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between 2002 and 2006, it grew by almost 3% per year in real terms.

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. Between 1986 and 2006, funding from these sectors grew almost 6% per year in real terms, faster than R&D funding from either the federal or business sectors. Most of these funds went to research performed within the academic sector.

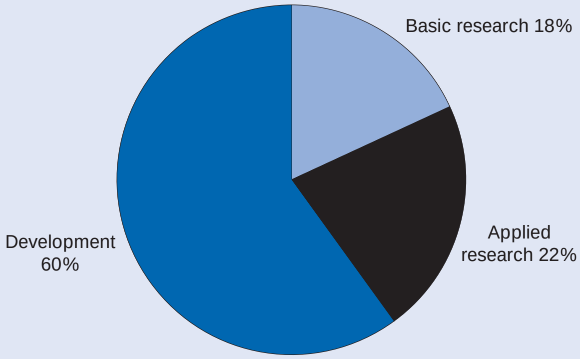
Unlike some other countries, the United States does not currently measure the amount of domestic R&D that is funded by foreign sources. However, data on investments of foreign MNCs provide some indication of this activity for the industrial sector (see the section entitled "R&D by Multinational Corporations" later in this chapter).

R&D by Character of Work

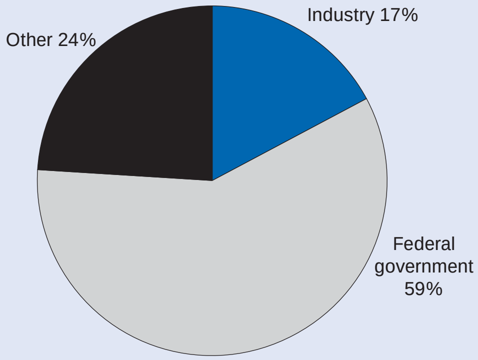
R&D encompasses a wide range of activities, from fundamental research in the physical, life, and social sciences; to research addressing critical issues such as global climate change, energy efficiency, and disease; to the development of new and improved goods and services (from razor blades to fighter jets to business software). Because these activities are so diverse, it is helpful to group them into categories when analyzing R&D expenditures. Historically, the most common set of categories used to classify R&D are basic research, applied research, and development. The categories have been criticized by some economists and policymakers as being overly simplistic and reinforcing the idea that innovation is a linear process beginning with basic research, followed by applied research and development, and ending with the production and diffusion of technology. Although alternative models have been proposed, they have not been widely adopted by policymakers because of a lack of consensus about them and/or a lack of official data robust enough to support them.[3] Despite the difficulties in classifying specific R&D projects, the categories presented here help characterize the motivation, expected time horizons, outputs, and types of investments associated with R&D expenditures.

In 2006, the United States performed an estimated $62 billion of basic research, $75 billion of applied research, and $204 billion of development. As a share of all estimated 2006 R&D expenditures, basic research represented 18%, applied research represented 22%, and development represented 60% (figure 4-4). Historically, the federal government has been the primary source of support for basic research. In 2006, federal funding accounted for 59% of U.S. basic research (figure 4-4). Moreover, in 2006 the federal government funded 64% of the basic research performed by universities and colleges, the largest performers of basic research in the United States. Industry devoted only a projected 4% of its total R&D support to basic research in 2006 (figure 4-5). The reason for industry's relatively small contribution to basic research is

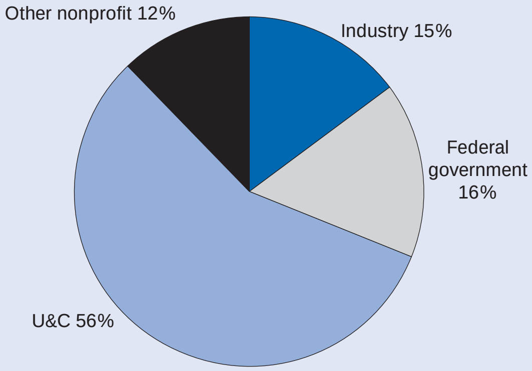
Figure 4-4
National R&D, by character of work, and basic research, by funding and performing sectors: 2006



National R&D, by character of work



Basic research, by funding sector



Basic research, by performing sector

U&C = universities and colleges

NOTES: National R&D expenditures projected at $340 billion in 2006. Federal performers include federal agencies and federally funded research and development centers. Figures rounded to nearest whole number. Due to rounding, detail may not sum to totals.

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.

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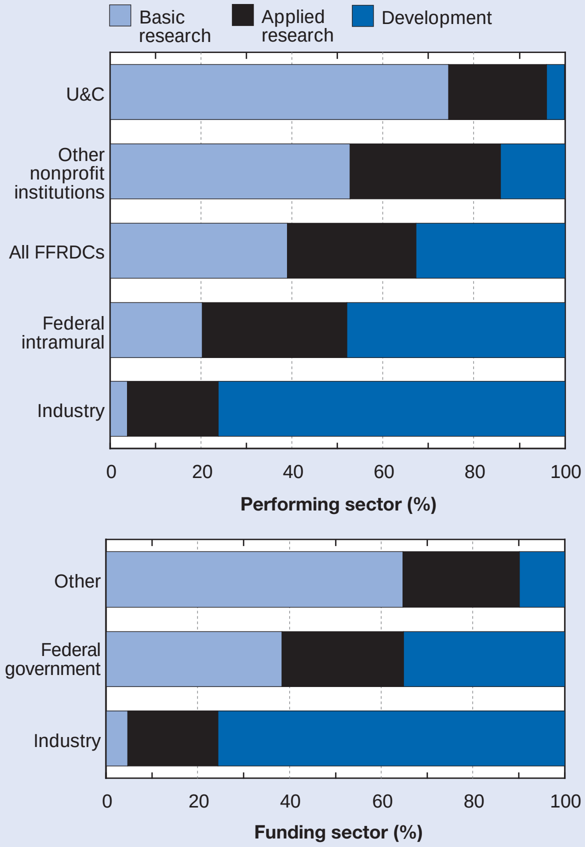
Figure 4-5
R&D performing and funding sectors, by character of work: 2006



FFRDCs = federally funded research and development centers; 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 ($3,057 million in total R&D) included in U&C support for U&C performance.

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.

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that basic research generally involves a high degree of uncertainty with respect to the near-term commercial value of any discovery and the ability of the firm to enforce property rights over the discovery. However, firms may have other reasons for performing basic research above and beyond 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&T, such as the pharmaceuticals industry and the scientific R&D services industry.

The business sector spends more than four times as much on applied research as on basic research and accounts for more than half of U.S. applied research funding. In 2006, industry invested an estimated $44 billion in applied research funding, 59% of the U.S. total. 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 companies whose business is licensing technology). Although most of the federal investment in basic research supports research at universities and colleges, the majority of federally funded applied research is performed by federal agencies and FFRDCs.

Development expenditures totaled an estimated $204 billion in 2006, representing the majority of U.S. R&D expenditures. The development of new and improved goods, services, and processes is dominated by industry, which funded 83% of all U.S. development in 2006 ($169 billion). The federal government funded most of the remaining development performed in the United States, totaling 16% or $33 billion. Most federal development spending is defense related. The federal government generally invests in the development of such products as military aircraft, for which it is the only consumer. The business sector conducts even more development than it funds, accounting for 90% of all development conducted in the United States in 2006. Universities, colleges, and other nonprofit institutions conducted less than 2% of U.S. development. The balance of development is conducted by federal agencies and FFRDCs.

The OECD notes that in measuring R&D, possibly the greatest source of error “is the difficulty of locating the cut-off point between experimental development and the related activities required to realize an innovation” (OECD 2002). Most definitions of R&D set the cut-off point to be when a particular product or process reaches the point of “market readiness.” At this point, the defining characteristics of the product or process (at least for manufacturers, if not also for services) are substantially set, and further work is primarily aimed at developing markets, doing preproduction planning, or getting a production or control system working smoothly.

Location of R&D Performance

R&D performance is geographically concentrated in the United States. More than 50% of U.S. R&D is performed in only seven states.[4] 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 table 4-23). (For a broader range of indicators of state-level S&E activities, see chapter 8.)

Distribution of R&D Expenditures Among States

In 2004, the 20 highest-ranking states in R&D expenditures accounted for 85% of U.S. R&D expenditures, whereas the 20 lowest-ranking states accounted for 5%. (A complete list of state rankings is provided in appendix table 4-24.) The top 10 states accounted for more than three-fifths of U.S. R&D expenditures in 2004 (table 4-2). California alone accounted for approximately one-fifth of the $300 billion U.S. R&D total, exceeding the next highest state (Michigan) by more than a factor of three.[5] 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 share of GDP. Like the ratio of national R&D to GDP discussed later in this chapter, the proportion of a state's GDP devoted to R&D is an indicator of R&D intensity. Some of the states with the highest R&D to GDP ratios include New Mexico and Maryland, home to major government research facilities; Massachusetts, home to a number of large research universities and a thriving high-technology industry; and Michigan, home to the major auto manufacturers. 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 U.S. R&D total that can be distributed among states, 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). Connecticut, 10th in terms of business sector R&D, replaced Maryland among the leading 10 states for total R&D. University-performed R&D accounts for only 15% of the U.S. total, but it is also highly correlated with the total R&D performance in a state. Only New Jersey and Washington, among the top 10 total R&D state locations, were not among the top 10 locations for university R&D performance. North Carolina and Ohio rounded out the academic R&D top 10.

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.[6] The top four states in terms of federal R&D (Maryland, California, New Mexico, and Virginia), along with the District of Columbia, account for two-thirds of all federal R&D performance. Federal R&D accounts for 85% 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 about 50% of all R&D performed in Maryland, Virginia, and the District of Columbia, reflecting the concentration of federal facilities and adminis-

Table 4-2
Top 10 states in R&D performance, by sector and intensity: 2004

	All R&D[a]		Sector ranking			R&D intensity (R&D/GDP ratio)		
Rank	State	Amount (current $millions)	Industry	U&C	Federal intramural and FFRDC[b]	State	R&D/GDP (%)	GDP (current $billions)
1	California	59,607	California	California	Maryland	New Mexico	8.01	63.9
2	Michigan	16,722	Michigan	New York	California	Maryland	6.26	229.2
3	Massachusetts	15,987	Massachusetts	Texas	New Mexico	Massachusetts	5.17	309.5
4	Maryland	14,341	New Jersey	Maryland	Virginia	Michigan	4.60	363.4
5	Texas	14,266	Texas	Pennsylvania	District of Columbia	Rhode Island	4.36	42.2
6	New York	13,113	Washington	Massachusetts	Massachusetts	Washington	4.33	252.4
7	New Jersey	12,460	New York	Illinois	Illinois	Connecticut	4.29	183.9
8	Illinois	11,300	Illinois	North Carolina	Washington	California	3.93	1,515.5
9	Washington	10,936	Pennsylvania	Michigan	Alabama	New Hampshire	3.22	51.7
10	Pennsylvania	10,813	Connecticut	Ohio	Tennessee	District of Columbia	3.06	77.8

FFRDC = federally funded research and development center; GDP = gross domestic 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.

NOTE: 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 Bureau of Economic Analysis, Gross Domestic Product by State (2006), http://www.bea.gov/regional/gsp, accessed 25 August 2007.

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trative offices within the national capital area. Federal R&D also represents 33% of the R&D performed in Alabama and West Virginia. The Departments of Energy (DOE) and Agriculture (USDA) account for the largest shares of federal intramural R&D performance in West Virginia, whereas DOD's Redstone Arsenal laboratories and the National Aeronautics and Space Administration's (NASA) George C. Marshall Space Flight Center, both in Huntsville, account for most of Alabama's federal R&D activity. Looking across all states, federal R&D represents 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 74% of industrial R&D in 2005, whereas it accounted for only 7% of the nation's total industrial R&D.

The computer and electronic products manufacturing industries perform 19% of the nation's total industrial R&D, but they perform a larger share of the industrial R&D in Massachusetts (41%), Texas (38%), Illinois (38%), and California (33%). These states have clearly defined regional centers of high-technology research and manufacturing: Cambridge and Route 128 in Massachusetts; the Silicon Hills of Austin, Texas; Champaign County in Illinois; and Silicon Valley in California. More than 70% of R&D performed in the United States by computer and electronic products companies in 2005 was located in these four states, representing 14% of all business R&D nationwide.

The R&D of chemicals manufacturing companies is particularly prominent in New Jersey, Pennsylvania, and Connecticut, all of which host robust pharmaceutical and chemical industries. According to the American Chemistry Council, together these states host more than 1,600 chemical manufacturing establishments and rank among the top 20 in chemical industry employment (American Chemistry 2007). These companies accounted for 66% of New Jersey's, 54% of Pennsylvania's, and 50% of Connecticut's business R&D in 2005. Together these three states represented more than 40% of the nation's R&D in this sector.

The R&D services sector, which consists largely of biotechnology companies, contract research organizations, and early-stage technology firms, is even more concentrated geographically, with California and Massachusetts accounting for more than 40% of R&D in this sector. The companies in this sector maintain strong ties to the academic sector and often are located near large research universities (Stuart and Sorenson 2003).

The R&D performance of small companies (defined as having from 5 to 499 employees) is also concentrated geographically.[7] Nationally, small companies perform 18% of the nation's total business R&D, but in California, Massachusetts, and New York these companies perform between 19% and 22% of the states' business R&D. About 39% of the R&D performed in the United States by companies in this category is performed in these three states. Overall, these companies performed 7% of the nation's R&D in 2005.

Table 4-3
Top 10 states in industry R&D performance and share of R&D, by selected industry: 2005
(Percent)

State	Industry-performed R&D (current $millions)	Chemicals	Computer and electronic products	Computer-related services	R&D services	Motor vehicles	Companies with 5–499 employees
All states	226,159	19.0	19.2 L	13.5	7.5	7.1 L	17.9
California	50,683	11.2	33.2	15.0	10.7	D	21.8
Michigan	16,752	9.5	2.3	D	1.5	74.3	6.2
Massachusetts	13,342	13.2	41.1	D	11.1	D	22.3
New Jersey	13,214	65.7	5.7	3.5	5.6	0.2	13.1
Texas	12,438	4.7	37.4	18.3	6.3	0.5	16.1
Washington	9,736	5.5	5.6	D	6.3	0.7	11.7
Illinois	9,712	18.9	37.4	5.1	1.7	2.4	12.4
New York	9,474	28.4	6.6	18.8	3.7	D	18.5
Pennsylvania	8,846	54.2	6.9	6.0	8.3	0.4	15.4
Connecticut	7,885	50.3	3.5	2.4	4.0	0.1	11.5

L = lower-bound estimate; D = suppressed to avoid disclosure of confidential information

NOTES: Rankings do not account for margin of error of estimates from sample surveys. Detail does not add to total because not all industries shown.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Industrial Research and Development.

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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. 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 improvements in the business sector. By extension, they may reflect firms' perceptions of the market's demand for new and improved technology.

R&D performed by the business sector reached $226 billion in 2005. The federal government funded 9.7% ($22 billion) of this total, and company funds and other private sources financed the remainder (appendix tables 4-19, 4-20, and 4-21). These estimates are derived from the NSF-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 R&D investment of the business sector and are the official source for U.S. business R&D estimates (see sidebar, "Industry Classification").

In addition to absolute levels of R&D expenditures, another key company 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, including the ratio of R&D to GDP discussed earlier. The measure used most frequently is the ratio of company-funded R&D to net sales.[8] 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 reached its highest reported level of 4.2% in 2001; R&D performance remained steady compared with the previous year, while sales of R&D-performing companies declined. Since then, R&D intensity has varied between 3.5% and 3.9%; in 2005, it was 3.7%.

Largest R&D Industries

Although all industries benefit from advances in S&T, industries perform different amounts of R&D.[9] Some industries have relatively low R&D intensities (0.5% or less), such as the utilities industry[10] and the finance, insurance, and real estate industries. Appendix table 4-22 provides data on company-funded R&D to net sales ratios for an array of industries.[11] Six industries, four manufacturing and two services industries, account for 75% of company-funded business R&D and 95% of federally funded business R&D (table 4-4).[12]

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 miniatur-

Industry Classification

As a result of classification conventions, interpretation of industry-level R&D data is not always straightforward. Initially, each company sampled in NSF's Survey of Industrial Research and Development is assigned to a single industry according to payroll data for the company,* and each is requested to report its R&D expenditures for the entire company. These expenditures are assigned to the previously classified 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.

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. Consequently, beginning with the 2004 cycle of the survey, the assigned industry classification of companies in selected industries (such as wholesale trade) and also companies that most influence the overall R&D performance estimates is subjected to manual review and potential reclassification. Wherever possible, this report includes industry-level data that results from this new method of industry classification.†

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* Details on how companies are assigned initial industry codes based on payroll in the NSF Survey of Industrial Research and Development can be found at NSF/SRS (2002b). For information on the current industry classification process, see NSF/SRS (2004b).

† The impact of the new industry classification methodology is detailed in NSF/SRS (2007d).

ization technologies are common elements in the production processes of the computer and electronic products sector.

In 2005, these industries performed at least $43.5 billion of R&D, or 19% of all business R&D.[13] Companies and other nonfederal sources funded almost this entire R&D. The focus of the R&D in this sector is on development, with less than 25% 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 2005.

Chemicals

The chemicals industry performed an estimated $43.0 billion of R&D in 2005. Like the computer and electronic products industries, relatively 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 2005, pharmaceutical companies performed $34.8 billion of company-funded R&D, representing 81% 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 about their R&D. In 2005, PhRMA estimated that its members invested $31.4 billion in R&D performed in the United States, which was 19.2% of domestic sales and 15.8% of global sales (PhRMA 2006a).[14] According to PhRMA, members' domestic R&D investment supports continuing R&D on projects that originated in their own laboratories, but 25% supports R&D on products licensed from other companies (notably biotechnology companies), universities, or the government (PhRMA 2006b). 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 sizable amount of biotechnology R&D that serves the pharmaceutical industry is reported in the R&D services sector (see the section entitled "R&D Services").

Computer-Related Services

Industries associated with software and computer-related services (such as data processing and systems design) performed approximately $30.5 billion of company-funded R&D in 2005. The R&D of these industries, combined with that of the computer and electronic products manufacturers discussed earlier, accounted for 33% of all industrial

Table 4-4

R&D and domestic net sales, by selected business sector: 2004 and 2005

(Millions of current dollars)

	All R&D		Federal R&D		Company R&D		Domestic net sales		All R&D/sales ratio (%)	
Sector	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005
All industries	208,301	226,159	20,266	21,909	188,035	204,250	5,601,729	6,119,133	3.7	3.7
Highlighted sectors	163,102 L	174,970 L	19,122 L	20,867 L	143,980	154,102	2,205,651	2,268,642	7.4	7.7
Computer and electronic products[a]	40,964	43,520 L	273	1,057 L	40,691	42,463	506,103	472,330	8.1	9.2
Chemicals	39,224 L	42,995	154 L	169	39,070	42,826	595,292	624,344	6.6	6.9
Computer-related services[b]	28,117 L	30,518	410 L	578	27,707	29,939	166,545	213,574	16.9	14.3
Aerospace and defense manufacturing[c]	23,567 L	24,926 L	14,343 L	13,998 L	9,224	10,928	228,018	227,271	10.3	11.0
R&D services[d]	15,620	16,986	3,942	5,065	11,678	11,921	66,614	84,637	23.4	20.1
Automotive manufacturing[e]	15,610 L	16,025	NA	NA	15,610	16,025	643,079	646,486	2.4	2.5
All other industries	45,199 L	51,189 L	1,144 L	1,042 L	44,055	50,148	3,396,078	3,850,491	1.3	1.3

L = lower-bound estimate; NA = not available

[a] Includes all nonfederal R&D and domestic net sales for the navigational, measuring, electromedical, and control instruments industry. All federal R&D for navigational, measuring, electromedical, and control instruments industry included in aerospace and defense manufacturing sector.

[b] Includes R&D and domestic net sales for software and computer systems development industries.

[c] Includes all R&D for aerospace products and parts, plus all federal R&D for navigational, measuring, electromedical, and control instruments and automotive and other transportation manufacturing industries. Domestic net sales not included for automotive and other transportation manufacturing industries.

[d] Includes R&D and domestic net sales for architectural, engineering, and related services and scientific R&D services industries.

[e] Federal R&D for all transportation manufacturing industries (including automotive manufacturing) included in aerospace and defense manufacturing sector.

NOTE: Potential disclosure of individual company operations only allows lower-bound estimates for some sectors.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Industrial Research and Development.

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R&D in 2005. As computing and information technology became more integrated with every sector of the economy, the demand for services associated with these technologies boomed.

Between 1987 and 2005, the R&D of companies providing these services grew dramatically. 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 2005, the company-funded R&D of these industries (excluding engineering and architectural services) accounted for 14.7% of all company-funded industrial R&D, and these companies accounted for 3.5% of domestic sales of R&D-performing companies (table 4-5).[15] 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. To approximate the cost of defense-related R&D, one can focus on the federally supported R&D performed by these industries. In 2005, these industries reported performing $14.0 billion of federal R&D, about two-thirds of all federal industrial R&D expenditures (table 4-4).[16] This accounts for more than half of the $25.0 billion the "defense industry" as a whole spent on R&D, including both federal and nonfederal sources of funds. (See the section entitled "Federal R&D" later in this chapter for further discussion of defense R&D.)

R&D Services

Companies in the business of selling S&E 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; $5.1 billion in 2005. 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 $11.9 billion in 2005.[17] 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 (20% in 2005).

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 "Technology Linkages.")

Table 4-5

Estimated share of computer-related services in company-funded R&D and domestic net sales of R&D-performing companies: 1987–2005

(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
2004	14.7	3.0
2005	14.7	3.5

NOTES: Before 1998 companies classified in Standard Industrial Classification (SIC) industries 737 (computer and data processing services) and 871 (engineering, architectural, and surveying services). 1998–2005 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 was 10.4% for 1998, indicating 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 (annual series 1987–2005); and special tabulations.

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Trends in R&D for Industrial Research Institute Members

For more than 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. Dr. Jules J. Duga, a senior analyst at the Battelle Memorial Institute in Columbus, Ohio, notes (in a personal communication) that the IRI survey

> . . . provides a reasonable overview of the actions that are being taken by industry. Although the internal analysis of IRI survey results does not delve deeply into the driving forces for the stated planning, the overall results are certainly a reflection of industrial response to markets, federal actions, and approaches for the most effective means for acquiring technological assets. Although there have been changes in the type of membership pattern that is represented within IRI, and there are similar changes in the character of the respondents, the IRI survey provides a long-term envelope of planning and practices as applied to R&D, and results in there being the raw material for qualitative and semi-quantitative longitudinal studies that well serve the objectives of industrial science policy analyses. One of the major characteristics of the IRI survey is that for all intents and purposes the questionnaire has maintained the same format for many years, thus permitting the development of a long-term analytical framework with a minimum of disruptions. The analysis of the responses to individual questions, as well as the introduction of a so-called “sea change” indicator, provides a series of snapshots of postures. Over the past few years, efforts have been directed toward viewing clusters of responses to questions that have internal conceptual linkages. Such an approach has provided a means for developing broader pictures of the driving forces and action items that are influencing industrial R&D strategy.

The most recent survey, administered during the summer of 2006, suggests that many companies continue to shift the focus of their R&D spending away from directed basic research and the support of existing business to new business projects (IRI 2007). 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 2007:

- 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
- Increase licensing of technology to and from other companies
- Increase acquisition of technological capabilities through mergers and acquisitions

Overall, these strategic moves are consistent with responses suggesting increased R&D budgets. 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 the section entitled “Technology Linkages.”)

Automotive Manufacturing

The sixth largest business sector in terms of R&D is automotive manufacturing. Companies in this industry reported performing $16.0 billion of company-funded R&D in 2005, accounting for 7.1% 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; for example, in 1959, automotive manufacturing accounted for as much as 16.2% of all company-funded and -performed R&D.

In 2004, nine companies in the automotive manufacturing industry reported R&D expenditures of more than $100 million, representing more than 80% 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 toward large companies, with the R&D activities of General Motors, Ford, and DaimlerChrysler dominating the sector. In their reports to the Securities and Exchange Commission, these companies reported R&D expenses of $21.1 billion in 2004 (see sidebars, “Trends in R&D for Industrial Research Institute Members” and “R&D Expenses of Public Corporations”).[18]

Federal R&D

In the president’s 2008 budget submission, the federal government is slated to invest $138 billion in R&D, amounting to 12.8% of its discretionary budget (i.e., that part of the annual federal budget that the president proposes and Congress debates and sets). The government supports S&T

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 2004, the 25 public corporations with the largest reported worldwide R&D expenses spent $127.3 billion on R&D. The three companies that topped the list were automobile manufacturers. Ford Motor Company, DaimlerChrysler, and Toyota, together with the other four automobile manufacturers on the list, reported spending $41.0 billion on R&D (32.5% of the total for the top 25) (table 4-6). There are 10 companies in the information and communications technologies (ICT) sector that spent a total of $49.4 billion (38.8% of the total). The remaining eight companies include six pharmaceutical manufacturers and two diversified consumer product-oriented manufacturers. As Hira and Goldstein (2005) point out, although four of the five top leaders in R&D in 2004 were automobile manufacturers, which is a marked difference compared with 2000, when the top four spenders were the telecommunications giants Ericsson, Lucent, Motorola, and Nortel, “automakers face an uncertain near-term outlook because of pressures from an increasing cost structure and the need to achieve shorter product life cycles to meet rapidly changing consumer preferences.”

The top 25 companies are headquartered in seven 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 by Multinational Corporations.”)

Overall, R&D spending for the top 25 increased 4.0% in 2004 compared with 2003. Sales for the group as a whole increased 6.8%; sales increased in the 6%–8% range for the automobile and pharmaceutical manufacturers and ICT companies in the group, and more than 11% for the consumer product manufacturers. R&D expenditures increased for the manufacturers (pharmaceutical, 6.9%; automobile, 6.3%; and consumer products, 10.4%). However, the ICT companies, representing the sector with traditionally the highest R&D intensity, reported only a 0.1% increase.

It should be noted that a recent change in accounting standards by the Financial Accounting Standards Board (FASB) may 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 2004, most large companies began following the guidelines of FASB’s Statement of Financial Accounting Standards, “Accounting for Stock-Based Compensation,” which requires companies to expense the fair value of all stock-based compensation.* 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 before these new guidelines. For example, according to Hira and Goldstein (2005), “Microsoft’s R&D spending decreased 20.5% in 2004 despite an increase in R&D employees. According to its U.S. Securities and Exchange Commission filings, the decrease was “‘due to lower stock-based compensation expense’ [because] in 2003 the company began offering its employees stock-based compensation in lieu of options. This affected its R&D accounting significantly. . . .” For information on how many of the largest U.S.-based corporations intended to adjust their R&D strategies and spending, see sidebar, “Trends in R&D for Industrial Research Institute Members.”

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* See FASB (2004); Hira and Goldstein (2005). For information about how FASB standards as they apply to U.S. firms compare and converge with the standards of the International Accounting Standards Board, see FASB (2007).

through a number of policy measures, the most direct of which is the conduct and funding of R&D that would not, or could not, be conducted or financed in the private sector. This section presents data on such R&D activities, on the government’s contribution to the U.S. R&D infrastructure, and on federal and state R&D tax credits (an indirect means of stimulating R&D in the private sector).

R&D by Federal Agency

Federal agencies are expected to obligate $113 billion for R&D support in FY 2007 (table 4-7). Although more than 25 agencies report R&D obligations, only 7 report expected R&D obligations of more than $1 billion in FY 2007. Together, these agencies account for 96% of total federal R&D. These agencies vary considerably in terms of their R&D funding, reflecting the unique mission, history, and culture of each.

Table 4-6
Top 25 R&D-spending corporations: 2004

	R&D rank		R&D expense ($millions)			Sales ($millions)		R&D intensity (%)	
Company (country)	2004	2003	2004	2003	Change (%)	2004	2003	2004	2003
Ford Motor (U.S.)	1	2	7,400	7,500	–1.3	171,652	164,196	4.3	4.6
DaimlerChrysler (Germany)	2	4	7,187	7,076	1.6	180,448	173,307	4.0	4.1
Toyota Motor (Japan)	3	6	7,052	6,372	10.7	173,254	161,517	4.1	3.9
Pfizer (U.S.)	4	3	6,613	7,131	–7.3	52,516	45,188	12.6	15.8
General Motors (U.S.)	5	7	6,500	5,700	14.0	190,812	182,005	3.4	3.1
Siemens (Germany)	6	5	6,431	6,436	–0.1	95,480	94,293	6.7	6.8
Microsoft (U.S.)	7	1	6,184	7,779	–20.5	39,788	36,835	15.5	21.1
Matsushita Electric Industrial (Japan)	8	8	5,748	5,409	6.3	81,377	69,854	7.1	7.7
GlaxoSmithKline (UK)	9	9	5,251	5,162	1.7	37,655	39,656	13.9	13.0
Johnson & Johnson (U.S.)	10	13	5,203	4,684	11.1	47,348	41,862	11.0	11.2
International Business Machines (U.S.)	11	10	5,167	5,068	2.0	96,293	89,131	5.4	5.7
Volkswagen (Germany)	12	14	4,823	4,479	7.7	113,004	110,705	4.3	4.0
Intel (U.S.)	13	15	4,778	4,360	9.6	34,209	30,141	14.0	14.5
Nokia (Finland)	14	12	4,742	4,776	-0.7	37,176	37,415	12.8	12.8
Sony (Japan)	15	11	4,688	4,805	-2.4	66,864	70,009	7.0	6.9
Samsung Electronics (South Korea)	16	25	4,529	3,337	35.7	77,494	61,284	5.8	5.4
Honda Motor (Japan)	17	16	4,368	4,193	4.2	80,784	76,231	5.4	5.5
Novartis (Switzerland)	18	20	4,207	3,756	12.0	28,247	24,864	14.9	15.1
Roche Holding (Switzerland)	19	17	4,192	3,925	6.8	25,742	25,698	16.3	15.3
Merck (U.S.)	20	29	3,885	3,178	22.2	23,430	22,486	16.6	14.1
AstraZeneca (UK)	21	23	3,803	3,451	10.2	21,426	18,849	17.7	18.3
Nissan Motor (Japan)	22	28	3,718	3,309	12.4	80,094	69,382	4.6	4.8
Robert Bosch (Germany)	23	24	3,681	3,366	9.4	50,818	46,182	7.2	7.3
Hitachi (Japan)	24	22	3,630	3,472	4.5	84,304	80,619	4.3	4.3
Hewlett-Packard (U.S.)	25	21	3,506	3,652	–4.0	79,905	73,061	4.4	5.0

UK = United Kingdom

SOURCE: Institute of Electronics and Electronics Engineers (IEEE), IEEE Spectrum Top 100 R&D Spenders, Standard & Poor's data (2005), http://www.spectrum.ieee.org/dec05/2395, accessed 24 April 2007.

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Department of Defense

According to preliminary data, DOD will obligate $56 billion for R&D support in FY 2007. DOD funds more R&D than any other federal agency, representing half of all federal R&D obligations. Of these funds, 89% ($50 billion) will be spent on development (figure 4-6). Most of the development funded by DOD is classified as "major systems development" ($44 billion), representing the cost of developing, testing, and evaluating combat systems. Industrial firms are expected to perform 74% of DOD-funded R&D in FY 2007. DOD accounts for more than 84% of all federal R&D obligations to industry in FY 2007. Federal intramural R&D and R&D performed by FFRDCs account for most of DOD's remaining R&D activity and represent 25% of its FY 2007 total.

Department of Health and Human Services

The Department of Health and Human Services (HHS), the primary source of federal health-related R&D funding (largely through its National Institutes of Health [NIH]), will obligate the second largest amount for R&D in FY 2007 at $29 billion, representing 26% of all federal R&D obligations. In contrast to DOD, HHS will allocate most of its R&D funding ($16 billion) for basic research. In FY 2007, HHS is expected to provide universities and colleges, the primary recipients of HHS funding, with $16 billion, which represents 65% of all federal R&D funds obligated to universities and colleges (table 4-8). HHS will provide 75% ($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 2007c).

National Aeronautics and Space Administration

The third largest agency in terms of R&D support is NASA, with R&D obligations expected to reach more than $8 billion in FY 2007. Almost half ($4 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 (55%) 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.

Table 4-7

Estimated federal R&D obligations, by performing sector and agency funding source: FY 2007

Character of work/performer	All obligations ($millions)	Primary funding source		Secondary funding source	
		Agency	Percent	Agency	Percent
All R&D	112,829.7	DOD	50	HHS	26
Federal intramural	24,741.5	DOD	53	HHS	23
Industrial firms	46,502.1	DOD	85	NASA	7
Industry-administered FFRDCs	1,477.8	DOE	58	HHS	24
U&C	24,968.5	HHS	65	NSF	13
U&C FFRDCs	6,136.3	DOE	54	NASA	29
Other nonprofit organizations	5,751.6	HHS	75	DOD	7
Nonprofit-administered FFRDCs	1,949.2	DOE	60	DOD	34
Basic research	28,264.4	HHS	57	NSF	13
Federal intramural	4,846.4	HHS	62	USDA	12
Industrial firms	2,211.1	HHS	44	NASA	39
Industry-administered FFRDCs	269.1	HHS	76	DOE	21
U&C	14,272.5	HHS	64	NSF	21
U&C FFRDCs	2,364.3	DOE	63	NASA	25
Other nonprofit organizations	2,927.9	HHS	82	NSF	10
Nonprofit-administered FFRDCs	897.7	DOE	98	HHS	1
Applied research	26,824.8	HHS	48	DOD	19
Federal intramural	7,828.1	HHS	33	DOD	27
Industrial firms	4,575.3	DOD	46	NASA	20
Industry-administered FFRDCs	708.5	DOE	73	HHS	21
U&C	9,088.9	HHS	78	DOD	6
U&C FFRDCs	1,701.5	DOE	87	DOD	4
Other nonprofit organizations	2,413.3	HHS	78	DOD	6
Nonprofit-administered FFRDCs	256.4	DOE	54	DOD	25
Development	57,740.5	DOD	86	NASA	7
Federal intramural	12,067.0	DOD	88	NASA	4
Industrial firms	39,715.7	DOD	93	NASA	4
Industry-administered FFRDCs	500.1	DOE	56	DOD	38
U&C	1,607.1	DOD	43	NASA	35
U&C FFRDCs	2,070.5	NASA	56	DOD	19
Other nonprofit organizations	410.4	DOD	37	NASA	19
Nonprofit-administered FFRDCs	795.1	DOD	74	DOE	20

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; U&C = universities and colleges

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 2005, 2006, and 2007 (forthcoming).

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Department of Energy

Of the large R&D-funding agencies, DOE invests the most resources in FFRDCs. In FY 2007, DOE obligated 67% of its estimated $8 billion in R&D funding to these organizations. Of the 37 FFRDCs, DOE sponsored 16 and accounted for more than half of all federal R&D obligations to FFRDCs in FY 2007. Much of DOE's research requires specialized equipment and facilities that are only available at its intramural laboratories and FFRDCs. (See the section on FFRDCs later in this chapter.)

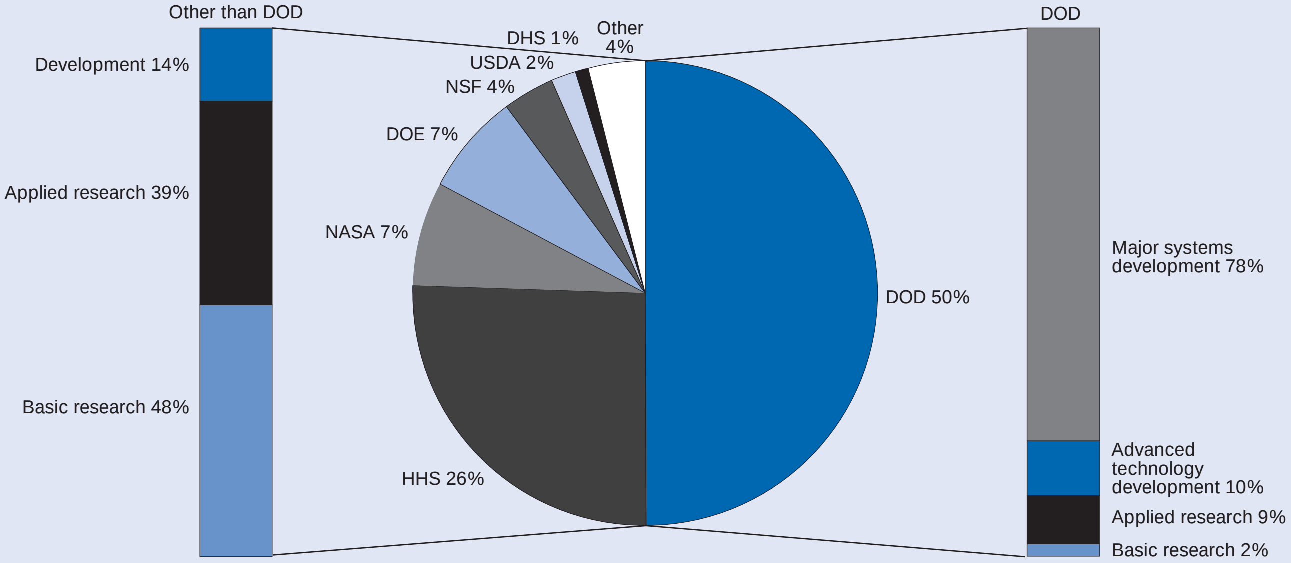
National Science Foundation

NSF is the federal government's primary source of funding for general S&E research and is expected to fund $4 billion of R&D in FY 2007. Of these funds, 91% are for basic research. Unlike many other federal agencies, NSF does not operate any of its own laboratories, but instead supports scientists and engineers through their home institutions. For the most part, these home institutions are universities and colleges; NSF is the second largest federal source of R&D funds to universities and colleges and is expected to invest more than $3 billion in academic research in FY 2007.

Department of Agriculture

USDA is expected to fund almost $2 billion of R&D in FY 2007, with most of this (69%) supporting USDA intramural R&D. Although USDA focuses most of its R&D in the life sciences, it is also one of the largest funding agencies for research in the social sciences, predominantly agricultural economics.

Figure 4-6
Projected federal obligations for R&D, by agency and character of work: FY 2007



DOD = Department of Defense; DOE = Department of Energy; DHS = Department of Homeland Security; HHS = Department of Health and Human Services; NASA = National Aeronautics and Space Administration; NSF = National Science Foundation; USDA = U.S. Department of Agriculture

NOTE: Detail may not add to total because of rounding.

SOURCE: NSF, Division of Science Resources Statistics, Federal Funds for Research and Development: Fiscal Years 2005, 2006, and 2007 (forthcoming). See appendix table 4-30.

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Department of Homeland Security

In FY 2007, the Department of Homeland Security (DHS) is expected to fund approximately $1 billion in R&D. DHS conducts and funds research in various areas but focuses significant resources on countering threats of catastrophic terrorism such as weapons of mass destruction. Most of this R&D is either conducted in DHS laboratories or under contract by industrial firms and FFRDCs. DHS also has established a grant-giving agency, Homeland Security Advanced Research Project Agency, modeled in part on the Defense Advanced Research Project Agency.

Other Agencies

Of the remaining R&D-funding federal agencies, 10 are expected to fund between $100 million and $1 billion of R&D in FY 2007. The largest of these agencies in terms of R&D funding are the Department of Commerce (DOC), the Department of the Interior (DOI), and the Environmental Protection Agency (EPA). Unlike most of the larger R&D-funding agencies, DOC, DOI, and EPA direct most of their R&D funds to their own laboratories, which are run by the National Institute of Standards and Technology (NIST), the U.S. Geological Survey, and the EPA Office of Research and Development, 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 FY 1955, obligations for academic R&D accounted for 7% of all federal R&D funding, or $0.8 billion in constant 2000 dollars. In FY 2007, R&D funding to academia represents an estimated 22% of all federal R&D obligations, or $21 billion in constant 2000 dollars. As figure 4-7 illustrates, funding to academia grew rapidly after FY 1998, the result of a successful bipartisan effort to double the budget of NIH from its FY 1998 level over 5 years. After FY 2004 however, federal R&D obligations to universities and colleges failed to keep pace with inflation.

Federal Funding to Industry

Since FY 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 4-7). 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

Table 4-8

Federal total, intramural, and FFRDC R&D obligations, by U.S. agency: FY 2007

(Millions of dollars)

Agency	All R&D obligations	Intramural	FFRDC	Intramural plus FFRDC (%)
All federal government	112,830	24,742	9,563	30
DOD	56,348	13,015	1,340	25
HHS	28,902	5,623	454	21
NASA	8,153	1,272	1,782	37
DOE	7,957	540	5,365	74
NSF	4,049	20	227	6
USDA	1,966	1,351	0	69
DHS	1,028	288	329	60
DOC	940	723	4	77
DOI	570	484	0	85
EPA	557	434	0	78
DOT	502	162	17	36
VA	412	412	0	100
ED	339	18	0	5
DOL	271	26	0	10
AID	255	30	0	12
DOJ	158	88	4	58
Smithsonian Institution	130	130	0	100
Other agencies	293	125	42	57

AID = Agency for International Development; DHS = Department of Homeland Security; DOC = Department of Commerce; DOD = Department of Defense; DOE = Department of Energy; DOI = Department of the Interior; DOJ = Department of Justice; DOL = Department of Labor; DOT = Department of Transportation; ED = Department of Education; EPA = Environmental Protection Agency; FFRDC = federally funded research and development center; HHS = Department of Health and Human Services; NASA = National Aeronautics and Space Administration; NSF = National Science Foundation; USDA = U.S. Department of Agriculture; VA = Department of Veterans Affairs

NOTES: Intramural activities include actual intramural R&D performance and costs associated with planning and administration of both intramural and extramural programs by federal personnel. Only agencies with >$100 million in R&D obligations shown.

SOURCE: NSF, Division of Science Resources Statistics, Federal Funds for Research and Development: Fiscal Years 2005, 2006, and 2007 (forthcoming).

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to the moon, R&D obligations to industry declined and did not experience another surge until more than 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 48% between FY 2001 and 2005. Beginning in FY 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."

Federal Intramural R&D

In FY 2007, obligations for federal intramural R&D totaled almost $25 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 2007 (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 of more than $1 billion in FY 2007, 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 needs that cannot be met as effectively by existing in-house or contractor resources." According to the Federal Acquisition Regulations (35.017), 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." 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 across a broad range of S&E fields.

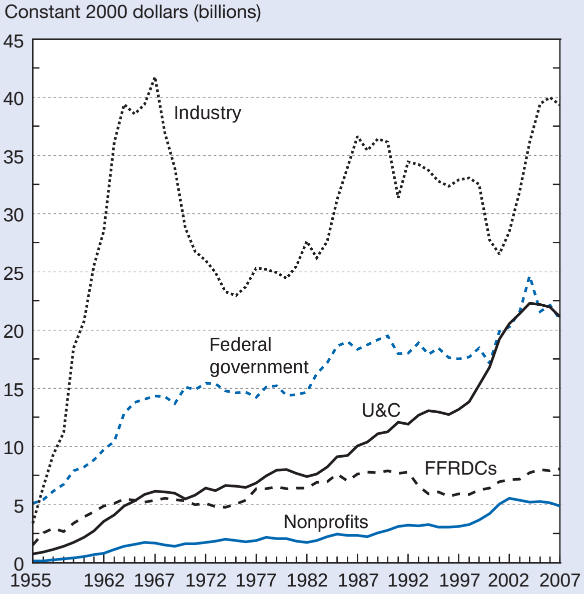
Of the 37 FFRDCs active in 2005, DOE sponsors 16, more than any other agency. These 16 organizations performed almost $10 billion of R&D in FY 2005, three-quarters of that performed by all FFRDCs combined (appendix table 4-25).

Four reported R&D expenditures of more than $1 billion in FY 2005: Los Alamos National Laboratory, Sandia National Laboratory, Jet Propulsion Laboratory, and Lawrence Livermore National Laboratory. Together, these four laboratories account for more than half of all FFRDC R&D expenditures. Los Alamos National Laboratory and the Lawrence Livermore National Laboratory are the only two laboratories in the United States where research on the nation's nuclear stockpile is conducted. See sidebar, "Federal R&D Infrastructure," for more information on FFRDCs' and other federal facilities' contributions to the U.S. R&D system.

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 (basic plus applied) research funding differs by field, as do trends in funding over time. According to preliminary estimates, federal obligations for research (excluding development) will total $55 billion in FY 2007 (see "Definitions of R&D" sidebar earlier in this chapter). Half of this funding, almost $28 billion, supports research in the life sciences. The next largest fields in terms of their share of expected federal research obligations in FY 2007 are engineering (17%), physical sciences (10%), environmental sciences (7%), and mathematics and computer sciences (6%) (figure 4-8). The balance of federal research obligations ($5 billion) supports the social sciences, psychology, and all other sciences.

Figure 4-7
Federal obligations for R&D, by performing sector: FY 1955–2007



FFRDCs = federally funded research and development centers; U&C = universities and colleges

NOTE: Preliminary 2006 and 2007 data.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Federal Funds for Research and Development: Fiscal Years 2005, 2006, and 2007 (forthcoming).

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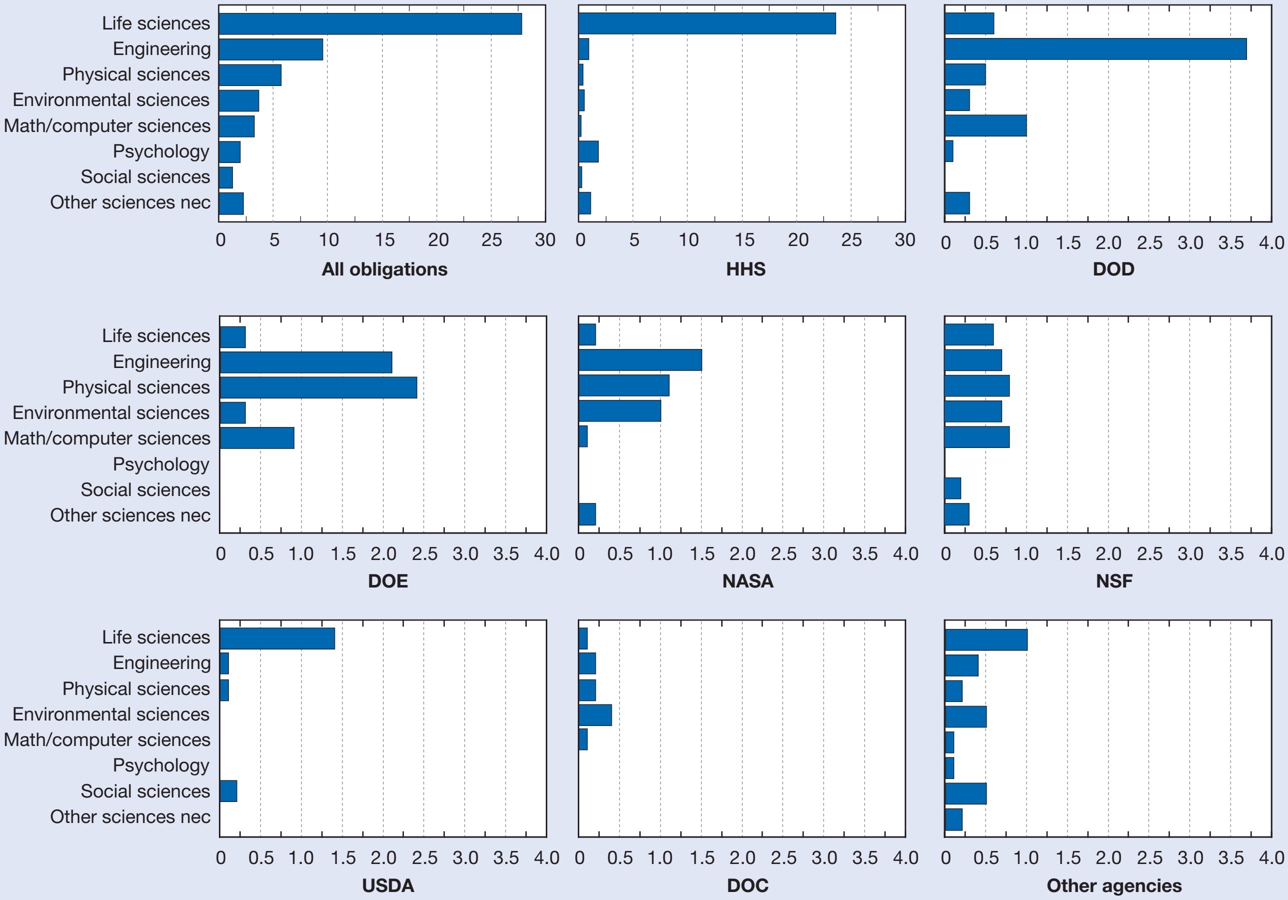
HHS, primarily through NIH, provides the largest share (52%) of all federal research obligations in FY 2007, with most of its obligations funding medical and other related life sciences. The next four largest federal agencies in terms of research funding in FY 2007 are DOD (12%), DOE (11%), NASA (7%), and NSF (7%). DOD's research funding is focused on engineering ($3.6 billion) and on mathematics and computer sciences ($1.0 billion). DOE provides substantial funding for research in the physical sciences ($2.4 billion) and engineering ($2.0 billion). NASA's research funding also emphasizes engineering ($1.5 billion), followed by physical sciences ($1.1 billion) and environmental sciences ($1.0 billion). NSF, whose mission is to "promote the progress of science," has a relatively balanced research portfolio, contributing between $0.5 and $0.9 billion to researchers in each of the following fields: mathematics and computer sciences, physical sciences, engineering environmental sciences, 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, and differences in scientific opportunities across fields. Over the period 1986–2007, total federal research obligations grew on average 3.4% per year in real terms, from $23 billion in 2000 dollars to $47 billion in 2000 dollars. The fields that experienced higher-than-average growth during this period were mathematics and computer sciences (5.6% per year in real terms), life sciences (4.6%), and psychology (6.1%) (appendix table 4-32). Funding for the remaining fields also grew at a faster rate than inflation over this period: social sciences (2.7%), engineering (2.0%), environmental sciences (1.9%), and physical sciences (0.5%).

Caution should be used 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 2005, for example, 1% 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 mathematics and computer sciences, in which all but 6% of the research dollars were subdivided. It was most pronounced in social sciences and psychology, in which, respectively, 69% and 97% of federal research obligations were not subdivided into detailed fields (appendix table 4-32).

Figure 4-8
Estimated federal obligations for research, by agency and major S&E field: FY 2007
(Billions of current dollars)



nec = not elsewhere classified

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; NSF = National Science Foundation; USDA = U.S. Department of Agriculture

NOTE: Scale differs for All obligations and HHS versus all other agencies.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Federal Funds for Research and Development: Fiscal Years 2005, 2006, and 2007 (forthcoming). See appendix table 4-31.

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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 2008 budget submission to Congress, the proposed total federal budget authority for R&D is $138 billion. Adjusting for inflation, this amount is a 1% decline from the previous year's budget. This decline follows a 5-year period of increasing inflation-adjusted federal R&D budgets. Although R&D tends to be a popular budgetary item, the growing federal debt may hamper future growth in federal R&D.

To assist Congress and the president in evaluating and adjusting the federal budget, the Office of Management and 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 (see sidebar, "Federal R&D Initiatives").

Defense-Related R&D

The largest R&D budget function in the FY 2008 budget is defense, with a proposed budget authority of $82 billion, or 60% of the entire federal R&D budget. (DOD requested $78 billion for its research, development, testing, and evaluation budget; the remainder of defense-related R&D is funded by DOE and HHS.) 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 4-11). The gap between the

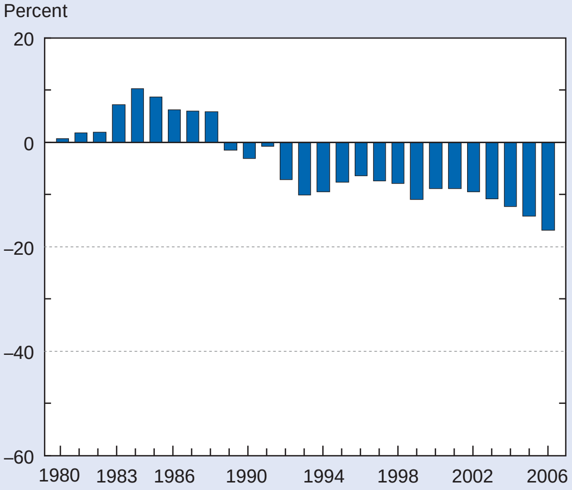
Tracking R&D: Gap Between Performer- and Source-Reported Expenditures

In some OECD countries, including the United States, total government R&D support figures reported by government agencies differ 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 2002). 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 U.S. R&D series has widened during the past decade or more.

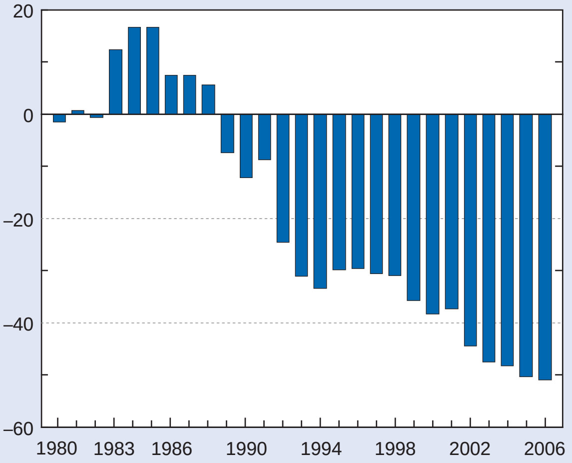
During the mid-1980s, performer-reported federal R&D in the United States exceeded federal reports of funding by \$3–\$4 billion annually (5%–10% of the government total). This pattern reversed itself toward the end of the decade; in 1989, the government-reported R&D total exceeded performer reports by \$1 billion. For FY 2005, federal agencies reported obligating \$109 billion in total R&D to all R&D performers (\$44 billion to the business sector), compared with \$94 billion in federal funding reported by the performers of R&D (\$23 billion by businesses). Hence, overall industrywide estimates equal approximately a 50% paper "loss" of federally reported 2005 R&D support (figure 4-9). The difference in federal R&D totals was primarily in DOD development funding of industry.

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 General Accounting Office (GAO 2001) investigation, "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 (2005a) notes that comparing federal outlays for R&D (as opposed to obligations) to performer expenditures results in a smaller discrepancy. In FY 2005, federal agencies reported total R&D outlays of \$103 billion.

Figure 4-9
Difference in U.S. performer- and agency-reported federal R&D: 1980–2006



All performers



Industrial performers

NOTE: Difference defined as percentage of federally reported R&D, with positive difference indicating that performer-reported R&D exceeds agency-reported R&D.

SOURCES: National Science Foundation, Division of Science Resources Statistics (NSF/SRS), National Patterns of R&D Resources (annual series); and NSF/SRS, Federal Funds for Research and Development: Fiscal Years 2005, 2006, and 2007 (forthcoming). See appendix table 4-29.

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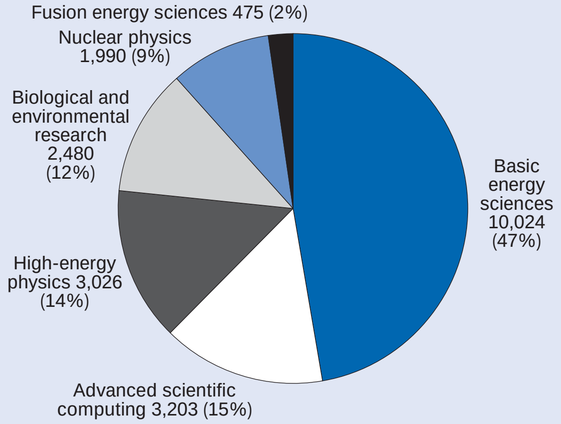
Federal R&D Infrastructure

The U.S. government invests substantial resources not only in R&D, but also in the facilities and instrumentation required by researchers to tackle problems at the frontier of S&T. In FY 2007, federal agencies are expected to obligate more than $3.5 billion for R&D plant, capital equipment, and facilities for use in R&D. Two agencies, NASA and DOE, account for more than two-thirds of all federal R&D plant obligations in FY 2007. Some examples of research infrastructure made possible through federal funding include:

- **Supercomputing resources.** As of November 2006, 6 of the top 10 supercomputers in the world were located in U.S. FFRDCs or government laboratories (TOP500 Supercomputer Sites 2007). The Terascale Simulation Facility at Lawrence Livermore National Laboratory houses two of the world's fastest supercomputers: BlueGene/L, ranked fastest in the world, and ASC Purple, ranked number four. These powerful computers support DOE's research on the safety and reliability of the nation's nuclear arsenal. The federal supercomputing resources are also used for nondefense purposes such as research on climate change and bioinformatics. For example, the DOE Joint Genome Institute leveraged the computing resources and research capabilities of multiple federal laboratories to contribute to the sequencing of the human genome. For more information, see DOE (2007).
- **Hubble Space Telescope.** Launched in 1990 and upgraded during four subsequent servicing missions, NASA's Hubble Space Telescope revolutionized astronomy by providing deep, clear views of the universe without the distorting effects of the Earth's atmosphere. Among its many highlights, Hubble was the first optical telescope to provide convincing proof of a black hole. More than 6,300 published scientific papers have been based on its data. At the time of its launch, the Hubble Space Telescope cost $1.5 billion. More details are available at NASA (2007).
- **Antarctic research stations.** NSF funds and manages the U.S. Antarctic Program, which coordinates almost all U.S. science on the continent, including research carried out by other federal agencies. The unique Antarctic environment has proven to be a boon to many fields of study. For example, astronomers and astrophysicists have benefited from the excellent optical properties of the atmosphere at the South Pole (resulting from its high elevation, low temperature, and low humidity) and from the extremely clear, thick, and homogeneous ice that makes neutrino detection possible. For additional information, see NSF/OPP (2007).
- **Highly Infectious Diseases Laboratories.** DOD and HHS (through both NIH and the Centers for Disease Control and Prevention) currently operate several laboratories that facilitate research on pathogens that require the highest levels of safety precaution, such as Ebola, viral hemorrhagic fevers, monkeypox, and avian influenza. DHS also plans to operate two such labs.

Many of the laboratories funded by the federal government provide scientists and engineers with tools and facilities that otherwise would not exist. For example, capabilities in DOE user facilities include particle and nuclear physics accelerators, synchrotron light sources, neutron scattering facilities, genome sequencing, supercomputers, and high-speed computer networks. By itself, DOE's Office of Science oversees facilities used by more than 20,000 non-DOE researchers each year in a range of scientific disciplines (figure 4-10). User facilities are one channel for collaborating and diffusing knowledge and technologies (see "Technology Transfer Metrics" later in this chapter).

Figure 4-10
External users at Department of Energy facilities, by science program: FY 2006



NOTES: External users are non-Department of Energy (DOE) researchers. One facility user may represent an individual researcher or a research team. Total external users = 21,198.

SOURCE: DOE, special tabulations, 1 June 2007. See appendix table 4-34.

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Federal R&D Initiatives

The 2008 budget targets R&D priority areas often involving the expertise of multiple federal agencies (OMB 2007). To improve the efficiency and effectiveness of federal R&D investments in these areas, the administration continues to encourage strategic coordination among stakeholder agencies. Priorities detailed in the Administration's FY 2008 budget include:

- **American Competitive Initiative (ACI).** The ACI invests in basic research areas that advance knowledge and technologies used by scientists in nearly every field through DOC's National Institute of Standards and Technology, DOE's Office of Science, and NSF. For FY 2008, the second year of ACI, President Bush proposes $11.4 billion for these three agencies. For an overview of the initiative, see OSTP (2006).
- **Climate Change.** The Climate Change Science Program (CCSP) is focused on improving decisionmaking on climate change science issues. This program has an FY 2008 R&D budget of $1.5 billion, of which the National Aeronautics and Space Administration accounts for 56%. More information is available at CCSP (2007) and Climate Change Technology Program (2007).
- **Combating Terrorism.** This area supports the president's strategy for homeland security by harnessing federal R&D programs that could help to deter, prevent, or mitigate terrorist acts. The FY 2008 budget provides support for capabilities in several areas including detection and imaging, cargo screening, biometric systems, and critical medical countermeasures. For an overview of homeland-security related R&D, see Knezo (2006).
- **Hydrogen Fuel.** The Hydrogen Fuel Initiative seeks to support R&D aimed at developing and improving technologies for producing, distributing, and using hydrogen to power automobiles. DOE will continue to lead this initiative. The 2008 budget completes the president's 5-year, $1.2 billion commitment announced in his 2003 State of the Union address, but work will continue on the many technical challenges that remain. For more details, see Interagency Working Group on Hydrogen and Fuel Cells (2007).
- **Nanotechnology.** The National Nanotechnology Initiative (NNI) supports basic and applied research on materials, devices, and systems that exploit the fundamentally distinct properties of matter at the atomic and molecular levels. The FY 2008 budget provides $1.4 billion for NNI R&D, three-fourths of which is allocated to NSF, DOD, and DOE. For more information, see NNI (2007).
- **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 2008 budget provides $3.1 billion for NITRD R&D, including about $1 billion each to DOD and NSF. Additional information is available at NITRD (2007).

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 an estimated $36 billion over the next 7 years.

Civilian-Related R&D

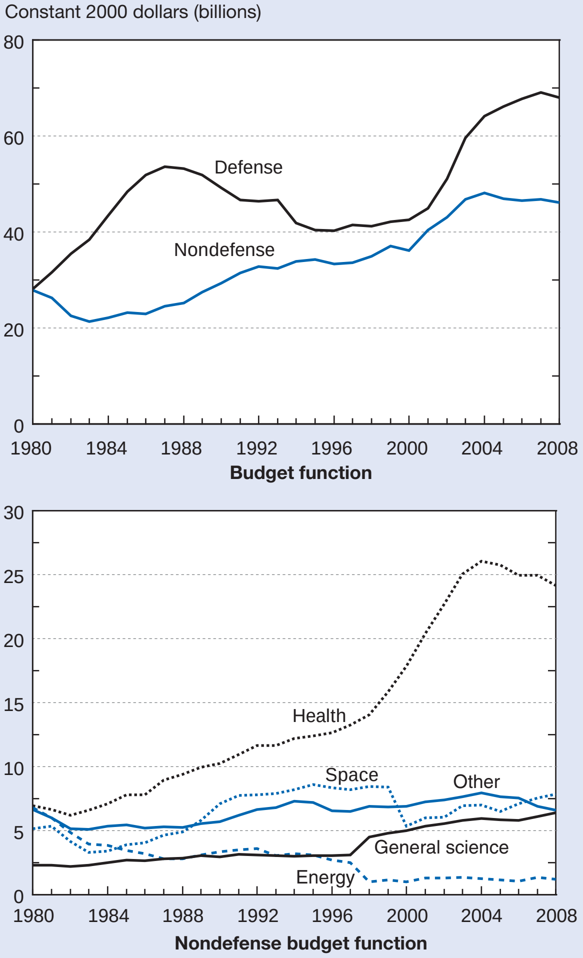
R&D accounts for 13.1% ($56 billion) of the FY 2008 federal nondefense discretionary budget authority of $428 billion, or slightly more than the R&D share reserved for defense activities (12.7% of the $647 billion discretionary defense budget authority in FY 2008). Almost 95% of federal basic research 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). Over the last several years, however, the budget authority for basic research has been rather flat. In FY 2002 that budget authority was approximately $23 billion (in constant 2000 dollars), and the same amount has been proposed for FY 2008.

The most dramatic change in national R&D priorities during the past 25 years has been the large rise in health-related R&D. As illustrated in figure 4-11, health-related R&D rose from representing 25% of the federal nondefense R&D budget allocation in FY 1980 to a high of 55% in FY 2005. Most of this growth occurred after 1998, when NIH's budget was set on a pace to double by 2003 (NSF/SRS 2002a). Growth in health-related R&D has since slowed considerably and accounted for 52% of the proposed FY 2008 nondefense R&D budget.

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 were curtailed. Nonetheless, the proportion of the proposed federal nondefense R&D budget for space research was higher in FY 2008 (17%) than in FY 2003 (15%). In the president's FY 2008 budget, 58% of NASA's $17 billion discretionary budget was allocated for R&D. This space R&D total is higher (in constant dollars) than at any time since FY 1999.

Compared with that of health-related R&D, the budget allocation for general science R&D has grown relatively little

Figure 4-11
Federal R&D budget authority, by budget function: FY 1980–2008



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 results of reclassification.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Federal R&D Funding by Budget Function: Fiscal Years 2006–08 (forthcoming). See appendix table 4-26.

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during the past 25 years. The growth that has occurred 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 it is the result of increased budget allocations (figure 4-11).

Federal and State R&D Tax Credits

Background

Governments have used multiple policy tools to foster R&D in diverse industries, technologies, and innovation environments (Martin and Scott 2000; Tassey 1996). Fiscal policy tools include direct funding (as discussed earlier in this chapter) and indirect incentives such as tax relief.[19] Tax relief may take the form of a tax allowance, exemption or deduction (a reduction in taxable income), or a tax credit (a reduction in tax liability). The United States offers both types of incentives, namely a deduction for qualified R&D under U.S. Internal Revenue Code (C.F.R. Title 26) Section 174 and a tax credit under Section 41 (Guenther 2006; Hall 2001). R&D tax incentives in advanced economies 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 Reenen 2002; OECD 2003). This section focuses on business R&D tax credits at the federal and state levels.

The federal research and experimentation (R&E) tax credit was established by the Economic Recovery Tax Act of 1981. Given its temporary status, it is subject to periodic extensions, and it was last renewed by the Tax Relief and Health Care Act of 2006 (Public Law 109–432) through 31 December 2007.[20] The Bush administration has proposed making the R&E tax credit permanent (OMB 2007).

Under the federal R&E tax credit, companies can take a 20% credit for qualified research above a base amount for activities undertaken in the United States.[21] For most companies, the base amount is determined by multiplying R&D-to-sales ratio by the average gross receipts for the previous 4 years. Currently, the reference period for R&D-to-sales ratio is fixed as the average from 1984 to 1988 (start-up companies follow different provisions). Thus, the credit is characterized as a fixed-base incremental credit (Hall 2001; Wilson 2007). Companies, however, benefit by less than the statutory credit rate of 20%, since benefits from the credit are taxable.[22]

An alternative R&E tax credit has been available since 1996 (Small Business Protection Act, Public Law 104–188). The 2006 Act (Public Law 109–432), signed into law in December 2006, not only extended the research credit for 2 years—2006 (retroactively) and 2007—but also increased the rates for the alternative credit for 2007. In addition, it created a new, simplified alternative credit beginning in 2007. Companies may select only one of these credit configurations on a permanent basis, unless the Internal Revenue Service (IRS) authorizes a change. A 20% credit with a separate threshold is provided for payments to universities for basic research.

Federal Corporate Tax Credit Claims

R&E tax credit claims reached an estimated $5.5 billion in 2003 ($5.2 billion in constant, or inflation-adjusted, dollars), involving just under 10,400 corporate tax returns, compared with the all-time high of $7.1 billion in 2000 (table 4-10), according to IRS Statistics of Income Division (SOI) estimates.[23] Even at their 2000 peak, R&E tax credit claims accounted for less than 4% of industry-funded R&D expenditures (figure 4-12). Since 1998, corporate tax returns classified in five North American Industry Classification System (NAICS) industries accounted for approximately 80% of

Table 4-9
Budget authority for R&D, by federal agency and character of work (proposed levels): FY 2008
(Millions of current dollars)

Agency	All discretionary budget authority	All R&D	Basic research	Applied research	Development	R&D share of discretionary budget (%)
All federal government	1,074,966	137,912	28,371	26,638	82,903	12.8
DOD	627,718	78,658	1,428	4,357	72,873	12.5
HHS	69,330	28,874	15,615	13,237	22	41.6
NASA	17,310	10,060	2,226	1,127	6,707	58.1
DOE	24,310	8,169	3,409	2,869	1,891	33.6
NSF	6,430	4,373	3,993	380	0	68.0
USDA	20,226	1,911	771	984	156	9.4
DHS	34,511	934	132	533	269	2.7
DOC	6,554	932	164	696	72	14.2
VA	39,418	822	330	444	48	2.1
DOT	12,110	793	0	541	252	6.5
DOI	10,610	619	39	525	55	5.8
EPA	7,200	562	94	364	104	7.8
Other	199,239	1,205	170	581	454	0.6

DHS = Department of Homeland Security; DOC = Department of Commerce; DOD = Department of Defense; DOE = Department of Energy; DOI = Department of the Interior; DOT = Department of Transportation; EPA = Environmental Protection Agency; HHS = Department of Health and Human Services; NASA = National Aeronautics and Space Administration; NSF = National Science Foundation; USDA = U.S. Department of Agriculture; VA = Department of Veterans Affairs

SOURCE: Office of Management and Budget, Budget of the United States Government, Fiscal Year 2008 (2007).

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Table 4-10
Federal research and experimentation tax credit claims and corporate tax returns claiming credit: 1990–2003

Year	Tax credit claims ($millions) Current	Tax credit claims ($millions) 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	10,389
2002	5,656	5,428	10,254
2003	5,488	5,158	10,369

NOTES: Data exclude Internal Revenue Service (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: IRS, Statistics of Income program, special tabulations. See appendix table 4-33.

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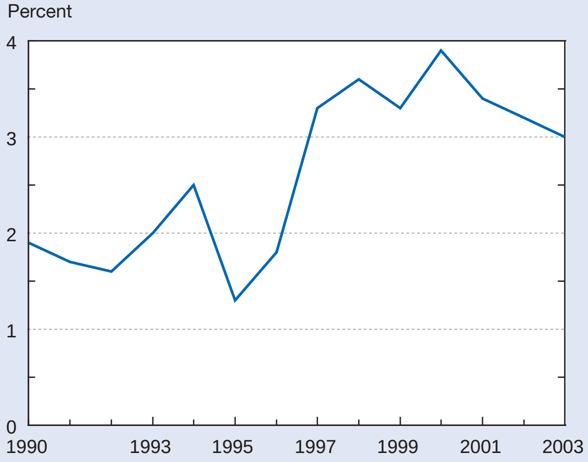
Figure 4-12
Research and experimentation credit claims as percentage of industry-funded R&D: 1990–2003



SOURCES: Internal Revenue Service, Statistics of Income, special tabulations; and National Science Foundation, Survey of Industrial R&D (annual series).

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R&E credit claims. In 2003, the top five industries accounted for a total of $4.2 billion or 77% of credit claims:

- Computer and electronic products (21%)
- Chemicals, including pharmaceuticals and medicines (18%)
- Transportation equipment, including motor vehicles and aerospace (16%)
- Information, including software (12%)
- Professional, scientific, and technical services, including computer services and R&D services (10%)

In 2003, companies classified in the professional, scientific, and technical services industry represented one-third of all corporate returns claiming the R&E tax credit, followed by computer and electronic products and information, each with about 15%. Consequently, among the top five industries listed above, professional, scientific, and technical services had the lowest average claims per return ($15.9 million) in 2003, compared with an average of $52.9 million per return overall.[24]

State Tax Credits

At least 32 states offered credits for company-funded R&D (table 4-11) in 2006, according to Wilson (2007). The first such credit was enacted by Minnesota in 1982 only a year after the federal R&E credit was enacted. Since then, the number of states offering a research credit has increased gradually (figure 4-13).

More than half of these states' research credits (19 of 32) mimic the structure of the federal credit, namely, an incremental credit with a fixed base (table 4-11). Another 10 states offer an incremental credit with a moving average

Table 4-11
Summary of state-level R&D tax credits: 2006

State	Year enacted	Top-tier statutory credit rate (%)	Base definition for credit
Arizona	1994	11.0	Federal (fixed-period)
California	1987	15.0	Federal (fixed-period)
Connecticut	1993	6.0	Nonincremental
Delaware	2000	10.0	Average of previous 4 years
Georgia	1998	10.0	Federal (fixed-period)
Hawaii	2000	20.0	Nonincremental
Idaho	2001	5.0	Federal (fixed-period)
Illinois	1990	6.5	Average of previous 3 years
Indiana	1985	10.0	Federal (fixed-period)
Iowa	1985	6.5	Federal (fixed-period)
Kansas	1988	6.5	Average of previous 2 years
Louisiana	2003	8.0	Federal (fixed-period)
Maine	1996	5.0	Average of previous 3 years
Maryland	2000	10.0	Average of previous 4 years
Massachusetts	1991	10.0	Federal (fixed-period)
Minnesota	1982	2.5	Federal (fixed-period)
Missouri	1994	6.5	Average of previous 3 years
Montana	1999	5.0	Federal (fixed-period)
Nebraska	2005	3.0	Average of previous 2 years
New Jersey	1994	10.0	Federal (fixed-period)
North Carolina	1996	5.0	Federal (fixed-period)
North Dakota	1988	4.0	Federal (fixed-period)
Ohio	2004	7.0	Average of previous 3 years
Oregon	1989	5.0	Federal (fixed-period)
Pennsylvania	1997	10.0	Average of previous 4 years
Rhode Island	1994	16.9	Federal (fixed-period)
South Carolina	2001	5.0	Federal (fixed-period)
Texas	2001	5.0	Federal (fixed-period)
Utah	1999	6.0	Federal (fixed-period)
Vermont	2003	10.0	Average of previous 4 years
West Virginia	1986	3.0	Nonincremental
Wisconsin	1986	5.0	Federal (fixed-period)
Median	na	6.5	na

na = not applicable

NOTES: Top-tier credit rate applies to highest tier of expenditure levels for states having multiple credit rates.

SOURCE: Dr. Daniel Wilson, Federal Reserve Bank of San Francisco, special tabulations (February 2007).

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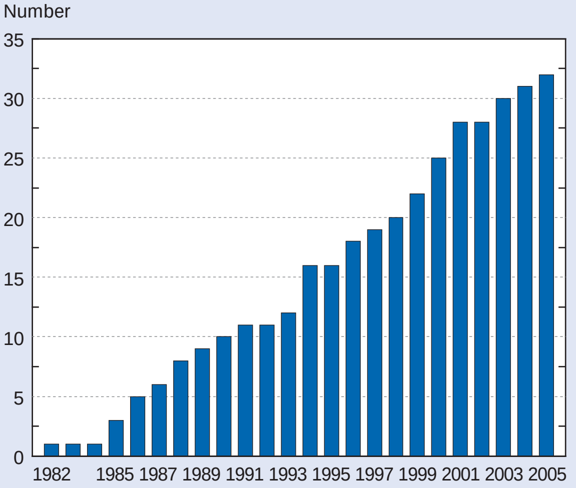
Figure 4-13
U.S. states with credits for company-funded R&D: 1982–2005



SOURCE: Dr. Daniel Wilson, Federal Reserve Bank of San Francisco, special tabulations (February 2007).

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(much like the earlier version of the federal credit). Three states (Connecticut, Hawaii, and West Virginia) have a nonincremental credit, that is, the credit applies to all qualified research. These counts do not include narrowly targeted credits (either by technology or geographically within the state) or credits with a cap.[25]

In a study attempting to measure the impact of states' research credits, Wilson (2007) was able to estimate increases in within-state R&D. At the same time, however, estimated effects appear to come from shifts in other states' R&D, raising questions about the aggregate effect of these state R&D incentives. Further empirical research on these issues is warranted given the recent enactment of some of these credits.

International R&D Comparisons

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 it is possible to compare the cost of R&D in two countries, differences in their national systems of innovation may make one country more effective than the other in translating investments in S&T into economic growth or other social benefits. Although it can be difficult to assess the qualitative differences in the R&D and innovation systems in different countries, it is important to keep these differences in mind when analyzing data presented in this section on international R&D spending patterns.

Most of the R&D data presented in this section are from the OECD, the most reliable source for such international comparisons. However, an increasing number of non-OECD countries and organizations now collect and publish R&D statistics (with variable levels of international comparability), 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").

Global R&D Expenditures

Worldwide R&D performance is concentrated in a few developed nations. In 2002, global R&D expenditures totaled at least $813 billion; one-third of this world total was accounted for by the United States, the largest country in terms of domestic R&D expenditures, and 45% of this total was accounted for by the two largest countries in terms of R&D performance, the United States and Japan.

As figure 4-14 illustrates, more than 95% of global R&D is performed in North America, Asia, and Europe. Within each of these regions, a small number of countries dominate in terms of expenditures on R&D: the United States in North America; Japan and China in Asia; and Germany, France, and the United Kingdom in Europe.[26]

Wealthy, well-developed nations, generally represented by OECD countries, perform most of the world's R&D, but R&D expenditures have grown rapidly in several lesser-developed nations. In 2004, Brazil performed an estimated $14 billion of R&D (RICYT 2007), although the compilations of its R&D statistics do not yet fully conform to OECD guidelines. India performed an estimated $21 billion in 2000, making it the seventh largest country in terms of R&D in that year, ahead of South Korea (UNESCO/Institute for Statistics 2007). China had the fourth largest expenditures on R&D in 2000 ($45 billion), behind Germany's $52 billion (OECD 2006b). In 2005, it is estimated that $115 billion of R&D was performed in China, making it the third largest country in terms of R&D expenditures. Given the lack of R&D-specific exchange rates (see sidebar, "Comparing International R&D Expenditures"), it is difficult to draw conclusions from these absolute R&D figures, but China's nearly decade-long ramp-up of R&D expenditures appears unprecedented in recent years.

OECD and G-7 R&D Expenditures

The 30 OECD countries represented 81% of global R&D, or $657 billion, in 2002. Although global R&D estimates are not available for later years, the R&D performance of OECD countries grew to $726 billion in 2004. The G-7 countries performed two-thirds of the world's R&D in 2002 and 83% of OECD's R&D in 2004. Outside of the G-7 countries, South Korea is the only country that accounted for a substantial share of the OECD total (4% in 2004).

More money was spent on R&D activities in the United States in 2004 than in the rest of the G-7 countries combined (figure 4-15). In terms of relative shares, the U.S. share of the G-7's R&D expenditures has fluctuated between 48%

Figure 4-14
Estimated R&D expenditures and share of world total, by region: 2002

NOTE: R&D estimates from 91 countries in billions of purchasing power parity dollars. Percentages may not add to 100 because of rounding.

SOURCES: Organisation for Economic Co-operation and Development, Main Science and Technology Indicators (2006); Ibero-American Network of Science and Technology Indicators, http://www.ricyt.edu.ar, accessed 5 March 2007; and United Nations Educational, Scientific and Cultural Organization (UNESCO), Institute for Statistics, http://www.uis.unesco.org.

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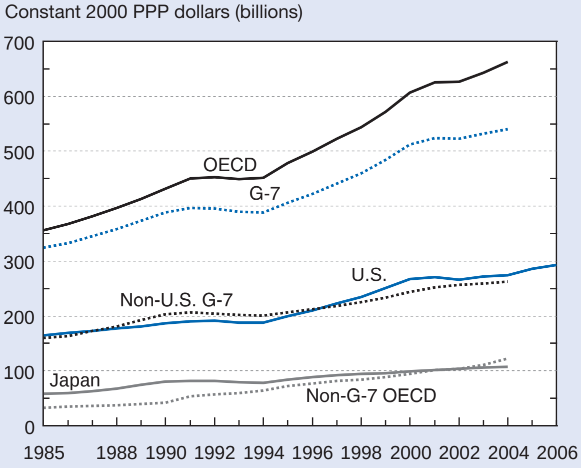
Figure 4-15
R&D expenditures of United States and G-7 and OECD countries: 1985–2006



OECD = Organisation for Economic Co-operation and Development; PPP = purchasing power parity

NOTE: Data not available for all countries for all years.

SOURCE: OECD, Main Science and Technology Indicators (2006). See appendix table 4-35.

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and 52% during the past 25 years. As a proportion of the G-7 total, U.S. R&D expenditures reached a low of 48% in 1990. After the early 1990s, the U.S. percentage of 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. R&D spending rebounded in the late 1990s in several G-7 countries, but the recovery was most robust in the United States, and the U.S. share of total G-7 R&D has exceeded 50% since 1997, peaking at 52% in 2000, before dropping slightly to 51% of total in 2004.

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 size of their population and economy. For example, although Germany and China had similar R&D expenditures in 2000, China's population was more than 15 times larger, and its economy more than twice as large, as Germany's in that year. Policy analysts commonly use various measures of R&D intensity to account for these size differences when making international comparisons.

One of the first (Steelman 1947) 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 na-

Comparing International R&D Expenditures

Comparisons of international R&D statistics are hampered by the lack of R&D-specific exchange rates. If countries do not share a common currency, some conversion must be made to compare their R&D expenditures. Two approaches are commonly used to facilitate international R&D comparisons: (1) normalize national R&D expenditures by dividing by GDP, which circumvents the problem of currency conversion; and (2) convert all foreign-denominated expenditures to a single currency, which results in indicators of absolute effort. The first method is a straightforward calculation that permits only gross national comparisons of R&D intensity. The second method permits absolute-level comparisons and analyses of countries' sector- and field-specific R&D, but it entails choosing an appropriate method of currency conversion.

Because no widely accepted R&D-specific exchange rates exist, the choice is between market exchange rates (MERs) and purchasing power parities (PPPs). These rates are the only series consistently compiled and available for a large number of countries over an extended period of time.

MERs. 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.

PPPs. PPPs were developed because of the shortcomings of MERs described above (Ward 1985). PPPs take into account the cost differences across countries of buying a similar "market 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 OECD.*

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 2005 R&D expenditures are $30 billion using MERs but are $115 billion using PPPs. Appendix table 4-2 shows the relative difference between MERs and PPPs for a number of 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 extrapolations 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 developing and developed 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 often is concentrated geographically in the most advanced cities and regions in terms of infrastructure and level of educated workforce. The costs of goods and services in these areas can be substantially greater than for the country as a whole.

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*Recent research calls into question the use of GDP PPPs for deflating R&D expenditures. Analyzing manufacturing R&D inputs and outputs in six industrialized OECD countries, Dougherty et al. (2007) conclude that "the use of an R&D PPP will yield comparative costs and R&D intensities that vary substantially from the current practice of using GDP PPPs, likely increasing the real R&D performance of the comparison countries relative to the United States."

tion's total economic activity. Policymakers often use this ratio for international benchmarking and goal setting.

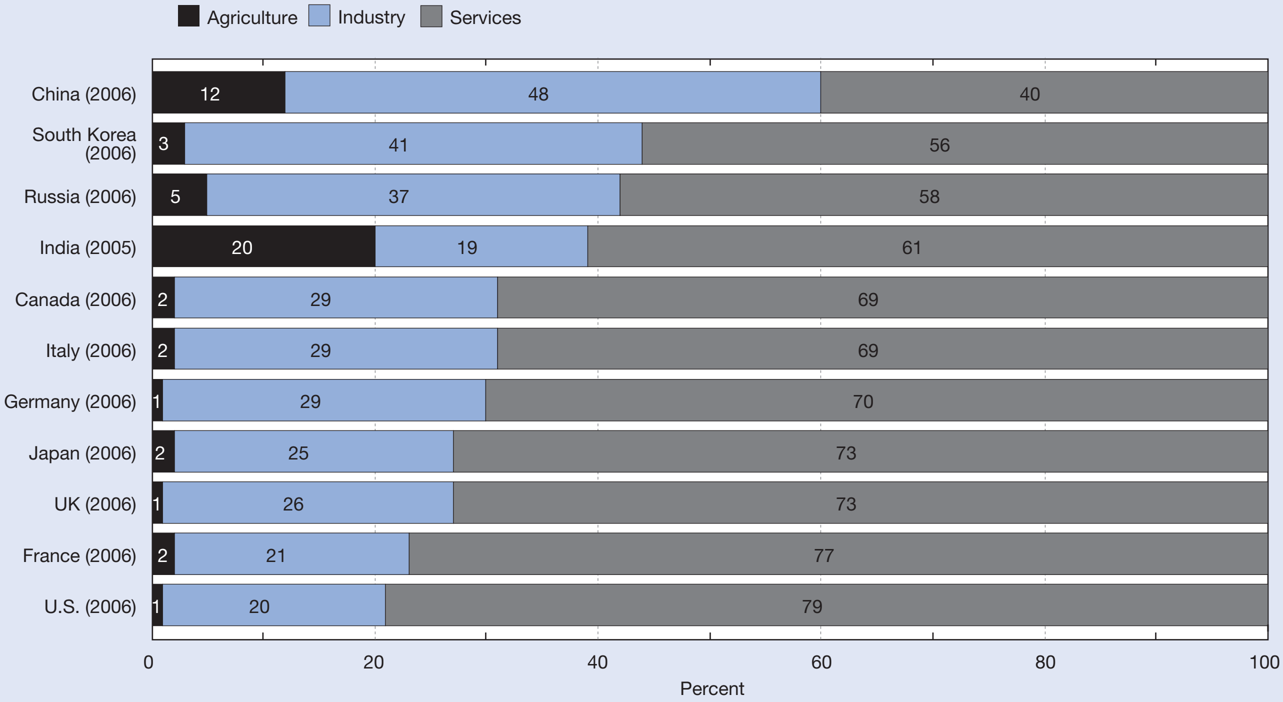
Normalized indicators, such as R&D/GDP ratios, are useful for international comparisons because they not only account for size differences between countries, but they also obviate the need for exchange rates. However, even normalized indicators are not always comparable from one country to another. This 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 4-16 shows, the agricultural and industrial sectors account for less than one-third of GDP in the United States and the other G-7 countries. These sectors represent similarly small shares of the labor force in the G-7 countries. This contrasts with less-developed nations such as China, where the agricultural and industrial sectors account for more than half of GDP and an even larger share of the labor force (estimated to be 69%) (CIA 2007). In recent years, the service sector has grown substantially in India in terms of its contribution to GDP (61% in 2005), but more than half of India's labor force works in the agricultural sector. Differences such as these in the structure of economies can result in significant country-to-country differences in terms of various R&D indicators.

Total R&D/GDP Ratios

The ratio of R&D expenditures to GDP can indicate 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. For example, since 1953, R&D expenditures as a percentage of GDP in the United States 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 increases in nonfederal R&D spending, the majority of which is company financed. Nonfederally financed R&D increased from 0.6% of GDP in 1953 to a projected 1.9% of GDP in 2006 (down from a high of 2.0% of GDP in 2000). The increase in nonfederally financed R&D as a percentage of GDP illustrated in figure 4-17 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, while growth in nonfederal sources of R&D spending generally kept pace with or exceeded GDP growth. Since 2000, defense-related R&D

Figure 4-16
Composition of gross domestic product for selected countries, by sector: 2005 or 2006



UK = United Kingdom

SOURCE: Central Intelligence Agency, *The World Factbook 2007*, http://www.cia.gov/cia/publications/factbook/index.html, accessed 2 March 2007.

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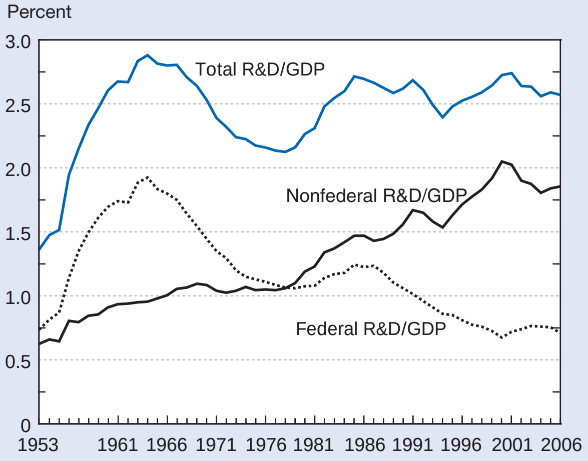
spending has surged, and federal R&D spending growth has outpaced GDP growth. (See the discussion of defense-related R&D earlier in this chapter.)

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 4-18). The two exceptions, Japan and Canada, both exhibited substantial increases on this indicator between 1990 and 2004. In Japan this indicator declined in the early 1990s 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 3.2% in 2004, the result of both a resurgence of industrial R&D in the mid-1990s coupled with slow GDP growth. By contrast, over the same period, GDP grew more robustly in Canada; therefore the rise in its R&D/GDP ratio is more indicative of R&D growth.

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. Geopolitical events also affect R&D intensity indicators, as evidenced by Germany and Russia. [West] Germany's R&D/GDP ratio fell from 2.8% at the end of the 1980s, before reunification, to 2.2% in 1994 for all of Germany. Its R&D/GDP has since risen to 2.5% in 2005. 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. Between 1998 and 2003, Russia's R&D doubled, and its R&D/GDP ratio rose from 1.0% to 1.3%. This growth was not maintained in the subsequent 2 years, and Russia's R&D/GDP ratio dropped to 1.1% in 2005.

Overall, the United States ranked seventh among OECD countries in terms of reported R&D/GDP ratios (table 4-12), but several of its states have R&D intensities of more than 4%. Massachusetts, a state with an economy larger than Sweden's and approximately twice the size 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 country), devoting 4.7% of its GDP to R&D, currently leads all countries, followed by Sweden (3.9%), Finland (3.5%), Japan (3.2%), and South Korea (3.0%). In

Figure 4-17
U.S. R&D share of gross domestic product: 1953–2006



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.

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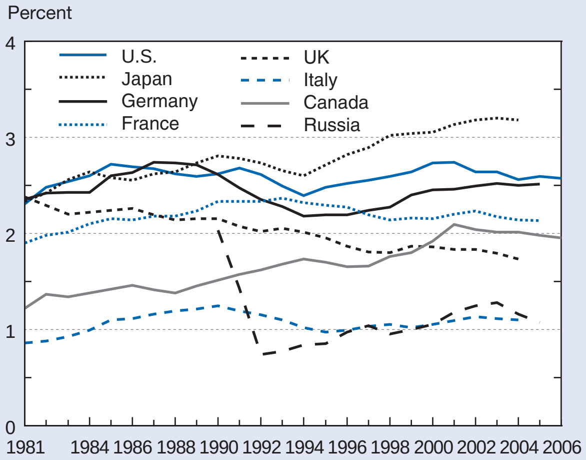
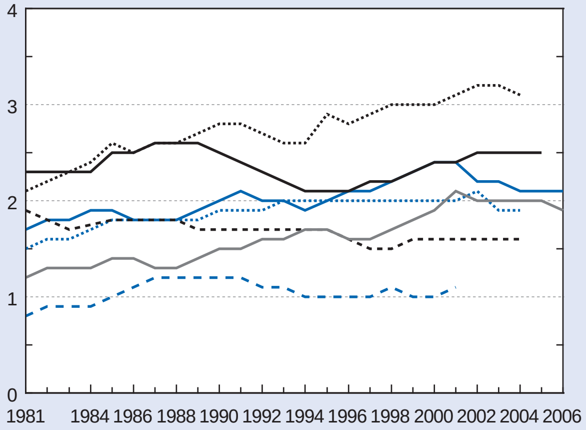
Figure 4-18
R&D share of gross domestic product, by selected countries: 1981–2006



All R&D/GDP



Nondefense R&D/GDP

GDP = gross domestic product; UK = United Kingdom

NOTE: Data not available for all countries for all years.

SOURCE: Organisation for Economic Co-operation and Development, Main Science and Technology Indicators (2006). See appendix tables 4-35 and 4-36.

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Table 4-12

R&D share of gross domestic product, by country/economy: Most recent year

(Percent)

Country/economy	Share	Country/economy	Share
All OECD (2004)	2.25	Luxembourg (2005)	1.56
EU-25 (2005)	1.77	Norway (2005)	1.51
Israel (2005)	4.71	Czech Republic (2005)	1.42
Sweden (2005)	3.86	China (2005)	1.34
Finland (2006)	3.51	Ireland (2005)	1.25
Japan (2004)	3.18	Slovenia (2005)	1.22
South Korea (2005)	2.99	New Zealand (2003)	1.14
Switzerland (2004)	2.93	Spain (2005)	1.12
Iceland (2003)	2.86	Italy (2004)	1.10
United States (2006)	2.57	Russian Federation (2005)	1.07
Germany (2005)	2.51	Hungary (2005)	0.94
Austria (2006)	2.44	South Africa (2004)	0.87
Denmark (2005)	2.44	Portugal (2005)	0.81
Taiwan (2004)	2.42	Turkey (2004)	0.67
Singapore (2005)	2.36	Greece (2005)	0.61
France (2005)	2.13	Poland (2005)	0.57
Canada (2006)	1.95	Slovak Republic (2005)	0.51
Belgium (2005)	1.82	Argentina (2005)	0.46
Netherlands (2004)	1.78	Mexico (2003)	0.43
Australia (2004)	1.77	Romania (2004)	0.39
United Kingdom (2004)	1.73		

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

NOTE: Civilian R&D only for Israel and Taiwan.

SOURCES: National Science Foundation, Division of Science Resources Statistics, National Patterns of R&D Resources (annual series); and OECD, Main Science and Technology Indicators (2006).

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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 1999). 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.

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 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% (RICYT 2007). 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 commercial and social benefits, nondefense R&D is more directly oriented toward national scientific progress, economic competitiveness, and standard-of-living improvements. Using this indicator, the relative position of the United States falls below that of Germany and just above Canada among the G-7 nations (figure 4-18). This is because the United States devotes more of its R&D, primarily for development rather than research, to defense-related activities than do most other countries. In 2006, approximately 16% of U.S. R&D was defense related, whereas for historical reasons, less than 1% of the R&D performed in Germany and Japan is defense related. Approximately 10% of the United Kingdom's total R&D was defense related in 2004.

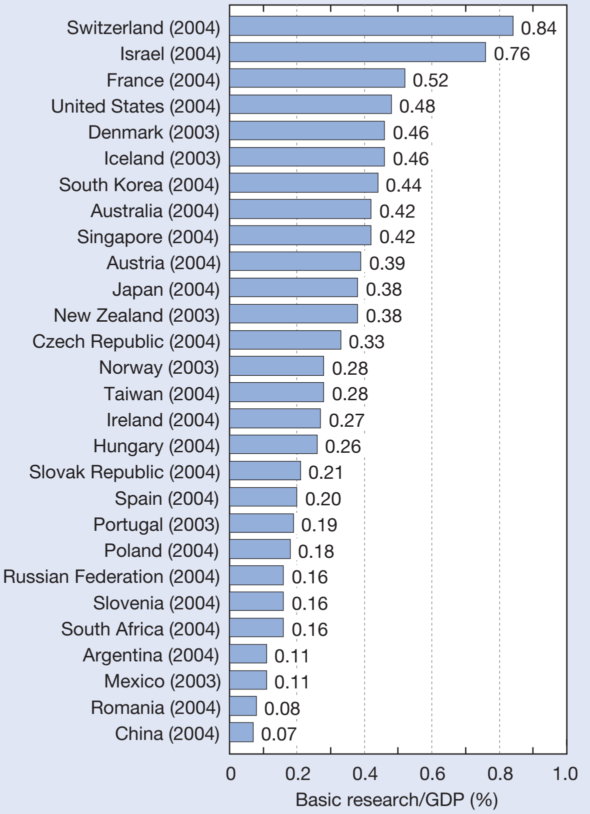
Basic Research/GDP Ratios

R&D involves a wide range of activities, ranging from basic research to the development of marketable goods and services. Because it is motivated primarily by curiosity, basic research generally has low short-term returns, but it builds intellectual capital and lays the groundwork for future advances in S&T. (See sidebar, "Definitions of R&D.") The relative investment in basic research as a share of GDP 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, approximately 40% of the OECD countries do not report these data at the national level. Nonetheless, where these data exist, they help differentiate national innovation systems 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 the section entitled "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 0.8% (figure 4-19). 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 almost 30% of its R&D to basic research in 2004 despite having an industrial R&D share comparable with 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 Romania (0.08%) and Mexico (0.11%). With its emphasis on applied research and development aimed at short-term economic development, China follows the pattern set by Taiwan, South Korea, and Japan. In each of these economies, basic research accounts for 15% or less of total R&D (figure 4-20). Singapore also followed this pattern, but since 2000, its expenditures on basic research have grown faster than its total R&D. In 2000, 12% of Singapore's R&D was basic research, but in 2004 this share was 19%, on par with the United States.

Figure 4-19
Basic research share of gross domestic product, by country/economy: 2003 or 2004



GDP = gross domestic product

NOTE: Countries with same values sorted alphabetically.

SOURCE: Organisation for Economic Co-operation and Development, Main Science and Technology Indicators (2006).

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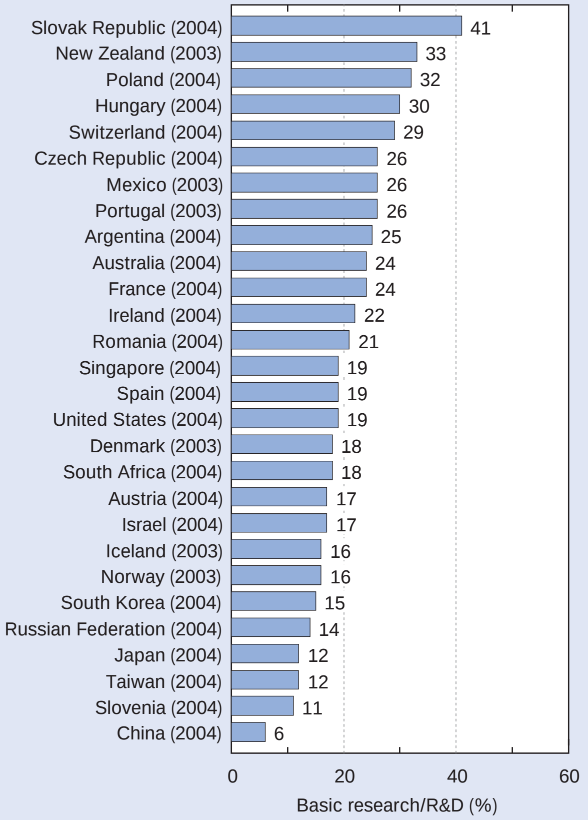
Figure 4-20
Basic research share of R&D, by country/economy: 2003 or 2004



NOTE: Countries with same values sorted alphabetically.

SOURCE: Organisation for Economic Co-operation and Development, Main Science and Technology Indicators (2006).

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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 (table 4-13). Industry's share of R&D performance ranged from 48% in Italy to more than 75% in Japan and South Korea; it was 71% in the United States. In China, much of the recent growth in R&D expenditures has occurred in the business sector, which performed 68% of China's R&D in 2005, up from 60% in 2000. In most countries, industrial R&D is financed primarily by the business sector. A notable exception is the Russian Federation, where government was the largest source of industrial R&D funding in 2005 (appendix table 4-37).

In all of the G-8 countries except Russia, the academic sector was the second largest performer of R&D (representing from 13% to 38% of R&D performance in each country). In Russia, government is the second largest R&D performer, accounting for 26% of its R&D performance in 2005. Government-performed R&D accounted for 22% of China's R&D in 2005, down from 32% in 2000.

Government and industry together account for more than three-quarters of the R&D funding in each of the G-8 countries, although their respective contributions vary (table 4-14). The industrial sector provided as much as 75% of R&D fund-

Table 4-13

R&D expenditures for selected countries, by performing sector: Most recent year

(Percent)

Country	Industry	Higher education	Government	Other nonprofit
South Korea (2005)	76.9	9.9	11.9	1.4
Japan (2004)	75.2	13.4	9.5	1.9
Germany (2005)	69.9	16.5	13.6	NA
United States (2006)	71.1	13.7	11.0	4.2
China (2005)	68.3	9.9	21.8	NA
Russian Federation (2005)	68.0	5.8	26.1	0.2
United Kingdom (2004)	63.0	23.4	10.3	3.3
France (2005)	61.9	19.5	17.3	1.2
Canada (2006)	52.4	38.4	8.8	0.5
Italy (2004)	47.8	32.8	17.9	1.5

NA = not available

SOURCES: National Science Foundation, Division of Science Resources Statistics, National Patterns of R&D Resources (annual series); and Organisation for Economic Co-operation and Development, Main Science and Technology Indicators (2006).

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Table 4-14

R&D expenditures for selected countries, by source of funds: Most recent year

(Percent)

Country	Industry	Government	Other domestic	Abroad
Canada (2006)	46.7	33.7	11.0	8.5
China (2005)	67.0	26.3	NA	0.9
France (2004)	51.7	37.6	1.9	8.8
Germany (2004)	66.8	30.4	0.4	2.5
Japan (2004)	74.8	18.1	6.8	0.3
Russian Federation (2005)	30.0	62.0	0.5	7.6
South Korea (2005)	75.0	23.0	1.3	0.7
United Kingdom (2004)	44.2	32.8	5.8	17.3
United States (2006)	65.6	28.6	5.8	NA

NA = not available

NOTES: 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 the source for 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: National Science Foundation, Division of Science Resources Statistics, National Patterns of R&D Resources (annual series); and Organisation for Economic Co-operation and Development, Main Science and Technology Indicators (2006).

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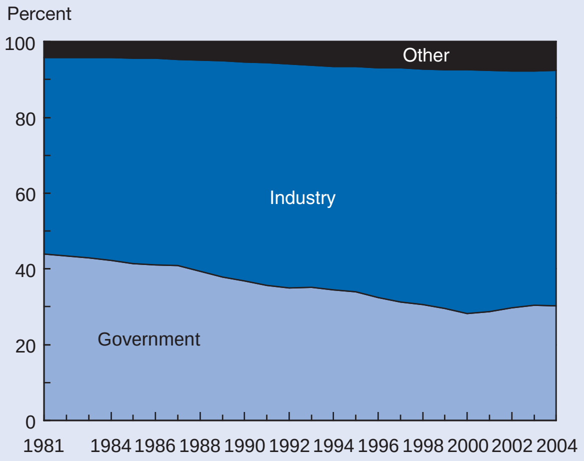
ing in Japan to as little as 30% in Russia. Government provided the largest share of Russia's R&D (62%), and although recent data for Italy are not available, its government funded 50% of Italy's R&D in 1999. In the remaining six G-8 nations, government was the second largest source of R&D funding, ranging from 18% of total R&D funding in Japan to 38% in France.

In nearly all OECD countries, the government's share of total R&D funding declined during the 1980s and 1990s as the role of the private sector in R&D grew considerably (figure 4-21). In 2000, 28% of all OECD R&D was funded from government sources, down from 44% in 1981. The relative decline of government R&D funding was 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, until rather recently, the United States). This trend also reflected the growth in business R&D spending during this period, irrespective of government R&D spending patterns. However, since 2000, government funding of R&D has grown in the OECD relative to funding from the business sector. In 2004, governments funded 30% of all OECD R&D.

Not all countries track the amount of domestic R&D that is funded by foreign sources, but of those that do, the United Kingdom reports a relatively large amount of R&D funding from abroad (17% in 2004) (table 4-14). 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.

Figure 4-21
Total OECD R&D, by funding sector: 1981–2004



OECD = Organisation for Economic Co-operation and Development

SOURCE: OECD, Main Science and Technology Indicators (2006). See appendix table 4-39.

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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

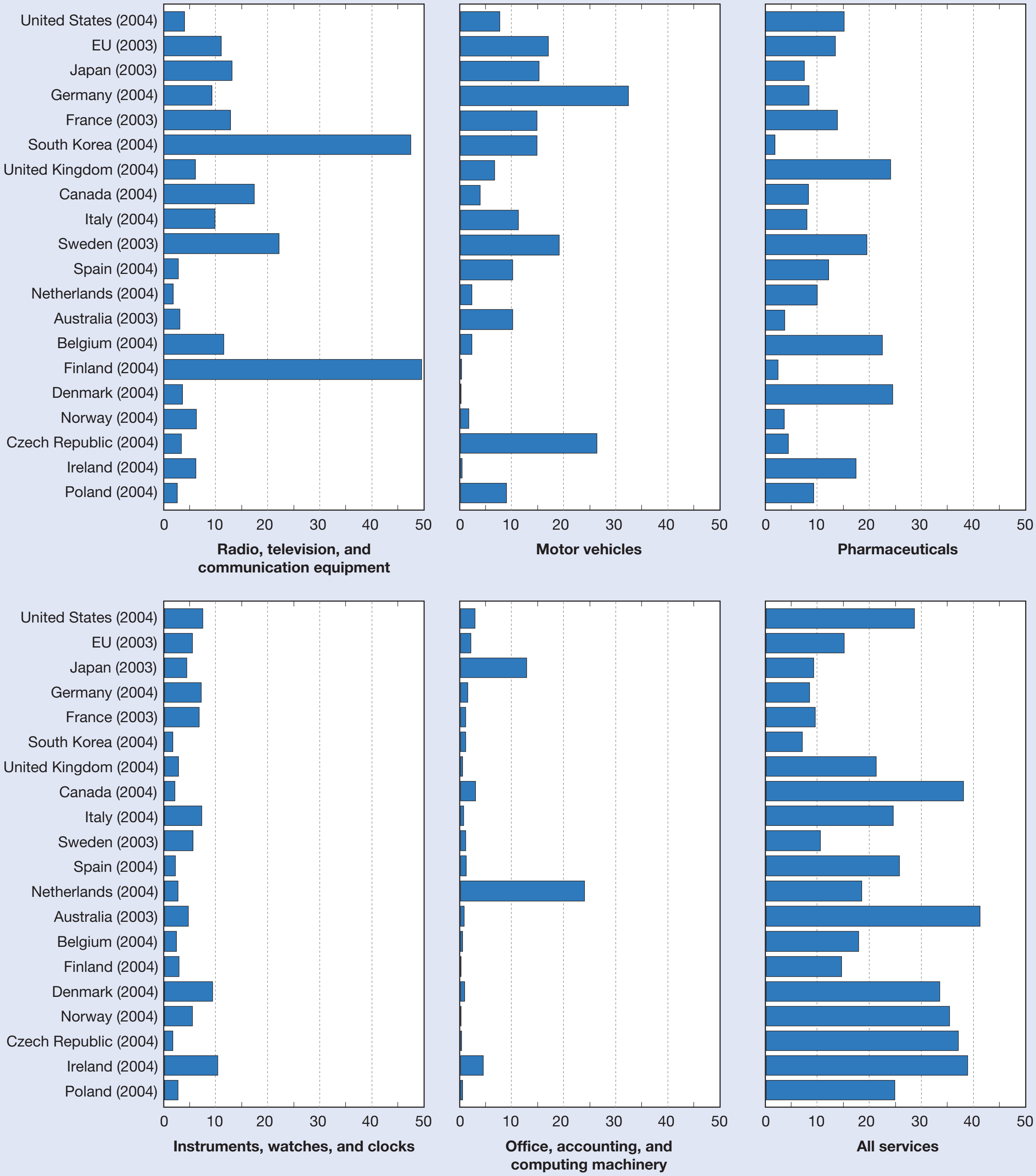
Using internationally comparable data, no one industry accounted for more than 16% of total business R&D in the United States in 2004 (figure 4-22; appendix table 4-42) (OECD 2006d). This is largely a result of the size of business R&D expenditures in the United States, which makes it difficult for any 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.[27]

Compared with the United States, many of the other countries shown in figure 4-22 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 2004. This high concentration most 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 (47% of business R&D in 2004) 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 among its top export commodities are semiconductors, cellular phones, and computers (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 32% of Germany's business R&D, 26% 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

Figure 4-22
Share of industrial R&D for selected countries and European Union, by industry sector: 2003 or 2004

Percent



EU = European Union

NOTE: Countries listed in descending order by amount of total industrial R&D.

SOURCE: Organisation for Economic Co-operation and Development, ANBERD database, http://www1.oecd.org/dsti/sti/stat-ana/stats/eas_anb.htm, accessed 1 March 2007. See appendix table 4-42.

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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 20% or more of business R&D in Denmark, the United Kingdom, Belgium, and Sweden. Denmark, the largest performer of pharmaceutical R&D in Europe, is home to Novo Nordisk, a world leader in the manufacture and marketing of diabetes-related drugs and industrial enzymes, and H. Lundbeck, a research-based company specializing in psychiatric and neurological pharmaceuticals. The United Kingdom is the second 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 expenditures in 2003 and 2004 (table 4-6).

The office, accounting, and computing machinery industry represents only a small share of business R&D in most countries. Among OECD countries (appendix table 4-42), only the Netherlands and Japan report double-digit concentration of business R&D in this industry, 24% (2004) and 13% (2003), respectively. The Netherlands is the home of Royal Philips Electronics, the largest electronics company in Europe.

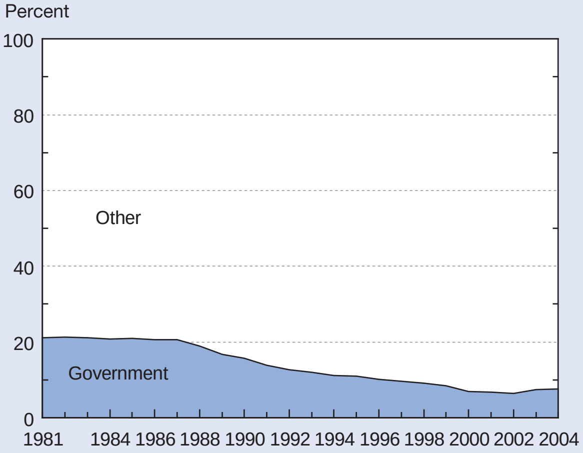
One of the more significant trends in both U.S. and international industrial R&D activity has been the growth of R&D in the service sector. In the European Union (EU), service-sector R&D has grown from representing 9% of business R&D in 1993 to 15% in 2003. In 2003, the EU's service-sector R&D nearly 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 four of the countries shown in figure 4-22 (Japan, Germany, France, and South Korea). Among the countries listed in this figure, the service sector accounted for as little as 7% of business R&D in South Korea to as much as 41% in Australia, and it accounted for 29% of total business R&D in the United States. 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, and in most OECD countries, government financing accounted for a small and declining share of total industrial R&D performance during the 1980s and 1990s (figure 4-23). In 1981, government provided 21% of the funds used by industry in conducting R&D within OECD countries. By 2000, government's funding share of industrial R&D had fallen to 7% but rose slightly to 8% in 2004. Among G-8 countries, government financing of industrial R&D performance shares ranged from as little as 1% in Japan in 2004 to 54% in Russia in 2005 (appendix table 4-37). In the United States in 2006, the federal government provided about 9% of the R&D funds used by industry, and the majority of that funding came from DOD contracts.

Foreign sources of funding for business R&D increased in many countries in the 1990s (figure 4-24). The role of foreign funding varies by country, accounting for less than 1% of industrial R&D in Japan to as much as 23% in the United Kingdom in 2004. The countries that exhibited the largest

Figure 4-23
OECD industry R&D, by funding sector: 1981–2004



OECD = Organisation for Economic Co-operation and Development

SOURCE: OECD, Main Science and Technology Indicators (2006). See appendix table 4-39.

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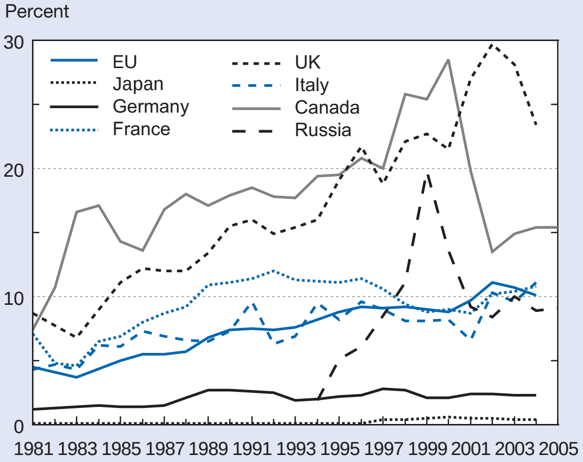
Figure 4-24
Industrial R&D financed, by foreign sources: 1981–2005



EU = European Union; UK = United Kingdom

NOTE: Data not available for all countries for all years.

SOURCE: Organisation for Economic Co-operation and Development, Main Science and Technology Indicators (2006). See appendix table 4-38.

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growth in this indicator during the 1990s (United Kingdom, Russia, and Canada), also experienced sharp drops in more recent years as shown by figure 4-25. Year-to-year variations in this measure can reflect changes in ownership of businesses conducting R&D in a country as well as changes in the level of foreign investment in the country.

This funding predominantly comes from foreign corporations and can be viewed as an indicator of the globalization of industrial R&D. However, some of this funding also comes from foreign governments and other foreign organizations. For European countries, growth in foreign sources of R&D funds may reflect the expansion of coordinated European Community (EC) efforts to foster cooperative shared-cost research through its European Framework Programmes.[28]

There are no data on foreign funding sources of U.S. R&D performance. However, data on investments by foreign MNCs provide some indication of this activity for the

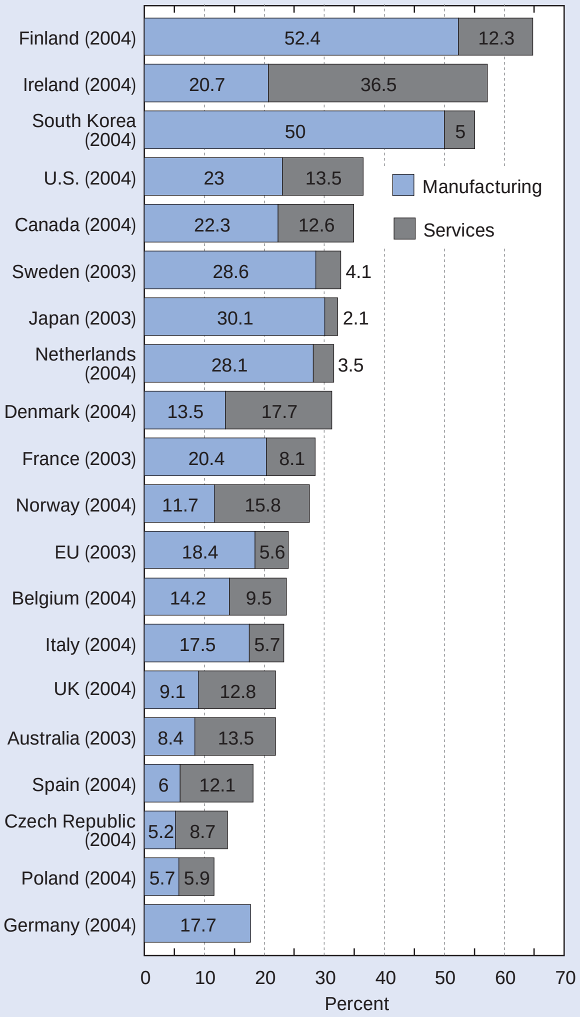
R&D in the ICT Sector

Information and communications technologies (ICTs) play an increasingly important role in the economies of 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 R&D 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 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 software and related activities) (OECD 2002)

The ICT sector accounted for more than one-quarter of total business R&D in 11 of the 19 OECD countries shown in figure 4-25, and more than half of total business R&D in Finland, Ireland, and South Korea. ICT industries accounted for 37% of the business R&D in the United States and 32% 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.

Figure 4-25
Industrial R&D by information and communications technologies sector for selected countries and European Union: 2003 or 2004



EU = European Union; UK = United Kingdom

NOTE: Information and communications technologies service-sector R&D data not available for Germany.

SOURCE: Organisation for Economic Co-operation and Development, ANBERD database, http://www1.oecd.org/dsti/sti/stat-ana/stats/eas_anb.htm, accessed 22 May 2007.

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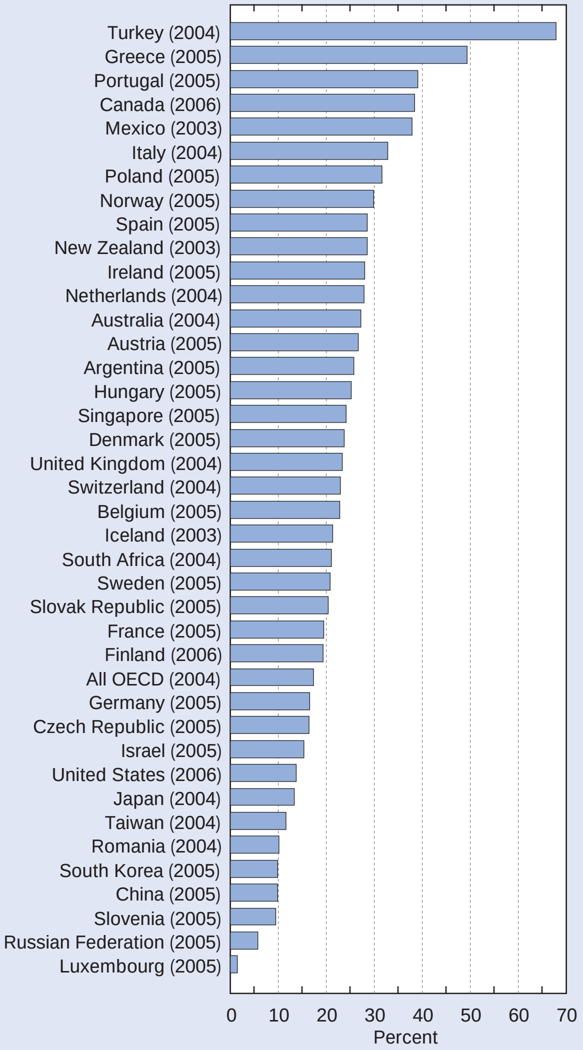
industrial sector (see the section entitled "R&D by Multinational Corporations" later in this chapter).

Academic Sector

In most 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 38% in Canada, and they accounted for 14% of U.S. total R&D (figure 4-26). In Asia, the academic sector generally performs a small share of national R&D in financial terms, accounting for 13% or less of total R&D expenditures in Japan, China, South Korea, and Taiwan. Each of these countries also reports relatively low amounts of basic research as a share of total R&D (figure 4-20).

Figure 4-26
Academic R&D share of all R&D for selected countries/economies and all OECD: Most recent year



OECD = Organisation for Economic Co-operation and Development

SOURCES: National Science Foundation, Division of Science Resources Statistics, National Patterns of R&D Resources (annual series); and OECD, Main Science and Technology Indicators (2006).

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Source of Funds

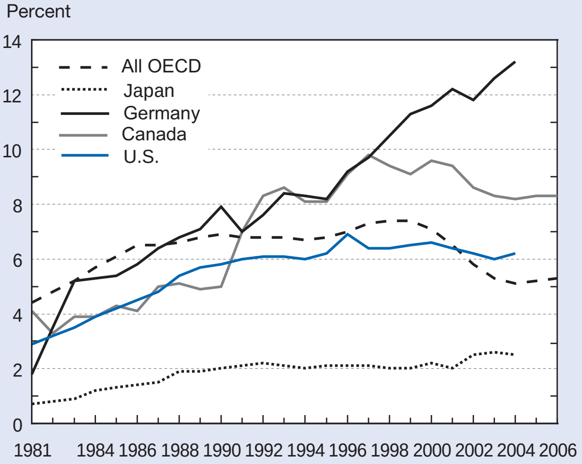
For most countries, the government is now, and historically has been, the largest source of academic research funding (see sidebar, "Government Funding Mechanisms for Academic Research"). However, in each of the G-7 countries for

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. GUF is not equivalent to basic research. The U.S. federal government does not provide research support through a GUF equivalent, preferring instead to support specific, separately budgeted R&D projects, usually to address the objectives of the federal agencies that provide the R&D funds. However, some state government funding probably does support departmental research at public universities in the United States.

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 in Canada it accounts for roughly 45% of 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.

Figure 4-27
Academic R&D financed by industry for selected countries and all OECD: 1981–2006



OECD = Organisation for Economic Co-operation and Development

NOTE: Data not available for all countries for all years.

SOURCES: National Science Foundation, Division of Science Resources Statistics, National Patterns of R&D Resources (annual series); and OECD, Main Science and Technology Indicators (2006). See appendix table 4-40.

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which historical data exist, the government's share declined and industry's share increased during the 1980s and 1990s. Business funding of academic R&D for all OECD countries combined peaked in 2000 at 7% but declined to 6% in 2004. In the United States, it slipped to 5% in 2003, where it has since remained. Among OECD countries, the business sector's role in funding academic R&D is most prominent in Germany where the industry-funded share of academic R&D is twice that of all OECD members combined (figure 4-27). The business sector plays an even greater role in other countries, however. In 2004, the business sector funded 37% of China's academic R&D and 33% of Russia's. With the launching in early 2007 of the European Research Council, a pan-European funding agency established as part of the EU's Seventh Research Framework Programme, the EU hopes to provide additional support to academic research. The European Research Council, with a 7-year budget of 7.5 billion (approximately $10 billion), will employ a competitive peer-review process similar to that employed by various government agencies in the United States to select grant recipients.

S&E Fields

Most countries supporting a substantial level of academic R&D devote a larger proportion of their R&D to engineering and social sciences than does the United States (table 4-15).

Table 4-15
Share of academic R&D expenditures, by country and S&E field: 2002 or 2003
(Percent distribution)

Field	U.S (2003)	Japan (2003)	Germany (2002)	Spain (2003)	Australia (2002)	Netherlands (2002)	Sweden (2003)	Switzerland (2002)
Academic R&D expenditure (PPP $billions)	41.4	15.4	9.7	3.4	2.6	2.6	2.3	1.5
Academic R&D	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
NS&E	91.0	67.8	77.0	62.8	73.2	72.8	79.6	47.6
Natural sciences	39.5	12.1	28.5	22.6	29.7	17.9	19.5	19.9
Engineering	14.5	24.7	19.8	23.5	11.5	21.0	26.1	9.8
Medical sciences	30.9	26.7	24.6	14.2	25.2	28.3	29.3	17.9
Agricultural sciences	6.2	4.3	4.0	2.5	6.9	5.5	4.7	NA
Social sciences and humanities	7.3	32.2	20.2	37.2	26.8	24.8	19.6	14.7
Social sciences	6.2	NA	8.2	21.8	20.6	NA	13.2	NA
Humanities	0.4	NA	12.1	15.4	6.2	NA	6.4	NA
Academic NS&E								
NS&E	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Natural sciences	43.4	17.8	37.0	36.0	40.5	24.7	24.5	41.8
Engineering	15.9	36.5	25.8	37.5	15.7	28.8	32.7	20.5
Medical sciences	33.9	39.4	32.0	22.6	34.4	38.9	36.8	37.6
Agricultural sciences	6.8	6.3	5.2	3.9	9.4	7.6	5.9	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 or because some R&D could not be allocated to specific fields. For United States, $0.7 billion could not be allocated between NS&E and social sciences. Data for years in parentheses.

SOURCES: National Science Foundation, Division of Science Resources Statistics, Academic Research and Development Expenditures: Fiscal Year 2003 (2005); and Organisation for Economic Co-operation and Development, R&D Statistics database (November 2005).

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Conversely, the U.S. academic R&D effort emphasizes the natural sciences and medical sciences more than do many other OECD countries. This is consistent with the emphases in health and biomedical sciences for which the United States is known. Japan, the country with the second largest amount of academic R&D ($16 billion in 2004, approximately one-third of the U.S. amount) places a roughly equal emphasis on engineering and medical sciences. Together, these two fields account for half of Japan's academic R&D expenditures.

Government R&D Priorities

Analyzing public expenditures for R&D by major socioeconomic objectives shows how government priorities differ between countries and change over time. Within the OECD, the defense share of governments' R&D financing declined from 43% in 1986 to 28% in 2001 (table 4-16). 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 58% in 2006 (appendix table 4-41).

Notable shifts also occurred in the composition of OECD countries' governmental nondefense R&D support over the past two decades. In terms of broad socioeconomic objectives, government R&D shares increased most for health and the environment. 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 the United States, health-related R&D has accounted for more than half of the government's nondefense R&D budget since 2000. Throughout the OECD, the relative share of government R&D support for economic development programs declined from 25% in 1981 to 15% in 2005. Economic development programs include the promotion of agriculture, fisheries and forestry, industry, infrastructure, and energy.

Differing R&D activities are emphasized in each country's governmental R&D support statistics (figure 4-28). As noted above, defense accounts for a relatively smaller

Table 4-16
Government R&D support for defense and nondefense purposes, all OECD countries: 1981–2005
(Percent)

			Nondefense R&D budget shares			
Year	Defense	Nondefense	Health and environment	Economic development programs	Civil space	Other purposes
1981	34.6	65.4	19.2	37.6	9.6	31.9
1982	36.9	63.1	18.9	37.8	8.3	33.2
1983	38.7	61.3	18.8	36.9	7.5	36.1
1984	40.8	59.2	19.7	36.0	7.8	34.7
1985	42.4	57.6	20.0	35.8	8.4	35.0
1986	43.4	56.6	20.0	34.7	8.6	35.9
1987	43.2	56.8	20.8	32.5	9.6	36.2
1988	42.6	57.4	21.2	30.8	10.0	37.2
1989	41.2	58.8	21.4	29.9	10.8	37.2
1990	39.3	60.8	21.8	28.8	11.7	36.8
1991	36.4	63.6	21.7	28.1	11.8	37.3
1992	35.3	64.8	22.0	27.0	11.9	37.7
1993	35.2	64.8	22.0	26.1	12.1	38.4
1994	32.9	67.2	22.2	25.1	12.3	38.7
1995	31.2	68.8	22.5	24.4	12.1	38.2
1996	30.9	69.1	22.6	24.4	11.9	38.7
1997	30.8	69.2	22.8	24.6	11.4	38.8
1998	30.0	70.0	23.6	22.8	11.4	39.8
1999	29.4	70.6	24.5	23.3	10.7	39.2
2000	28.1	71.9	25.0	23.4	9.9	39.3
2001	28.1	71.9	26.1	23.1	9.8	39.0
2002	29.5	70.5	27.1	22.7	9.4	39.2
2003	31.5	68.5	28.0	22.2	9.5	38.7
2004	31.9	68.1	29.1	22.0	9.2	38.4
2005	33.2	66.8	29.2	22.2	9.4	38.5

OECD = Organisation for Economic Co-operation and Development

NOTE: Nondefense R&D classified as Other purposes consists primarily of university funds and nonoriented research programs.

SOURCE: OECD, Main Science and Technology Indicators (2006).

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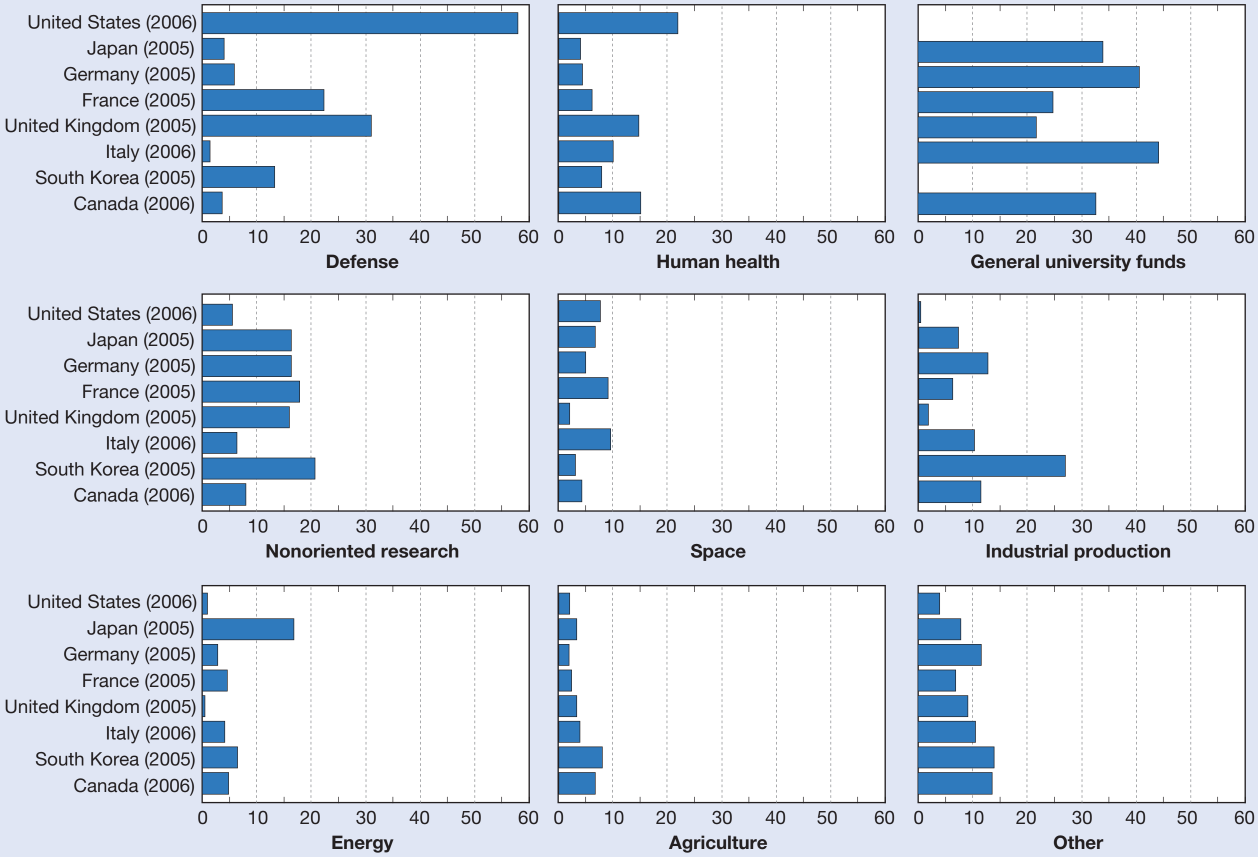
Figure 4-28

Government R&D support for selected countries, by socioeconomic objective: 2005 or 2006

(Percent)



NOTE: Countries listed in descending order by amount of total goverment R&D. 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 (2007). See appendix table 4-41.

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government R&D share in most countries outside the United States. In recent years, the defense share was relatively high in the United Kingdom and France at 31% and 22%, respectively, but was 6% or less in Germany, Italy, Canada, and Japan. In 2005, South Korea allocated 13% of its government R&D budget for 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. Industrial production and technology is the leading socioeconomic objective for R&D in South Korea, accounting for 27% of its government's R&D budget. This funding is primarily oriented toward the development of science-intensive industries and is aimed at increasing economic efficiency and technological development. 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).

Compared with other countries, France and South Korea invested relatively heavily in nonoriented research at 18% and 21% of government R&D appropriations, respectively. The U.S. government invested 6% of its R&D budget in nonoriented research, largely through the activities of NSF and DOE. However, differences in countries' classification practices affect the size of this apparent gap.

R&D by Multinational Corporations

The internationalization of R&D through foreign direct investment (FDI) by MNCs is one indicator of increasing globalization of innovation activities (Carlsson 2006; OECD 2006c). Related indicators include international trade and cross-country business alliances, which are discussed later

Foreign Direct Investment in R&D

Foreign direct investment (FDI) refers to the ownership of productive assets outside the home country by multinational corporations (MNCs). More specifically, the 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 (BEA 1995). 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 technology adaptation to the development of new products or services (Kumar 2001; Niosi 1999). The location decision for global R&D sites is driven by market- and science-based factors, including cost considerations, the investment climate, the pull of large markets, and the search for location-specific expertise (von Zedtwitz and Gassmann 2002). Furthermore, the relative importance of these factors is likely to vary depending on the industry, the technology objectives of the overseas activity, and host country characteristics relative to those of home countries. For example, in a recent study examining motives to locate R&D overseas, Thursby and Thursby (2006) report that the size of output markets and the quality of R&D personnel are the top "attractors" for FDI R&D in emerging markets, whereas the activities associated with strong research universities remain a key factor for R&D in the home market or in overseas developed economies. Barriers or challenges include managing and coordinating knowledge on a global scale and intellectual property protection.

in this chapter. 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, Singapore, and India. For general information about R&D by MNCs, see sidebar, "Foreign Direct Investment in R&D."

U.S. Affiliates of Foreign Companies

Majority-owned affiliates of foreign companies located in the United States performed $29.9 billion in U.S. R&D expenditures in 2004, little changed from 2003.[29] However, between 1999 and 2004, R&D by these affiliates increased faster than overall industrial R&D in the United States (2.1% on an annual average rate basis after adjusting for inflation, compared with 0.2%). Currently, there are no data on the R&D character of work for MNCs separate from the national trends discussed earlier in this chapter. However, an interagency project involving NSF, the Census Bureau, and BEA is aimed, in part, at developing these data, not only for affiliates of foreign MNCs in the United States, but also for parents of U.S. MNCs discussed below. (See sidebar, "Linking MNC Data From International Investment and Industrial R&D Surveys.")

In 2004, manufacturing accounted for 70% of U.S. affiliates' R&D, including 34% in chemicals (of which 86% were in pharmaceuticals), 13% in transportation equipment, and 11% in computer and electronic products (table 4-17; appendix table 4-44). U.S. affiliates owned by European parent companies accounted for three-fourths ($22.6 of $29.9 bil-

Linking MNC Data From International Investment and Industrial R&D Surveys

An ongoing data development project aims to integrate the statistical information from the BEA's international investment surveys with the NSF/Census Survey of Industrial Research and Development. Such data sharing among federal statistical agencies has been facilitated by the Confidential Information Protection and Statistical Efficiency Act of 2002. Combining technological and investment data from these separate but complementary sources will facilitate a better assessment of globalization trends in R&D and technological innovation. The initial methodological study (completed in 2005) demonstrated not only the feasibility of such a linkage, but also its utility.

A combined preliminary dataset provided information for the first time on R&D expenditures by U.S. and foreign MNCs by character of work (basic research, applied research, development). The study also has produced tangible benefits for the participating agencies, including improvements in survey sampling and the quality of reported data. As a result of these promising initial results, the three participating agencies are considering future work in this area. For more information, see NSF/SRS (2007e) and Census Bureau et al. (2005).

Table 4-17

R&D performed by majority-owned affiliates of foreign companies in United States, by selected NAICS industry of affiliate and country/region: 2004

(Millions of current U.S. dollars)

Country/region	All industries	Manufacturing						Nonmanufacturing	
		Total	Chemicals	Machinery	Computer and electronic products	Electrical equipment	Transportation equipment	Information	Professional, technical, scientific services
All countries	29,900	20,891	10,045	1,547	3,279	238	3,728	898	1,442
Canada	1,458	940	38	3	D	D	D	D	40
Europe	22,648	17,710	9,606	1,382	1,999	164	3,282	549	560
France	3,738	3,050	2,064	D	D	D	D	261	28
Germany	5,929	5,345	1,375	987	246	18	2,553	D	D
Netherlands	1,316	579	353	D	0	2	4	3	D
Switzerland	4,004	3,462	3,201	112	25	5	5	3	411
United Kingdom	5,924	4,273	2,225	50	1,248	10	445	D	73
Asia/Pacific	3,725	1,403	291	D	422	17	D	46	D
Japan	3,413	1,232	281	72	354	16	334	D	699
Latin America/OWH	D	645	3	D	D	D	2	1	D
Middle East	D	134	80	*	D	0	7	D	D
Africa	36	D	D	0	0	0	0	D	0

D = suppressed to avoid disclosure of confidential information; * = ≤$500,000

NAICS = North American Industry Classification System; OWH = other Western Hemisphere

NOTES: Preliminary 2004 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: Bureau of Economic Analysis, Survey of Foreign Direct Investment in the United States (annual series), http://www.bea.gov/bea/di/di1fdiop.htm, accessed 24 April 2007. See appendix tables 4-43 and 4-44.

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lion) of U.S. affiliates' R&D (figure 4-29), compared with their 66% share in value-added by U.S. affiliates.

Affiliates from some investing countries are particularly notable in some industries. German-owned affiliates classified in transportation equipment performed $2.6 billion of R&D, or 68% of all U.S. affiliates' R&D in this industry and 43% of total R&D performed by German-owned U.S. affiliates (table 4-17). On the other hand, affiliates owned by Swiss, British, and French parent companies performed about three-fourths of U.S. affiliates' R&D in chemicals (which includes pharmaceuticals). British-owned affiliates performed 38% of U.S. affiliates' R&D in computers and electronic products, whereas Japanese-owned affiliates accounted for just under half of R&D expenditures in professional, scientific, and technical services.

U.S. MNCs and Their Overseas R&D

Majority-owned foreign affiliates of U.S. MNCs (henceforth, foreign affiliates) performed $27.5 billion in R&D abroad in 2004 after adjusting for inflation, up $4.7 billion or 17.4% from 2003, which was the largest annual increase since a 22% rise in 1999.[30] In general, changes in FDI R&D reflect a combination of activities in existing facilities, the acquisition of R&D-performing companies, and the establishment of new industrial laboratories or other facilities engaged in technical activities. However, available data do not allow for distinguishing between these FDI alternatives.

U.S. MNCs comprise U.S. parent companies and their foreign affiliates.[31] Since 1994, at least 85% of the combined global R&D expenditures by U.S. MNCs were performed at home (table 4-18).

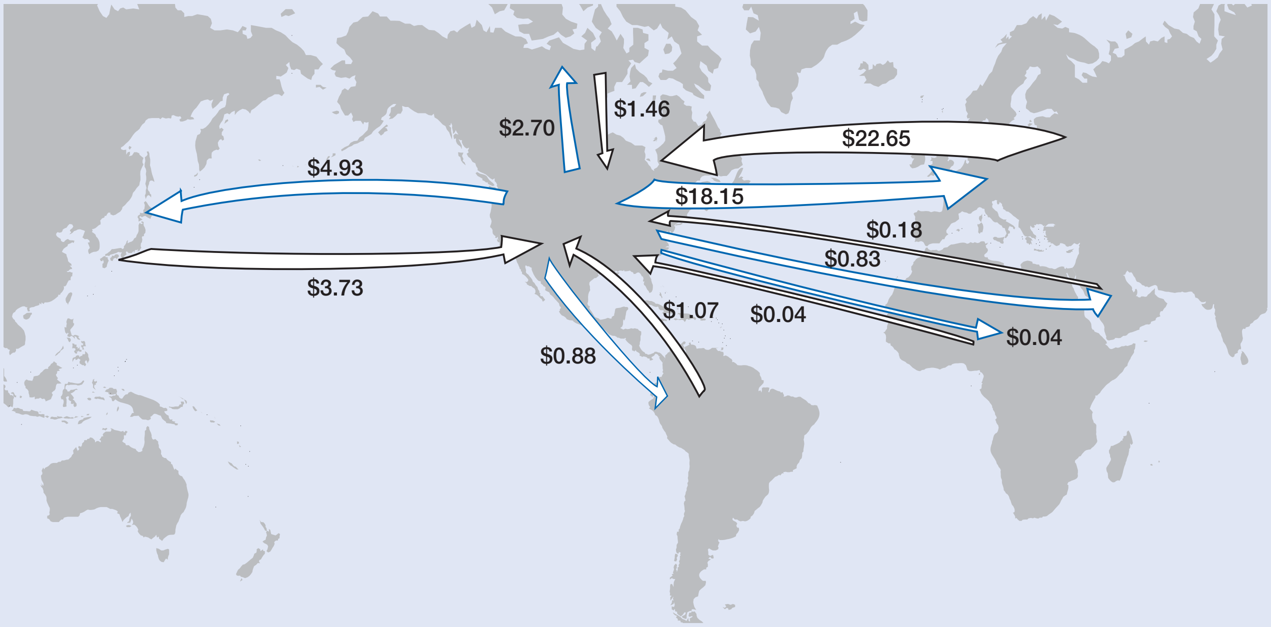
At the same time, however, foreign affiliates' R&D expenditures and value-added by foreign affiliates grew at a faster rate than U.S. parents' after adjusting for inflation. Consequently, the share of foreign affiliates' R&D expenditures within U.S. MNCs increased from 11.5% in 1994 to 15.3% in 2004, comparable with the increase in their value-added share from 23.5% to 27.1% over the same period.

Perhaps more revealing than aggregate figures are changes in the geographic distribution of these expenditures, reflecting the changing dynamics of international R&D (figure 4-30). 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%. However, Europe's share rebounded from an all-time low of 61% in 2001 to 66% in 2004, representing slightly more than two-thirds of the $4.7 billion increase in 2004, driven by affiliates in the United Kingdom, Germany, and Switzerland. At the same time, however, foreign affiliates of U.S. MNCs have increasingly engaged in R&D activities in Asian emerging markets (figure 4-30; appendix table 4-45).

Figure 4-29

R&D performed by U.S. affiliates of foreign companies in U.S., by investing region, and performed by foreign affiliates of U.S. multinational corporations, by host region: 2004 or latest year

Current U.S. dollars (billions)



NOTES: Preliminary estimates for 2004. 2002 data for U.S. affiliates of foreign companies from Latin America and Middle East.

SOURCES: 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 4-43 and 4-45.

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Table 4-18

R&D performed by parent companies of U.S. multinational corporations and their majority-owned foreign affiliates: 1994–2004

	R&D performed (current US$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	136,977	21,063	158,040	86.7	13.3
2003	139,884	22,793	162,677	86.0	14.0
2004	152,384	27,529	179,913	84.7	15.3

MNC = multinational corporation; MOFA = majority-owned foreign affiliate

NOTES: MOFAs are affiliates in which combined ownership of all U.S. parents is >50%. Detail may not add to total because of rounding.

SOURCE: Bureau of Economic Analysis, Survey of U.S. Direct Investment Abroad (annual series), http://www.bea.gov/bea/di/di1usdop.htm, accessed 24 April 2007.

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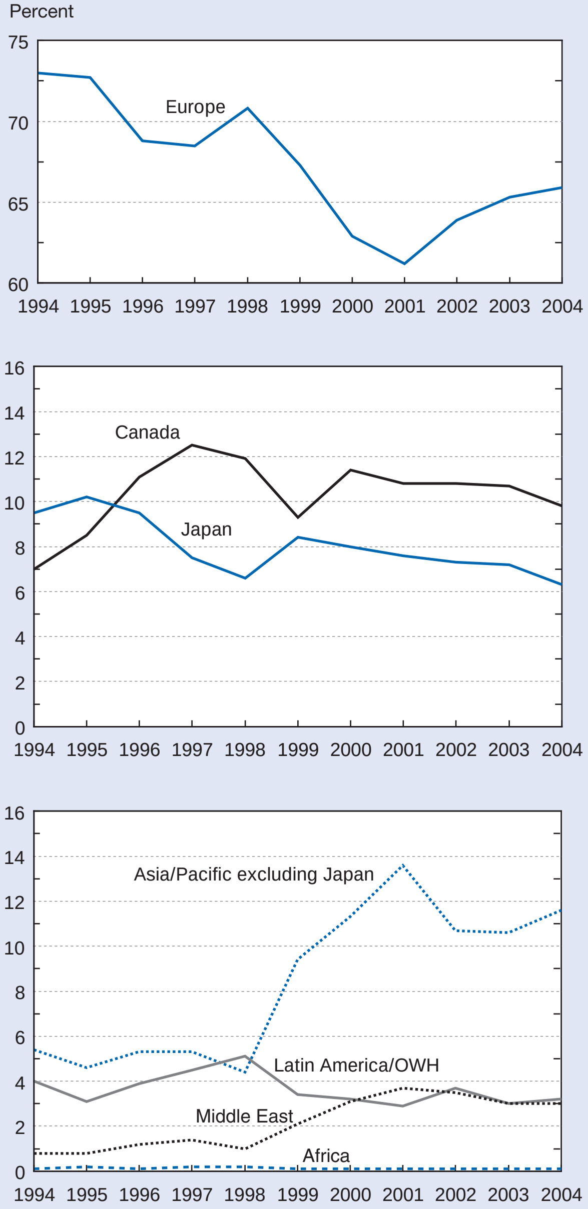
Figure 4-30
Regional shares of R&D performed abroad by foreign affiliates of U.S. MNCs: 1994–2004



MNC = multinational corporation; OWH = other Western Hemisphere

NOTES: Data for majority-owned affiliates. Preliminary estimates for 2004.

SOURCE: Bureau of Economic Analysis, Survey of U.S. Direct Investment Abroad (annual series). See appendix table 4-45.

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Within the Asia-Pacific region (which also includes Australia and New Zealand), the share for Japan decreased from 64% in 1994 to 35% in 2004, even though this country remains the largest host of U.S.-owned R&D in the region. In contrast, the shares of foreign affiliates located in China and Singapore increased from 0.4% and 9.4%, respectively, to 12.6% and 14.4%. Other countries with sizable 2004 shares within this region include Australia (9.5%), Taiwan (7.4%), Malaysia (6.1%), and South Korea (5.0%). Notably, R&D by affiliates located in India doubled from $81 million in 2003 to $163 million in 2004, increasing the share within this region to 3.3%.

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 4-45).

In 2004, three manufacturing industries accounted for most foreign-affiliate R&D: transportation equipment (28.1%), chemicals (including pharmaceuticals) (22.7%), and computer and electronic products (19.2%) (table 4-19; appendix table 4-46). Within the nonmanufacturing sector, the professional, technical, and scientific services industry (which includes R&D and computer services) accounted for 7.7%. The industry distribution in European locations is similar to the average across all host countries, whereas at least half of affiliates' R&D expenditures in Canada and Japan are performed by affiliates classified in transportation equipment and chemicals, respectively. Affiliates classified in computer and electronic products performed 63.1% of U.S.-owned R&D in Israel and 42.7% of U.S.-owned R&D in the Asia-Pacific region, excluding Japan.

Technology Linkages: Contract R&D, Trade in R&D Services, Business Alliances, and Federal Technology Transfer

Collaboration with external technology sources, including universities and federal laboratories, has long played a key role in U.S. industrial innovation (Bozeman 2000; Mowery 1983; Rosenberg and Nelson 1994). Increasingly, however, industrial innovation requires partners, resources, and ideas outside company and national boundaries (Chesbrough, Vanhaverbeke, and West 2006; EIU 2006; IBM 2006; IRI 2007). (See sidebar, "A Window Into Open or Collaborative Innovation.") Factors behind this trend include the complex and multidisciplinary nature of scientific research, coupled with the increased relevance of science for industrial technology in a globally competitive environment. Several terms in the academic and business literature capture diverse but related dimensions of this new environment, including open or collaborative innovation, networked R&D, innovation sourcing, and technology markets.[32] The resulting exchanges or joint activities involve customers, suppliers, competitors, and public institutions such as universities and government agencies.

Table 4-19
R&D performed abroad by majority-owned foreign affiliates of U.S. parent companies, by selected NAICS industry of affiliate and country/region: 2004
(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, electronic scientific services
All countries	27,529	23,288	6,254	791	5,283	551	7,741	843	2,120
Canada	2,702	2,517	503	26	472	16	1,334	38	D
Europe	18,148	15,198	4,451	656	2,117	422	5,750	317	1,477
Belgium	628	465	D	18	D	12	23	0	80
France	1,854	1,762	912	75	136	12	422	D	23
Germany	4,693	4,144	269	190	543	240	2,462	11	D
Sweden	1,525	1,483	83	11	51	D	D	1	D
Switzerland	868	361	104	31	76	4	15	10	236
United Kingdom	5,462	4,434	1,711	177	762	34	1,339	46	849
Asia and Pacific	4,934	4,426	1,164	81	2,108	95	435	D	D
Australia	471	426	92	D	D	1	222	*	D
China	622	538	18	7	468	D	5	D	21
Hong Kong	220	196	4	*	D	2	0	D	D
Japan	1,742	1,552	1,004	45	244	D	114	127	D
Singapore	711	698	8	*	677	D	D	8	4
Taiwan	363	349	11	6	14	0	D	D	1
Latin America/OWH	882	581	124	26	66	16	206	D	D
Brazil	340	328	67	21	61	D	144	2	5
Mexico	D	199	36	5	1	D	53	0	D
Middle East	826	539	6	1	520	1	0	D	D
Israel	824	539	6	1	520	1	0	D	D
Africa	36	27	6	1	0	0	16	2	*
South Africa	30	24	5	*	0	0	16	2	*

D = suppressed to avoid disclosure of confidential information; * = ≤$500,000
NAICS = North American Industry Classification System; OWH = other Western Hemisphere

NOTES: Preliminary 2004 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: Bureau of Economic Analysis, Survey of U.S. Direct Investment Abroad (annual series), http://www.bea.gov/bea/di/di1usdop.htm, accessed 24 April 2007. See appendix tables 4-45 and 4-46.

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Major channels to acquire or codevelop knowledge and technologies include alliances or partnerships, external R&D services, and technology licensing. Each may interact differently with internal R&D and each present different risks and benefits in terms of innovation strategies and management (Cassiman and Veugelers 2002; Fey and Birkinshaw 2005). In turn, each channel has different implications for public policies aiming at promoting innovation. Indeed, public policies in advanced economies concerned with enhancing growth have evolved to address the many dimensions of industrial innovation. Several policies in the United States have facilitated R&D collaboration among industry, universities, and federal laboratories since the 1980s (see sidebar, "Major Federal Legislation Related to Cooperative R&D and Technology Transfer").

This section discusses three different types of indicators of knowledge flows and technology linkages: transactions involving R&D, business alliances, and technology transfer from federal sources. Indicators of transactions include domestic contract R&D by R&D-performing companies, exports by U.S. establishments classified in the R&D services industry, and international transactions of R&D services by all companies located in the United States. Not surprisingly, there are differences in scope and methodology across the different sources, as detailed throughout this section. However, each source explores complementary dimensions in the complex web of domestic and international transactions involving R&D and R&D-related services.

Contract R&D Expenses Within the United States

R&D-performing companies in the United States reported $11.7 billion (including $8.9 billion reported by manufacturers) in R&D contracted out to other domestic companies and

A Window Into Open or Collaborative Innovation

Industrial innovation is increasingly global and performed collaboratively, requiring partners, resources, and ideas outside the company and national boundaries (Chesbrough, Vanhaverbeke, and West 2006; OECD 2006c). Knowledge may be generated internally, codeveloped, or acquired from a variety of private and public sources, then further developed for a specific market. Often, to successfully enter the marketplace ahead of competitors, an invention or new organizational method requires a new business model (Chesbrough 2007), as well as complementary assets such as manufacturing, marketing, or distribution capabilities. The latter may also be developed internally, acquired, or outsourced (Howells 2006; Teece 1986). The following excerpts from publications provide a flavor of some of the current industry thinking and activities in this area.

Harvard Business Review
Connect and Develop: Inside Proctor & Gamble's New Model for Innovation

> As we studied outside sources of innovation, we estimated that for every P&G [Procter & Gamble] researcher there were 200 scientists or engineers elsewhere in the world who were just as good—a total of perhaps 1.5 million people whose talents we could potentially use. But tapping into the creative thinking of inventors and others on the outside would require massive operational changes. We needed to move the company's attitude from resistance to innovations "not invented here" to enthusiasm for those 'proudly found elsewhere.' And we needed to change how we defined, and perceived, our R&D organization—from 7,500 people inside to 7,500 plus 1.5 million outside, with a permeable boundary between them. (Huston and Sakkab 2006)

Business Week
Crowdsourcing: Milk the Masses for Inspiration

> Business model innovation is happening at a lightning clip. First there was outsourcing, then open-sourcing, and now crowdsourcing. . . . Crowdsourcing often produces a wealth of ideas, and companies need effective filters to pick the gems. Consider IBM's innovation jam, a two-part brainstorming session launched in July [2006] designed to tap the collective minds of employees, family members, and customers to target potential areas for innovation. CEO Sam Palmisano will put $100 million into promising ideas. (Hempel 2006).

Chemical & Engineering News
Start-Up Firm NineSigma Uses Internet To Match Industrial Clients With Inventive Partners

> In his 28 years at Procter & Gamble, Paul Stiros says he never doubted the wisdom behind connecting R&D to customer needs. As president and chief executive officer of privately held NineSigma, Stiros heads a firm committed to helping corporations acquire technical innovations that will quickly bring tomorrow's star products to market. . . . Competing firms such as InnoCentive and YourEncore also help corporations get research help outside the usual channels. InnoCentive posts specific problems for corporate customers on the Internet and pays a bounty for solutions. YourEncore connects technology and product development needs of member companies with retirees who have scientific backgrounds. (American Chemical Society 2006)

Boeing
YourEncore and Your Retirement

> Boeing partnered in August 2003 with YourEncore Inc. to provide Boeing retirees with scientific and engineering skills [and] challenging and rewarding project opportunities in various industries, including aerospace, chemical, communications, pharmaceutical and consumer products. Retirees can contribute their expertise to major companies on high-level projects while networking among peers and gaining experience in new industries. . . . "YourEncore is an ideal opportunity for Boeing retirees to stay intellectually engaged on a part-time basis to the degree the retiree wishes and get fairly compensated," said Dick Paul, Boeing Phantom Works* vice president, strategic development and analysis. "Boeing retirees can join YourEncore and consult either back at Boeing or with other member companies in varied industries." (Sopranos 2004)

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*Phantom Works is the advanced R&D unit at Boeing.

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, which let companies collaborate on production and research activities.

Federal Technology Transfer Act (1986). Amended the Stevenson-Wydler Technology Innovation Act to authorize cooperative R&D 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 NIST 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.

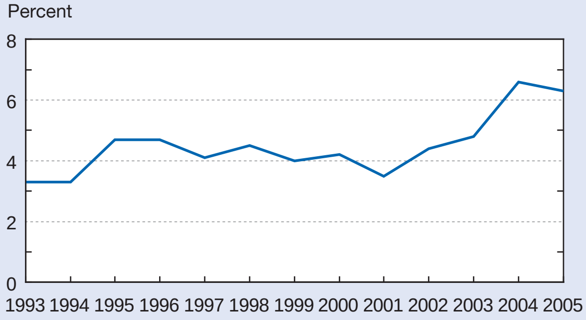
other organizations in 2005, compared with $12.3 billion in 2004, according to NSF data (appendix table 4-50).[33] The ratio of contracted-out R&D to company-funded, company-performed R&D declined from 6.6% in 2004 to 5.7% for all industries in 2005 but remained above 6% for manufacturing (figure 4-31). However, since 1993, these contracted-out expenditures have grown faster than company-funded, company-performed expenditures.

The relative magnitude of payments for R&D conducted by others varies across industries. In 2005, pharmaceutical companies reported $4.6 billion in contracted-out R&D (appendix table 4-51), or 13.2 % of their company-funded, company-performed R&D, followed by scientific R&D services (11.4%); navigational, measuring, electromedical, and control instruments (7.9%); and motor vehicles, trailers, and parts (7.2%). The ratio was only 2.8% for companies classified in computer and electronic products.

For most of the industries highlighted above, close to 80% of contracted-out R&D payments were received by other companies. For scientific R&D services, however, only 53% of these expenditures were received by other companies.[34]

Figure 4-31

R&D contracted out in United States by manufacturing companies as ratio of company-funded and -performed R&D: 1993–2005



SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Industrial Research and Development (annual series).

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International Trade in R&D Services

The international flow of knowledge through trade in services represents the convergence of two recent trends: an increase in R&D performance in the service sector and an increase in transactions with external parties (Arora, Fosfuri, and Gambardella 2001; OECD 2006c). U.S. R&D-related trade in services is a relatively new indicator of international industrial knowledge and technology flows. Other such indicators include FDI, trade in high-technology goods, patent royalties, and license fees (see the section entitled "R&D by Multinational Corporations" and also chapter 6). Trade in R&D and technical services are also key to understanding the growing role of services in the U.S. economy and the extent and impact of services "offshoring " (GAO 2004; Graham 2007; NAPA 2006).[35]

Exports by R&D Services Establishments

The Service Annual Survey (SAS) conducted by the Census Bureau provides national estimates of total revenues, export revenue, and expenses of establishments (single physical locations at which business is conducted and/or services are provided) classified in NAICS service industries.[36] Scientific R&D services (NAICS 5417) cover establishments devoted primarily to R&D, either as stand-alone enterprises or within larger companies.[37] Newly available data on export revenues for this industry are based on revenues for basic and applied research, production services for development, testing services, and licensing of intellectual property. In 2005, U.S. establishments classified in NAICS 54171 (physical, engineering, and life sciences) exported $3.0 billion in R&D services, or 3.9% of their total revenue ($76.4 billion) (table 4-20). Notably, this proportion was about twice as large as the export revenue share for all professional, scientific, and technical services in 2004 and 2005.

Exports and Imports of R&D Services

The preceding discussion of R&D services exports was based on establishments classified in a specific industry sector. The present section examines patterns in services trade, regardless of industry classification, and focuses on research, development, and testing (RDT) services.[38] Since 2001, these data have been available for two major categories of customers or suppliers: trade among unaffiliated companies and trade among affiliates of MNCs. In 2005, total exports (affiliated and unaffiliated) of RDT services reached a record $10.1 billion, compared with record imports of $6.7 billion, resulting in a trade surplus of $3.4 billion (figure 4-32). This trade surplus is little changed from the $3.8 billion surplus in 2004 but smaller than trade surpluses (approximately $5 billion) in both 2002 and 2003. Affiliated exports and imports have been larger than unaffiliated exports and imports (table 4-21). Furthermore, affiliated trade has recorded trade surpluses between $4 billion and $5 billion since 2001. However, unaffiliated trade moved from relatively small surpluses (less than $500 million) in the 1990s to small deficits in the early 2000s, reaching a deficit of slightly more than a billion dollars in 2005 (appendix table 4-52) (NSF/SRS 2006c).

The prominence of affiliated trade in business services, particularly R&D-related services, may reflect advantages of internally managing, exploiting, and protecting complex or strategic transactions involving proprietary technical information (Caves 1996; McEvily, Eisenhardt, and Prescott 2004). For the United States, the large size of affiliated relative to unaffiliated trade in RDT services is consistent with strong U.S. FDI activity, which increases the number of potential affiliated trading partners. It is also consistent with expanded MNC R&D (see the section entitled "R&D by Multinational Corporations"), which increases opportunities for intracompany knowledge flows.

Table 4-20
Estimated total revenue and export revenue for U.S. establishments classified in selected service industries: 2004 and 2005
(Millions of current dollars)

		Revenue		Export revenue		Export revenue as percent of total revenue	
Service industry	NAICS code	2004	2005	2004	2005	2004	2005
Professional, scientific, and technical services (except notaries)	54	966,008	1,058,196	18,415	21,670	1.9	2.0
Scientific R&D services	5417	74,789	81,539	2,680	3,074	3.6	3.8
R&D in physical, engineering, and life sciences	54171	69,989	76,381	2,585	2,978	3.7	3.9
R&D in social sciences and humanities	54172	4,800	5,158	95	96	2.0	1.9

NAICS = North American Industry Classification System

NOTES: Data for taxable and nontaxable employer establishments. Export revenue includes services for unaffiliated and affiliated firms located outside United States. Export revenue excludes services provided to U.S. subsidiaries of foreign mutlinational corporations.

SOURCE: Census Bureau, 2005 Service Annual Survey, Current Business Reports (2007).

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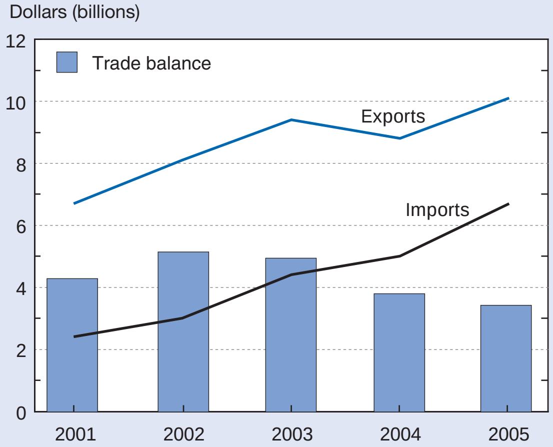
Business Technology Alliances

Industrial technology alliances bring together legally distinct companies for the purpose of collaboration in R&D and other technology activities.[39] Business alliances represent an intermediate organizational mode between full integration (as in mergers and acquisitions or FDI) and arms-length transactions (as in contracts for R&D services with external parties). Drivers for R&D collaboration include cost and risk reductions afforded by pooling resources, strategic or long-term considerations regarding the acquisition of innovation capabilities or entry into new product markets, and the policy environment, notably antitrust regulation and intellectual property protection. In the United States, restrictions on multifirm cooperative research were loosened by the National Cooperative Research Act in 1984 (Public Law 98–462), given concerns about the technological leadership and international competitiveness of American firms in the early 1980s.[40]

The Cooperative Agreements and Technology Indicators database-Maastricht Economic Research Institute on Innovation and Technology (CATI-MERIT), funded in part by NSF, includes domestic and international technology agreements. It is based on public announcements, tabulated according to the country of ownership of the parent companies involved.[41] According to this database, in 2003 (latest data available) there were 695 new industrial technology alliances worldwide (figure 4-33). 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. Other technology areas include advanced materials, aerospace and defense, automotive, and (nonbiotechnology) chemicals. For additional details, see Hagedoorn (2002) and NSB (2006).

Figure 4-32
U.S. trade in research, development, and testing services: 2001–05



SOURCE: Bureau of Economic Analysis, U.S. International Services: Cross-Border Trade 1986–2005, and Sales Through Affiliates, 1986–2004, http://www.bea.gov/international/intlserv.htm, accessed 4 December 2006. See appendix table 4-52.

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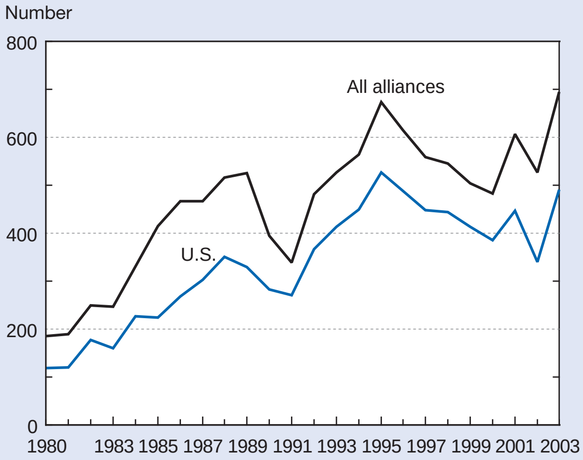
Figure 4-33
Worldwide industrial technology alliances and those with at least one U.S.-owned company: 1980–2003



NOTE: Annual counts of new alliances.

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

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Table 4-21
U.S. trade in research, development, and testing services: 2001–05
(Millions of dollars)

	Exports			Imports			Trade balance		
Year	Total	Affiliated	Unaffiliated	Total	Affiliated	Unaffiliated	Total	Affiliated	Unaffiliated
2001	6,746	5,700	1,046	2,425	1,700	725	4,321	4,000	321
2002	8,142	7,000	1,142	3,028	2,000	1,028	5,114	5,000	114
2003	9,376	8,200	1,176	4,410	3,100	1,310	4,966	5,100	–134
2004	8,760	7,500	1,260	4,993	3,100	1,893	3,767	4,400	–633
2005	10,095	8,800	1,295	6,717	4,400	2,317	3,378	4,400	–1,022

SOURCE: Bureau of Economic Analysis, U.S. International Services: Cross-Border Trade 1986–2005, and Sales Through Affiliates, 1986–2004, http://www.bea.gov/international/intlserv.htm, accessed 10 December 2006. See appendix table 4-52.

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Federal Technology Transfer and S&T Programs

In the late 1980s, concerns about U.S. industrial strength and global competitiveness led to a series of legislative changes that facilitated public-private partnerships involving industry, universities, and government laboratories (NRC 2003). These partnerships can facilitate technology transfer from the research laboratory to the market in support of both public agencies' missions and technology-based economic growth. Federal technology transfer statutes apply to federally owned or originated technology (see sidebar, "Major Federal Legislation Related to Cooperative R&D and Technology Transfer"). Federal technology indicators include government-owned patents, licensing, and cooperative research and development agreements (CRADAs). This section covers federal technology transfer metrics and federal S&T programs.

Technology Transfer Metrics

R&D performed at federal laboratories, whether run by federal agencies themselves or by contractors,[42] represents a key source for knowledge and technologies supporting both federal agency missions such as defense, health, and energy, as well as economic growth, and general social welfare (Crow and Bozeman 1998; RAND 2003). Technology transfer refers to the exchange or sharing of knowledge, skills, or technologies from sources to users within or across organizations. Federal technology transfer activities and metrics reflect the variety of agency missions, R&D organization and funding structure (e.g., intramural versus extramural laboratories), the character of R&D activities, and the types of potential downstream technologies or users.

For example, scientific or technical publications are a major channel for disseminating R&D results by agencies with large intramural basic research such as NIH (at HHS). Agencies also offer direct technical assistance to private users in settings such as agricultural extension services (USDA), manufacturing extension services (NIST), and federal laboratories (e.g., DOE and NIST). DOE laboratories and FFRDCs offer technical assistance to industrial and academic researchers in the form of user facilities agreements and "work-for-others" agreements. User facilities are advanced scientific facilities, equipment, and software available at DOE laboratories. Work-for-others is work performed for nonfederal sponsors (DOE 2006). In FY 2005, DOE reported about 2,400 work-for-others-agreements and about 2,800 user facility agreements (DOE 2006). In addition, all major U.S. R&D funding agencies, including DOD, HHS, NASA, DOE, and NSF, participate in technology transfer programs involving small businesses and technology entrepreneurs, as described below.

A major technology transfer channel involves cooperative R&D. In particular, CRADAs are agreements between federal laboratories and industrial firms and other organizations for joint R&D activities 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. Federal agencies are engaged in about 3,000 CRADAs annually (NSB 2006), including about 1,500 reported by DOD and 661 by DOE in FY 2003 (latest year available with comparable CRADA data across agencies).

A different set of federal technology transfer metrics involves intellectual property measures such as invention disclosures, patents, and licenses (for academic and corporate patents, see chapters 5 and 6, respectively). Invention disclosures 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 may find applications in agency missions or the marketplace. Table 4-22 shows the 2005 distribution for these metrics for selected agencies.[43]

Table 4-22
Federal technology transfer indicators and intellectual property measures, by selected U.S. agency: FY 2005

Disclosures/patenting/licenses	DOE	DOD	NASA	NIH/FDA	USDA
Invention disclosures and patenting					
Inventions disclosed	1,776	1,220	687	388	125
Patent applications filed	812	798	154	186	88
Patents issued	467	430	157	66	27
Invention licenses					
Active invention licenses	1,535	406	345	NA	320
New invention licenses	198	60	90	313	33

NA = not available

DOD = Department of Defense; DOE = Department of Energy; NASA = National Aeronautics and Space Administration; NIH/FDA = National Institutes of Health/Food and Drug Administration; USDA = U.S. Department of Agriculture

NOTE: NASA data for FY 2004.

SOURCES: USDA, FY 2006 Annual Reporting on Agency Technology Transfer (2006); DOD, Report to Congress on the activities of the DOD Office of Technology Transition (2006); DOE, Annual Report on Technology Transfer and Related Technology Partnering Activities at the National Laboratories and Other Facilities – Fiscal Year 2005 (2006); NASA, Annual Report on Technology Transfer, Programs, Plans, FY 2004 Activities and Achievements (2006); NIH, Office of Technology Transfer Activities, Statistical Tables (2006), http://www.ott.nih.gov/about_nih/statistics.html, accessed 28 February 2007. See appendix table 4-53.

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DOE and DOD had the largest shares of inventions disclosed and patents, whereas NIH/FDA had the largest share of new invention licenses, according to available data. 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 (table 4-8).[44]

S&T Programs

S&T programs support the development of early-stage technologies and are key components in the dynamics of technology-based entrepreneurship and innovation (Audretsch, Aldridge, and Oetll 2005; Branscomb and Auerswald 2002). This section briefly describes trends in the Small Business Innovation Research (SBIR) program, the Small Business Technology Transfer Program (STTR), and the Advanced Technology Program (ATP) through the latest data available. The section ends with a brief description of the Technology Innovation Program, which replaces ATP.

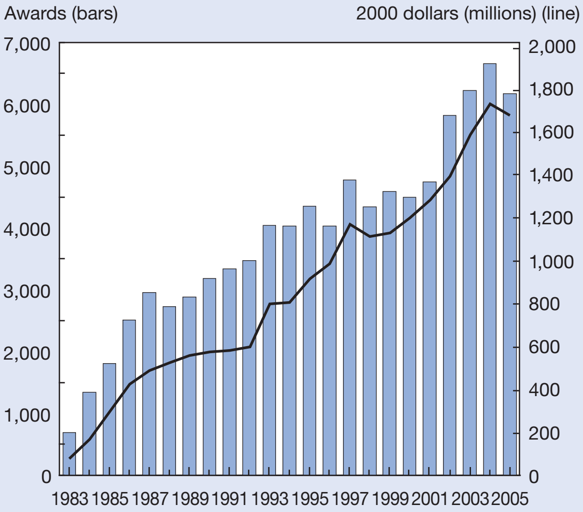
The SBIR program, created in 1982, leverages existing federal R&D funding toward small companies (those with 500 or fewer employees).[45] SBIR's sister program, the STTR program, was created in 1992 to stimulate cooperative R&D and technology transfer involving small businesses and nonprofit organizations, including universities and FFRDCs.[46]

Statutory goals of the SBIR program include the promotion of technological innovation through commercialization of federally funded projects and increasing the participation of small firms and companies owned by minorities or disadvantaged individuals in the procurement of federal R&D. The 1992 SBIR reauthorization bill[47] stipulated a stronger emphasis on the technology commercialization objectives of the program (NRC 2007).

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. As of FY 2005, a total of 11 federal agencies participated in the program, including most recently DHS.[48] SBIR has awarded $118.8 billion to more than 89,000 projects through FY 2005. Funded technology areas include computers and electronics, information services, materials, energy, and life sciences applications. In FY 2005, the program awarded $1.9 billion in R&D funding to 6,171 projects (figure 4-34). 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 4-54).

STTR involves cooperative R&D performed jointly by small businesses and nonprofit research organizations.[49] As of FY 2005, five federal agencies with extramural R&D budgets exceeding $1 billion participate in the STTR program: DOD, NSF, DOE, NASA, and HHS. Starting in FY 2004, the required set-aside rose from 0.15% to 0.3%, compared with the 2.5% set-aside for SBIR. From FY 1994 to FY 2005, STTR awarded $1.04 billion to 5,000 projects, including $220 million to 832 projects in FY 2005 (appendix table 4-55).

Figure 4-34
SBIR awards and funding: 1983–2005



SBIR = Small Business Innovation Research Program

SOURCE: Small Business Administration, Small Business Innovation Research Program Annual Report (various years). See appendix table 4-54.

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ATP was established by the Omnibus Trade and Competitiveness Act of 1988 to promote the development and commercialization of generic or broad-based technologies.[50] Through FY 2004, ATP 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 more than 1,500 participants, which include established companies and start-ups as well as universities and other nonprofit institutions (appendix table 4-56). In FY 2004, 59 R&D projects were initiated, totaling $270 million in combined program and industry funds. The program received $79 million in FY 2006 and an estimated $40 million in FY 2007. The America COMPETES Act (Public Law 110–69 signed in August 2007) replaced ATP in favor of a successor program, the Technology Innovation Program (TIP) also housed at the DOC's National Institute of Standards and Technology.[51] The goal of the program is to assist U.S. "businesses and institutions of higher education or other organizations, such as national laboratories and nonprofit research institutions, to support, promote, and accelerate innovation in the United States through high-risk, high-reward research in areas of critical national need."[52]

Conclusion

U.S. R&D expenditures reached an estimated $340 billion in 2006, having risen steadily since 2002, the year expenditures declined for the first time since 1953. In inflation-adjusted terms, this increase represents a rather steady 2.5% average annual change over the past 4 years.

The business sector accounts for the largest share of U.S. R&D performance. The performance share of this sector peaked in 2000 at 75%, declined following the economic slowdown of 2001 and 2002, but has since leveled to an estimated 71% of U.S. R&D in 2006. The major industrial R&D performers include four manufacturing industries (computer and electronic products; chemicals, including pharmaceuticals and biotechnology; aerospace and defense; and automotive) and two services industries (computer-related services and R&D services). In terms of funding, the industry share peaked at 70% also in 2000, but is estimated to have since dipped somewhat to 64% in 2004 before climbing back to 66% of the 2006 R&D total. On the other hand, the federal share of R&D funding dropped to a low of 25% in 2000. Reflecting primarily increased spending in the areas of defense, health, and counterterrorism, the federal share of R&D funding has inched up in recent years and is estimated at 28% of the R&D funding total in 2006.

The international character of the U.S. R&D enterprise may be examined from different perspectives, including comparisons with other countries, business alliances, MNCs, and, according to recently available data, cross-country linkages in the form of exports and imports of R&D services.

In 2002 (latest available cross-country data), global R&D expenditures totaled at least $813 billion, largely funded by and performed in developed countries. The United States and Japan accounted for 45% of total performance, and OECD countries as a group for more than three-quarters. Some non-OECD countries are growing in international prominence in R&D. South Korea maintained its sizable R&D effort and, according to OECD calculations, China has rapidly moved into the top group of R&D-performing nations while India and Brazil are expanding their R&D activities. However, a solid basis is lacking for direct comparisons of R&D effort across developed and developing countries, leading to uncertainty in the cross-country relationship of absolute spending magnitudes.

Between 1999 and 2004, R&D expenditures by affiliates of foreign companies located in the United States increased faster than overall U.S. industrial R&D (2.1% versus 0.2% annual average rate, inflation-adjusted, respectively). Over the same period, overseas R&D by foreign affiliates of U.S. MNCs increased even faster (6.3% annual average rate, inflation-adjusted), particularly in Asian emerging markets such as China, Singapore, and India. Indeed, the share of R&D by foreign affiliates of U.S. MNCs located in Asian countries except Japan surpassed the shares for affiliates located in Japan for the first time in 1999. In 2004, the former had a share of 11.6%, compared with 6.3% for Japan.

The flow of knowledge through trade in services reflects the growing role of services in global innovation and economic activity. U.S. international trade in research, development, and testing services has posted surpluses since 2001. In 2005, exports of these services reached $10.1 billion, compared with imports of $6.7 billion. Furthermore, U.S. trade surpluses in these services have been driven more by exports from affiliates of foreign MNCs located in the United States rather than by exports from parent companies of U.S. MNCs. This finding is consistent with the growing share these affiliates have in U.S. industrial R&D.

In light of the fast pace of international science, technology, and innovation and related policy analysis needs, federal statistical agencies continue to fine-tune their surveys while engaging in interagency and international collaboration. For example, the ability of respondents in industry to answer questions on innovation beyond R&D inputs is being investigated as part of the redesign of the Survey of Industrial R&D. Another strategy for developing new indicators is mining and integrating related data. Planned or ongoing interagency projects include linking data from R&D and international investment surveys and the development of an R&D Satellite Account. The latter not only measures R&D as an investment within GDP, but also serves as a methodology to measure the impact of R&D on productivity and economic growth. Lastly, federal agencies continue to collaborate with international organizations to facilitate comparable data reflecting the ever-changing innovation landscape.

Notes

1. In this chapter, adjustment for inflation is based on the GDP implicit price deflator. Because GDP deflators are calculated on an economywide rather than R&D-specific basis, their use should be interpreted as a measure of real resources forgone in engaging in R&D rather than in other activities (such as consumption or physical investment), and not a measure of cost changes in doing research. See appendix table 4-1.

2. 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 nonprofit institution, a university, or a consortium. 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.

3. See Godin (2006) for a history of the linear model of innovation.

4. The latest data available on the state distribution of R&D performance are for 2004. In 2004, $283.4 billion of the $300.1 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 equal shares of the R&D that could not be associated with a particular state were R&D performed by the nonprofit sector and by industry. State totals differ from U.S. totals reported elsewhere for four reasons: some R&D expenditures

cannot be allocated to any of the 50 states or the District of Columbia; nonfederal sources of nonprofit R&D expenditures, totaling an estimated $7.1 billion in 2004, could not be allocated by state; state-level university R&D data have not been adjusted for double-counting of R&D passed through from one academic institution to another; and state R&D data are not converted from fiscal years to calendar years.

5. Rankings do not take into account the margin of error of estimates from sample surveys.

6. 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.

7. For most manufacturing industries, the Small Business Association has established a size standard of 500 employees. The NSF Survey of Industrial Research and Development does not sample companies with fewer than five employees because of concerns about respondent burden.

8. 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 more detailed discussion of value-added, see United Nations System of National Accounts 1993 (SNA 1993). For a discussion of the connection between R&D intensity and technological progress, see Nelson (1988).

9. Industry-level estimates are complicated by the fact that each company's R&D is reported in only one industry (see sidebar, "Industry Classification").

10. According to NAICS, the utilities industry is limited to establishments engaged in the provision of electric power, natural gas, steam, water, and the removal of sewage. Establishments that provide telephone and other communication services are included in other NAICS industries.

11. Because federal R&D funding is concentrated among a few companies in a small number of industries, the potential for disclosing information about a particular company is high. Therefore, these data often are suppressed. This prevents the precise tabulation of total R&D performance and the calculation of R&D to net sales ratios for many industries. Appendix table 4-22 presents company-funded R&D to net sales ratios for a wide array of industries.

12. For a recent study on the role of services industries in R&D and innovation, see Gallaher, Link, and Petrusa (2006).

13. Suppression of federal R&D funding prohibits the precise tabulation of total R&D performance for some industries (see note 11). Lower-bound analyst estimates are given in cases where potential disclosure of company-reported data or classification issues prevents the publication of total estimates from survey data.

14. 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 (which are trials conducted after the drug is licensed and available for doctors to prescribe), whereas the NSF survey definition does not. Also, the NSF survey sales data may contain income from sources not related to the production of drugs and medicines.

15. The introduction of a more refined industry classification scheme in 1999 allowed more detailed reporting in nonmanufacturing industries. For the cited 2005 statistic, the R&D expenditures 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.

16. Suppression of federal R&D funding prohibits the precise tabulation of total R&D performance for some industries (see notes 11 and 13). Lower-bound analyst estimates are given in cases where potential disclosure of company-reported data or classification issues prevents the publication of total estimates from survey data.

17. NAICS-based R&D estimates are available only 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 $16.9 billion in 2005.

18. 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. For an explanation of the differences between the two, see Shepherd and Payson (1999).

19. Both tax incentives and direct federal funding represent federal expenses. In terms of the budget, tax incentives generate tax expenditures and government revenue losses because of tax exclusions or deductions. For estimates of tax expenditures arising from the R&E tax credit, see OMB (2007).

20. The federal credit was not in place for activities conducted from July 1995 to June 1996.

21. For tax purposes, R&D expenses are restricted to the somewhat narrower concept of R&E expenditures (Internal Revenue Code Section 174; see also NSF/SRS [2006b]). 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 (Internal Revenue Code Section 41).

22. The credit was not taxable from 1981 to 1988; 50% taxable in 1989; and fully taxable since 1990.

23. Not all R&E claims are allowed. For example, there are limitations on the reduction of total tax liabilities. Data exclude IRS tax forms 1120S (S corporations), 1120-REIT (real estate investment trusts), and 1120-RIC (regulated investment companies).

24. For more information about the 2003 research credit, see tables in IRS (2007). These tables have additional details based on IRS tax form 4765. The return counts obtained from SOI and used in the text represent returns claiming "current year credit for increasing research" (i.e., the number of returns with a non-zero amount in line 41 of IRS tax form 4765).

25. Differences in the structure of tax credits are important in determining effective rates (compared with statutory rates).

26. For other S&T indicators on Asian countries relative to the United States and the EU, see NSF/SRS (2007a).

27. For discussions of R&D diversity measurement, see Archibugi and Pianta (1992). Also see Archibugi and Pianta (1996).

28. Since the mid-1980s, 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 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).

29. For these data, the United States includes the 50 states; Washington, DC; Puerto Rico; and all U.S. territories and possessions.

30. For 1999 and 2004 data on U.S. MNCs R&D employment, see BEA (2007b); for 1994 and 1999 comparisons, see NSF (2004a).

31. BEA defines a parent company of a U.S. 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. For selected NSF data on overseas R&D funded by companies with R&D activities in the 50 U.S. states and Washington, DC, see appendix tables 4-48 and 4-49.

32. For example, see Arora, Fosfuri, and Gambardella (2001); Bozeman (2000); and Chesbrough, Vanhaverbeke, and West (2006).

33. Data are for R&D contract expenditures paid by U.S. industrial R&D performers (using company and other nonfederal R&D funds) to other domestic performers. In this section, contract R&D refers to a transaction with external parties involving R&D payments or income, regardless of its legal form. Transactions by companies that do not perform internal R&D in the United States are excluded, as are R&D activities contracted out to companies located overseas.

34. Approximately 3% of expenditures involved universities and colleges, and 44% involved "other R&D performers."

35. Offshoring refers to the sourcing of production inputs through companies located overseas. Offshoring may be done internally through controlled subsidiaries or affiliates, which involves FDI and related transactions (e.g., affiliated trade), or through external providers. The latter is part of outsourcing activities that in general involve either domestic or overseas external suppliers.

36. Revenue data include operating surplus and other generally acceptable charges for services rendered. For SAS methodology and sample forms, see Census Bureau (2007).

37. Note that except for small companies with a single physical location, company-based and establishment-based industry data are not comparable, even when they refer to the same metric. Furthermore, NSF data for companies classified in NAICS 5417 refer to R&D expenditures, whereas SAS data covered in this section refer to total exports by establishments classified in NAICS 5417. SAS data for establishments classified in professional, scientific, and technical services (NAICS 54) are available since 1998. SAS data for R&D services (NAICS 5417) is available for R&D in the physical, engineering, and life sciences (54171) and social sciences and humanities (54172). Data used in this section are limited to the former. For case studies in services industries, including the scientific R&D services industry, see Gallaher and Petrusa (2006).

38. The category of RDT services is part of business, professional, and technical services (or business services, for short). The latter include royalties and license fees, discussed in chapter 6.

39. Technology alliances may or may not be part of larger agreements involving manufacturing, licensing, or other forms of business collaboration. For recent studies on the role of technology licensing (e.g., technology development, commercialization strategy), see Fosfuri (2006) and Hagedoorn, Lorenz-Orlean, and Kranenburg (2007).

40. As amended by the National Cooperative Research and Production Act of 1993 (Public Law 103–42). See U.S.C. Title 15, Chapter 69. More recently, federal patent and trademark law was amended in order to facilitate patenting inventions resulting from collaborative efforts across different companies or organizations. 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.

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.

42. Federal laboratories are facilities owned, leased, or otherwise used by a federal agency, according to 15 U.S.C. 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. See also the section entitled "Federal R&D."

43. For additional metrics and agencies up to FY 2003, see chapter 4 in NSB (2006), based on data from DOC, 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). An updated report was not available at the time of writing.

44. For studies on patents, citations, and other technology transfer metrics at NASA and DOE, see chapters 9 and 10, respectively, in Jaffe and Trajtenberg (2001). For technology transfer activities and case studies involving USDA R&D, see Heisey et al. (2006).

45. SBIR was created by the Small Business Innovation Development Act of 1982 (Public Law 97–219, U.S.C. Title 15, Section 631). It was last reauthorized in 2000 through September 2008. The 2000 reauthorization bill (Public Law 106–554) also requested that the National Research Council conduct a multiyear SBIR study at five federal agencies with SBIR budgets exceeding $50 million (DOD, HHS, NASA, DOE, and NSF). The study is in progress. See NRC (2007) and National Academies (2007).

46. STTR was created by the 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.

47. Title I of the Small Business Research and Development Enhancement Act, Public Law 102–564.

48. 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.

49. STTR is also structured in three phases.

50. Public Law 100–418; 15 U.S.C. Section 278n.

51. According to the America COMPETES Act, TIP will "continue to provide support originally awarded under [ATP], in accordance with the terms of the original award and consistent with the goals of the Technology Innovation Program." See Library of Congress (2007). For more information on the new bill, see sidebar, "Recent Developments in Innovation-Related Metrics."

52. See Library of Congress (2007).

Glossary

Affiliate: A company or business enterprise located in one country but owned or controlled (in terms of 10% or more of voting securities or equivalent) by a parent company in another country; may be either incorporated or unincorporated.

Applied research: The objective of applied research is to gain 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: The objective of basic research is to gain more comprehensive knowledge or understanding of the subject under study without specific applications in mind. Although basic research may not have specific applications as its goal, it can be directed in fields of present or potential interest. This is often the case with basic research performed by industry or mission-driven federal agencies.

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.

EU-15: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, and the United Kingdom.

EU-25: In 2004, the EU expanded to 25 members with the addition of 10 more countries: Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia, and Slovenia. (Bulgaria and Romania joined the EU in January 2007, for a total of 27 member countries, EU-27.)

Federally funded research and development center (FFRDC): 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.

Foreign affiliate: Company located overseas but owned by a U.S. parent.

Foreign direct investment (FDI): Ownership or control of 10% or more of the voting securities (or equivalent) of a business located outside the home country.

G-7 countries: The group of seven industrialized nations, which are Canada, France, Germany, Italy, Japan, the United Kingdom, and the United States.

G-8 countries: G-7 countries plus Russia.

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 (GDP): 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 (MNC): 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.

Public-private partnership: Collaboration between private or commercial organizations and at least one public or nonprofit organization such as a university, research institute, or government laboratory. Examples include cooperative research and development agreements (CRADAs), industry-university alliances, and science parks.

R&D: Research and development, 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 its use to devise new applications.

R&D employees: Scientists and engineers who perform R&D functions.

R&D intensity: Measure of R&D expenditures relative to size, production, or other characteristic of a country or R&D-performing sector. Examples include company-funded R&D to net sales ratio, R&D to GDP ratio, and R&D per employee.

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.

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

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Highlights

Financial Resources for Academic R&D

In 2006, U.S. academic institutions spent $48 billion on R&D. Since 2000, average annual growth in R&D was stronger for the academic sector than for any other R&D-performing sector.

- Academic R&D reached about 0.4% of the gross domestic product in 2006.
- Academic performers are estimated to account for 56% of U.S. basic research ($61 billion), about 33% of total (basic plus applied) research ($140 billion), and 14% of all R&D ($340 billion) estimated to have been conducted in the United States in 2006.

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 2000, even after adjusting for inflation. Beginning in 2001, funding from industry declined for 3 straight years but then rebounded between 2004 and 2006. Support from the federal government decreased in 2006 as funding growth failed to outpace inflation for the first time since 1982.

- The federal government provided 63% of funding for academic R&D expenditures in 2006, representing substantial growth from the 58% share of support provided in 2000 but less than the 68% share supplied in 1972.
- Institutions themselves contributed 19% of funds in 2006, compared with 12% 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 thereafter to 5% in 2003 as a result of absolute constant dollar declines in 2002 and 2003. Despite the recent increase in absolute dollars between 2004 and 2006, industry's share remained at 5% in 2006.

Between 1996 and 2006, the distribution of academic R&D funds received by different S&E fields remained relatively constant, with the largest shift in the field of life sciences.

- Only the life sciences and psychology (up 5.2 and 0.2 percentage points, respectively) saw their share of the academic R&D total increase between 1996 and 2006.
- The share held by engineering decreased by 1.3 percentage points between 1996 and 2006 after having gained almost 5 percentage points overall between 1975 and 1996.
- The fields of environmental sciences, mathematics, physical sciences, and social sciences experienced modest share declines between 1996 and 2006 (1.0, 0.1, 1.8, and 1.2 percentage points, respectively).
- The social sciences experienced the largest decrease in share over the past three decades, dropping by more than half from 7.5% in 1975 to 3.6% in 2006.

The share of all academic R&D funded by the federal government varies significantly by field, and the fields of life sciences and psychology have seen the largest increases in their federal share in recent years.

- The fields with the largest share of federally funded R&D in 2006 were the atmospheric sciences (80%), physics (75%), aeronautical/astronautical engineering (74%), and psychology (72%).
- Economics (35%), political science (34%), and the agricultural sciences (32%) had the smallest shares of federal funding in 2006.
- Between 1998 and 2004, the period in which federal policies doubled the R&D budget of the National Institutes of Health, the share of federally financed R&D funding for the life sciences increased rapidly, from 57% to 64%, and the share in psychology increased from 67% to 75%.

The historical concentration of academic R&D funds among the top research universities has remained relatively steady over the past 20 years.

- In terms of total R&D funding, the share of all academic R&D expenditures received by the top 100 academic institutions decreased from 83% to 80% between 1986 and 1993 and has remained at that level through 2006.
- Only 5 of the top 20 institutions in 1986 were not in the top 20 in 2006.

In 2006, 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 continued a two-decade decline.

- After reaching a high of 7% in 1985 and 1986, the share of R&D spent on equipment declined to 4% in 2006.
- About 83% of equipment expenditures were concentrated in the life sciences (41%), engineering (24%), and the physical sciences (18%).
- After more than doubling in constant 2000 dollars between 1985 and 2004, the life sciences subfields of medical and biological sciences experienced declines in equipment expenditures in 2005 and 2006. Engineering equipment expenditures also doubled between 1985 and 2005 but declined in 2006.

Research-performing colleges and universities continued to expand their stock of research space in FY 2005, but at a significantly slower rate than in the previous 2-year period. In addition to the traditional "bricks and mortar" research infrastructure, "cyberinfrastructure" may be playing an increasingly important role in the conduct of S&E research.

- In FY 2004–05, all S&E fields except for the earth, atmospheric, and ocean sciences experienced increases in research space.
- Based on current construction of new space and plans for new construction, the biological and medical sciences will continue to dominate the share of total research space and funds for new construction.
- In FY 2005, 21% of academic institutions reported bandwidth of 1 gigabit or faster, and this percentage is estimated to increase to 30% in FY 2006.

Doctoral Scientists and Engineers in Academia

The size of the doctoral academic S&E workforce reached an estimated 274,200 in 2006 but grew more slowly than the number of S&E doctorate holders in other employment sectors. Full-time tenure-track faculty positions, although still the predominant employment mode, 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 2006.
- The share of full-time faculty declined from 88% in the early 1970s to 72% in 2006. Other full-time positions rose to 14% of the total, and postdoc and part-time appointments stood at 9% and 6%, respectively.

The demographic composition of the academic doctoral labor force changed substantially between 1973 and 2006.

- The number of women in academia increased more than eightfold, from 10,700 to about 90,700, raising their share from 9% to 33%.
- The number of underrepresented minorities (blacks, Hispanics, and American Indians/Alaska Natives) rose about ninefold, from 2,400 to 22,400, but remain a small percentage (8%) of the S&E doctorate holders in academia.
- The number of Asians/Pacific Islanders entering the academic S&E doctoral workforce, many of them foreign born, increased substantially, from 5,000 to about 38,800, raising their share from 4% to 14%.
- The share of whites in the academic S&E doctoral workforce fell during the period from 91% to 78%; the white male share fell from about 83% to about 52%.

Foreign-born scientists and engineers are an increasing share of doctoral S&E faculty.

- Foreign-born scientists and engineers were 28% of all full-time doctoral S&E faculty in 2003, up from 21% in 1992.
- In the physical sciences, mathematics, computer sciences, and engineering, 47% of full-time doctoral S&E faculty in research institutions were foreign born, up from 38% in 1992.

The average age of the academic doctoral labor force has been rising during the past quarter century.

- Both the mean age (42–48) and median age (40–48) increased almost monotonically between 1973 and 2006.
- In 2006, a growing, albeit small, fraction of employment (6%) was made up of individuals age 65 or older.
- Retirement rates remained relatively stable from 1993 to 2003.

A substantial academic researcher pool has developed outside the regular faculty ranks.

- Postdocs and others in full-time nonfaculty positions constitute an increasing percentage of those doing research at academic institutions, having grown from 13% in 1973 to 27% in 2006. This change was especially pronounced in the 1990s.
- The share of full-time doctoral S&E instructional faculty who are engaged primarily in research increased from 20% to 26% between 1992 and 2003.

In most fields, the percentage of academic researchers with federal support for their work was about the same in 2006 as it was in the late 1980s.

- Among all academic S&E doctorate holders employed in academia, 47% received federal support in 2006, compared with 48% in 1989.
- Among life scientists, the percentage of academic S&E doctorate holders with federal support dropped from 65% in 1989 to 58% in 2006, although the actual number reporting federal support increased during the period.
- Full-time doctoral S&E faculty in the academic workforce were less likely to receive federal support (46%) than postdocs (71%).
- Among full-time faculty, recent doctorate recipients were less likely to receive federal support than their more established colleagues.

Outputs of S&E Research: Articles and Patents

S&E article output worldwide grew at an average annual rate of 2.3% between 1995 and 2005, but the U.S. growth rate was much lower.

- U.S. output grew 0.6% annually over the same period, compared with 1.8% for the European Union and 6.6% for a group of 10 Asian countries/economies (Asia-10), including China at 17% and South Korea at 16%.
- The U.S. share of total world article output fell between 1995 and 2005, from 34% to 29%, as did the European Union share, which declined from 35% to 33%, whereas the Asia-10 share increased from 13% to 20%.

On a national basis, the United States, Japan, the United Kingdom, and Germany dominated total S&E article output in both 1995 and 2005.

- China advanced from 14th to 5th place overall, to 2nd place in engineering and chemistry, and to 3rd place in physics and mathematics.
- South Korea, Brazil, and Turkey, not among the top 20 national producers in 1995, held 10th, 17th, and 19th place, respectively, in 2005.

S&E research is an increasingly collaborative activity. Between 1988 and 2005, the share of publications with authors from multiple institutions grew from 40% to 61%.

- Coauthored articles with only domestic institutions in the bylines grew from 32% to 41% of all articles.
- Articles with institutions from multiple countries—an indicator of international collaboration and the globalization of science—grew from 8% to 20%.

The United States has the largest share of all internationally authored articles, and U.S. researchers collaborate most often with counterparts in Germany, the United Kingdom, and Canada.

- However, when U.S. international collaboration is normalized for the volume of its partner's international coauthorship, only collaboration between the United States and Canada, Israel, South Korea, and Taiwan is more frequent than would be predicted.
- Higher rates of research collaboration are to be found, for example, between Argentina and Brazil, South Korea and Japan, Australia and New Zealand, and among the Scandinavian countries.

Indicators of collaboration based on coauthorship among U.S. sectors and between U.S. sectors and foreign authors show that integration of R&D activities is occurring across the full range of R&D-performing institutions in the United States.

- U.S. cross-sectoral coauthorship between all sectors except federally funded research and development centers (FFRDCs) and industry increased during the 1995–2005 period. The largest gains in all sectors were with coauthors in academia: By 2005, the percentage of articles with coauthors from academia was 71% for state/local government, 62% for private nonprofit institutions, and 59% for the federal government.
- Between 1995 and 2005, coauthorship with foreign authors increased by 10 percentage points for authors in FFRDCs, industry, and private nonprofit institutions and by 9 percentage points for authors in the federal government and academia.
- Of the S&E fields, astronomy had the highest rate of international coauthorship in 2005, at 58%, well above the U.S. national average of 27% across all fields.

Although the U.S. share of world article output and article citations has declined, the influence of U.S. research articles has increased, as indicated by the percentage of U.S. articles that are among the most highly cited worldwide.

- In 1995, authors from U.S. institutions had 73% more articles in the top 1% of cited articles in all S&E fields than would be expected based on U.S. total article output; in 2005, the percentage had grown to 83%.
- In 2005, the European Union had 16% fewer articles in the top 1% of cited articles than would be expected, and the Asia-10 had 59% fewer than would be expected. However, both the European Union and Asia-10 have advanced on this indicator since 1995.

Indicators of academic patenting are mixed. The U.S. Patent and Trademark Office (USPTO) reports that patent grants to universities have declined since 2002, but other indicators suggest continued expansion of activities related to patents and patent/licensing revenues.

- According to USPTO, patent grants to universities and colleges increased sharply from 1995 to about 2002, when they peaked at just under 3,300 patents per year, and then fell to about 2,700 in 2005. Three biomedically related patent classes continued to dominate these awards, accounting for more than one-third in 2005.
- Other data indicate, however, that invention disclosures filed with university technology management offices grew from 13,700 in 2003 to 15,400 in 2005 and that patent applications filed by reporting universities and colleges increased from 7,200 in 2003 to 9,500 in 2004 and 9,300 in 2005.
- University inventories of revenue-generating licenses and options also continued to grow, as did the annual number of new licenses and options executed. The annual number of startup companies established as a result of university-based inventions rebounded after 2 years of downturns in 2002 and 2003 to more than 400 in both 2004 and 2005.

Introduction

Chapter Overview

U.S. universities and colleges are key contributors to the nation's S&E enterprise. The academic sector develops scientists and engineers through its education and training activities (see chapter 2, "Higher Education in Science and Engineering") and generates new knowledge and ideas through its research activities. Almost 60% of the nation's basic research and about a third of its total research are carried out in academic institutions. The federal government has been and continues to be the major financial supporter of academic R&D, providing almost two-thirds of the funding in 2005. Other major funding sources are the institutions themselves, industry, and state and local government.

The allocation of the national academic R&D investment has been changing over time, with the share going to the life sciences growing substantially over the past several decades. This has prompted serious discussion about the appropriate distribution of funds across disciplines. The President's FY 2008 R&D budget signals a goal to double federal funds for agencies supporting physical sciences and engineering research over the coming decade.

Doctoral S&E faculty in universities and colleges play a critical role in performing research and in ensuring a well-trained, diverse supply of S&E personnel for all sectors of the economy. Hiring of S&E doctorate holders into academic positions over the past decade suggests a relative decline in reliance on full-time tenure-track faculty positions in favor of other forms of employment. This shift is expected to continue as academia approaches a period of potentially increasing retirements because of its aging labor force. The demographic composition of new hires is likely to continue the trend toward more women and minorities that mirrors similar changes in the student population. Trends in foreign-born faculty and foreign graduate students, stabilizing after the events of September 11, 2001, remain uncertain because of the rapid development of higher education and research capacities in many countries and the growing international competition for highly skilled talent. All these changes will affect the composition and teaching and research roles of the future doctoral S&E faculty.

A measure of research output, the number of U.S. S&E articles published in the world's leading S&E journals, recently began to increase after remaining flat for almost a decade. During that time, the number of articles by scientists in the European Union (EU) and several Asian countries grew strongly. As a result of these combined trends, the U.S. share of the world's S&E article output has declined since the early 1970s. The number of influential articles from U.S. institutions, as measured by citation frequency, remained fairly flat, and as a result, the U.S. share of the world's influential articles also declined. However, U.S. scientific publications remain influential relative to those of other countries.

Article output by the academic sector, which publishes most U.S. research articles, mirrored the overall U.S. trend, even though research inputs (specifically, academic R&D expenditures and research personnel) continued to increase. Both domestic and international collaboration have increased significantly over the past two decades as academic scientists and engineers collaborated extensively with colleagues in other U.S. sectors (federal and state government, industry, nonprofit institutions, and federally funded research and development centers) and abroad. The results of academic S&E research increasingly extend beyond articles to patents, which are an indicator of academic institutions' efforts to protect the intellectual property derived from their inventions, technology transfer, and university-industry collaboration, and other related activities such as revenue-generating licenses and formation of startup companies.

To help provide a context for discussions about the organization, focus, and mission of U.S. universities and colleges, this chapter addresses key aspects of the academic R&D enterprise, including the level, field allocation, and institutional distribution of academic R&D funds; the state of research equipment and facilities at academic institutions; trends in the number and composition of the academic S&E doctoral labor force; and indicators of research outputs.

Chapter Organization

The first section of this chapter discusses the role of academia within the national R&D enterprise. This discussion is followed by an examination of trends in the financial resources provided for academic R&D, including identification of key funders and allocations of funds 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, including cyberinfrastructure.

The next section discusses trends in employment of academic doctoral scientists and engineers with special reference to research. Major trends examined include numbers of academic doctoral scientists and engineers, the types of institutions in which they are employed, the types of positions they hold, their research activities, and federal support for research. Differences between S&E faculty and non-S&E faculty and between doctoral and nondoctoral S&E faculty are taken into account. The section also examines shifts in faculty age structure, trends in retirement patterns, and demographic characteristics, including characteristics and employment patterns of recent doctorate holders entering academic positions and participation of women and minorities.

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 chapter 2.) This section looks specifically at the volume of research (article counts), collaboration in the conduct of research (joint authorship), and use in subsequent scientific activity (citation patterns). 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:

- Growth in federal funding of academic R&D has slowed.
- Continued but differential increases in funding for all fields resulted in a relative shift in the distribution of funds, with increasing shares for the life sciences, engineering, and the computer sciences.
- The field of medical sciences experienced the largest increase in the past several decades, its share having risen by 10 percentage points since 1975.
- R&D activity expanded to a wider set of institutions, but the concentration of funds among the top research universities remained relatively constant over the past two decades.
- The share of all annual R&D expenditures spent on research equipment reached a historic low.
- Growth in academic S&E research space continued, particularly in the medical and biological sciences.

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 plays an important role in the nation's overall R&D effort, especially by contributing to the generation of new knowledge through basic research. Since 1998, academia has accounted for more than half of the basic research performed in the United States.

In 2006, U.S. academic institutions spent $48 billion, or $41 billion in constant 2000 dollars, on R&D.[2] Academia's role as an R&D performer 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 2006 (figure 5-1). For a comparison with other countries, see "International R&D Comparisons" in chapter 4.

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." In 2006, an estimated 96% of academic R&D expenditures went for research (75% for basic and 22% for applied) and 4% for development (figure 5-2; appendix table 5-1). 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 2006. In terms of basic research alone, the academic sector is the country's largest performer, currently accounting for an estimated 56% 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 (figure 5-1). In the early 1990s, its share of the national total began to increase once again.

Growth

Between 1970 and 2006, the average annual R&D growth rate (in constant 2000 dollars) of the academic sector (4.3%) was higher than that of any other R&D-performing sector except the nonprofit one (4.6%). (See figure 5-3 and appendix table 4-4 for time-series data by R&D-performing sector.) Since 2000, the academic sector has grown faster than any U.S. R&D-performing sector (4.6%). As a proportion of gross domestic product (GDP), academic R&D rose from 0.24% in 1970 to 0.35% in 2006, almost a 50% increase. (See appendix table 4-1 for GDP time series.)

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 collect data from universities and colleges. (For descriptions of the methodologies of the NSF surveys, see NSF/SRS 1995a, b and the Division of Science Resources Statistics website, http://www.nsf.gov/statistics/.)

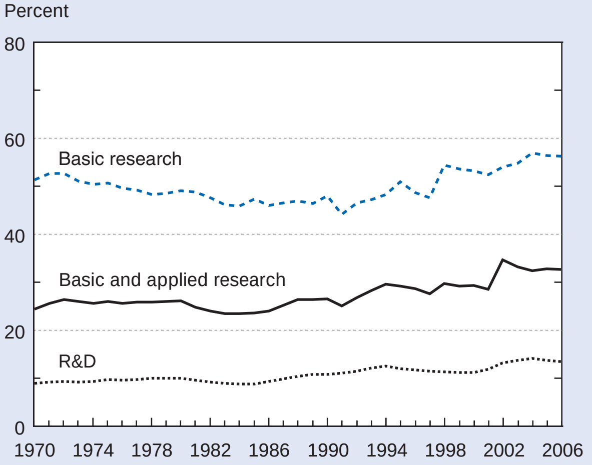
Data presented in the context section, "Academic R&D Within the National R&D Enterprise," are derived from special tabulations that aggregate NSF survey data on the various sectors of the U.S. economy so that the components of the overall R&D effort are placed in a national context. These data are reported on a calendar-year basis, and the data for 2005 and 2006 are preliminary. Since 1998, these data also attempt to eliminate double counting in the academic sector by subtracting current fund expenditures for separately budgeted S&E R&D that do not remain in the institution reporting them but are passed through to other institutions via subcontracts and similar collaborative research arrangements. 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 2006 and FY 2007 are preliminary estimates. The amounts reported for FY 2006 and FY 2007 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 2005. 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 in this chapter) are purchased with *current funds* (those in the yearly operating budget for ongoing activities) and included within R&D expenditures. Because donated research equipment is not typically captured in university accounting systems, the value of donated research equipment is not reported. Because the categories are not mutually exclusive, some large instrument systems could be classified as either facilities or equipment. Generally, academic institutions keep separate accounts for current and capital funds.

Figure 5-1
Academic R&D, basic and applied research, and basic research as share of total of each category: 1970–2006



NOTES: Preliminary data for 2005 and 2006. Because of changes in estimation procedures, character of work data before FY 1998 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 R&D 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.

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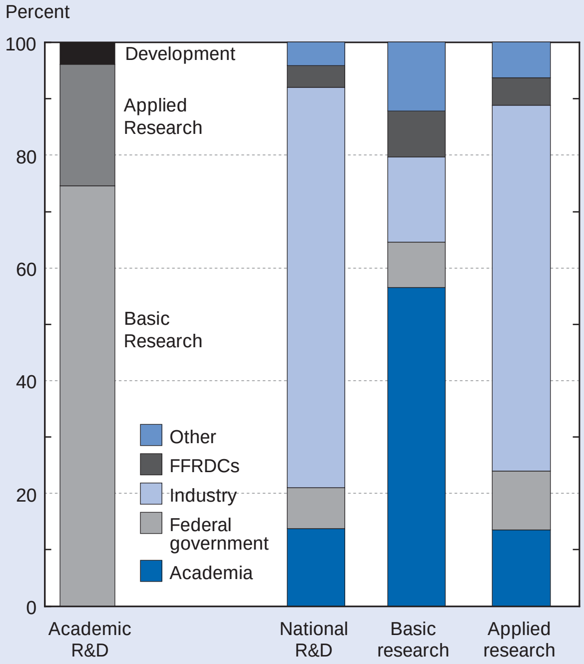
Major Funding Sources

The academic sector relies on a variety of funding sources for support of its R&D activities, although the federal government has consistently contributed the majority of the funds (figure 5-4). In 2006, the federal government accounted for about 63% of the funding of the $48 billion of R&D performed in academic institutions (figure 5-5; appendix table 5-2). This share represents a slight decline after an increase from 58% to 64% between 2000 and 2004. In 2006, federal funding failed to outpace inflation for the first time since 1982.

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 2006, institutional funds from universities and colleges constituted the second largest source of funding for academic R&D, accounting for 19% ($9.1 billion), slightly below a 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 in which research activities are not separately budgeted.

Figure 5-2
Academic R&D expenditures, by character of work, and national R&D expenditures, by performer and character of work: 2006



FFRDC = federally funded research and development center

NOTE: Preliminary data.

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.

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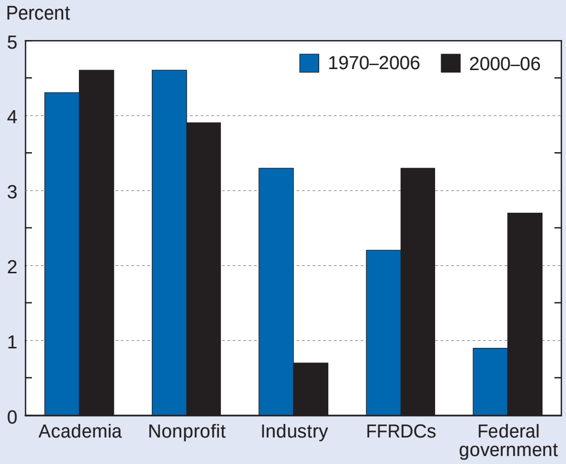
Figure 5-3
Average annual R&D growth, by performing sector: 1970–2006 and 2000–06



FFRDC = federally funded research and development center

NOTE: R&D data for calendar year.

SOURCE: National Science Foundation, Division of Science Resources Statistics, National Patterns of R&D Resources, special tabulations (preliminary data for 2005 and 2006). See appendix table 4-4.

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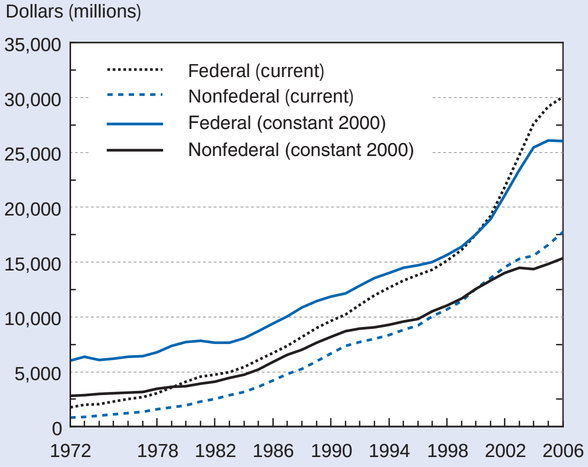
Figure 5-4
Federal and nonfederal academic R&D expenditures: 1973–2006



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 2006; and WebCASPAR database, http://webcaspar.nsf.gov. See appendix table 5-2.

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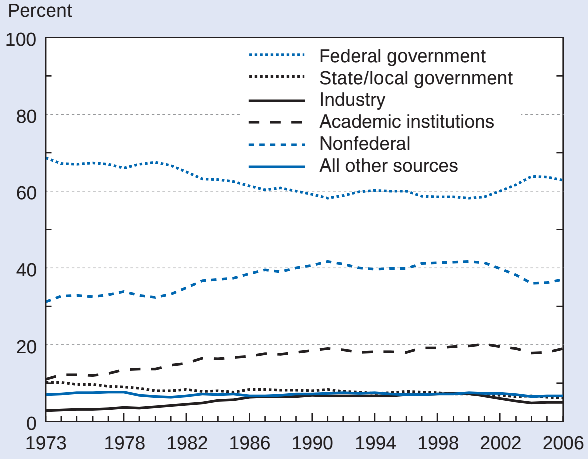
Figure 5-5
Sources of academic R&D funding: 1973–2006



SOURCES: National Science Foundation, Division of Science Resources Statistics, Academic Research and Development Expenditures: Fiscal Year 2006; and WebCASPAR database, http://webcaspar.nsf.gov. See appendix table 5-2.

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The share of support represented by institutional funds increased steadily between 1972 (12%) and 1991 (19%) but since then has remained fairly stable at roughly one-fifth of total funding. 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 funds 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 section "Patent-Related Activities and Income" later in this chapter for a discussion of patent and licensing income.)

- **State and local government funds.** State and local governments provided 6% ($3.0 billion) of academic R&D funding in 2006. Even though their absolute funding total continues to rise annually, the nonfederal government share has been slowly declining since its peak of 10.2% in 1972 to 1974. This share only reflects funds that state and local governments directly target to academic R&D activities.[5] 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.[6] 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, "State Indicators," for some indicators of academic R&D by state.)
- **Industry funds.** After a 3-year decline between 2001 and 2004, industry funding of academic R&D increased for the second year in a row, to $2.4 billion in 2006. After reaching a high of 7% in 1999, industry's share has remained at 5% since 2003. 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. (See appendix table 4-5 for time-series data on industry-reported R&D funding.)
- **Other sources of funds.** In 2006, other sources of support accounted for 7% ($3.2 billion) of academic R&D funding, a level that has stayed about the same since 1972. This category of funds includes grants and contracts 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.[7]

Expenditures by Field and Funding Source

Examining and documenting academic R&D investment patterns across disciplines allows assessment of the funding balance in the academic R&D portfolio. For a discussion of non-S&E R&D expenditures see sidebar, "Non-S&E R&D." In 2006, the life sciences continued to receive the largest share of investment in academic R&D, accounting for roughly 60% of all expenditures and also of federal and nonfederal expenditures (appendix table 5-3). Within the life sciences, the medical sciences accounted for 33% of all academic R&D expenditures and the biological sciences accounted for another 19%.[8] The field of medical sciences has experienced the greatest increase in R&D investment over the past three decades. Between 1975 and 2006, R&D expenditures in the medical sciences grew from $2.2 billion to $13.7 billion in constant 2000 dollars (figure 5-6).

The distribution of academic R&D expenditures across the various broad S&E fields has remained relatively constant since 1975 (figure 5-7). The largest shifts between 1975 and 2006 were in the fields of life sciences (up 4.6 percentage points), engineering (up 3.6 percentage points), and social sciences (down 3.9 percentage points). More recently, however, between 1996 and 2006, only the life sciences and psychology (up 5.2 and 0.2 percentage points, respectively) saw their share of the academic R&D total increase.

More significant shifts in the relative shares of academic R&D expenditures occurred within the life sciences subfields. The medical sciences' share increased by 10 percentage points between 1975 and 2006, from 24% to 33%, and the share for agricultural sciences declined by 5 percentage points from 11% to 6% (appendix table 5-4).

The proportion of academic R&D expenditures funded by the federal government also varies significantly by field (appendix table 5-5). The field with the largest share of federal funding in 2006 was atmospheric sciences at 80%, followed by the fields of physics (75%), aeronautical/astronautical engineering (74%), and psychology (72%). The fields with the smallest shares of federal funding in 2006 were economics (35%), political science (34%), and agricultural sciences, which at 32% had the smallest share.

Non-S&E R&D

Beginning in 2003, the Survey of Research and Development Expenditures at Universities and Colleges has reported information at the institutional level on non-S&E R&D expenditures in addition to expenditures on S&E R&D. In 2003, 82% of the survey respondents provided data on R&D expenditures by non-S&E field, reporting a total of $1.4 billion in non-S&E R&D expenditures. In 2004, a slightly higher percentage of institutions provided data (85%), and the reported amount of non-S&E R&D expenditures increased to $1.6 billion. In 2005, the percentage of institutions providing these data increased to 94% and the reported amount of non-S&E R&D expenditures increased to $1.8 billion. Finally, 96% of institutions reported non-S&E R&D expenditures in 2006 totaling $1.9 billion (table 5-1). This amount is in addition to the $48 billion expended on S&E R&D. The largest amounts reported for individual non-S&E fields were in education ($817 million), business and management ($248 million), and humanities ($214 million). More than half of the federally financed non-S&E R&D expenditures (56.2%, or $435 million) were in the field of education.

Table 5-1
R&D expenditures in non-S&E fields at universities and colleges: FY 2006
(Millions of current dollars)

Field	All expenditures	Federal expenditures
All fields	1,880	773
Business and management	248	53
Communications/journalism/library science	85	30
Education	817	435
Humanities	214	56
Law	68	28
Social work	90	40
Visual/performing arts	46	4
Other non-S&E fields nec	313	128

nec = not elsewhere classified

NOTE: Detail may not add to total because some respondents reporting non-S&E R&D expenditures did not break out total and federal funds by non-S&E fields.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Research and Development Expenditures at Universities and Colleges, Fiscal Year 2006.

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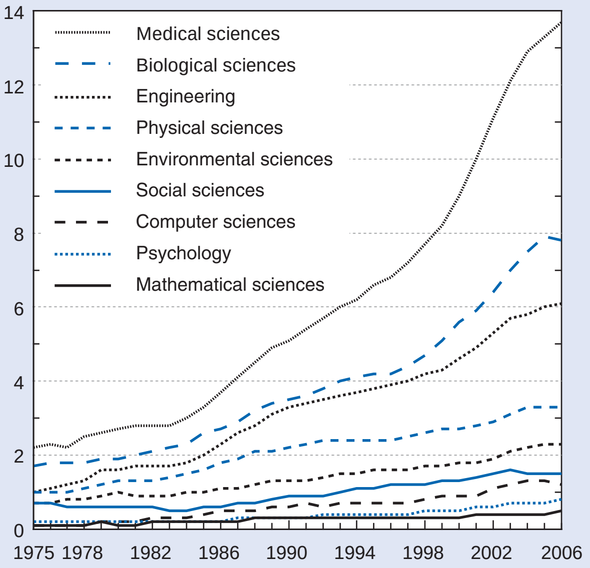
Figure 5-6
Academic R&D expenditures, by field: 1975–2006
Constant 2000 dollars (billions)



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 2006; and WebCASPAR database, http://webcaspar.nsf.gov. See appendix table 5-4.

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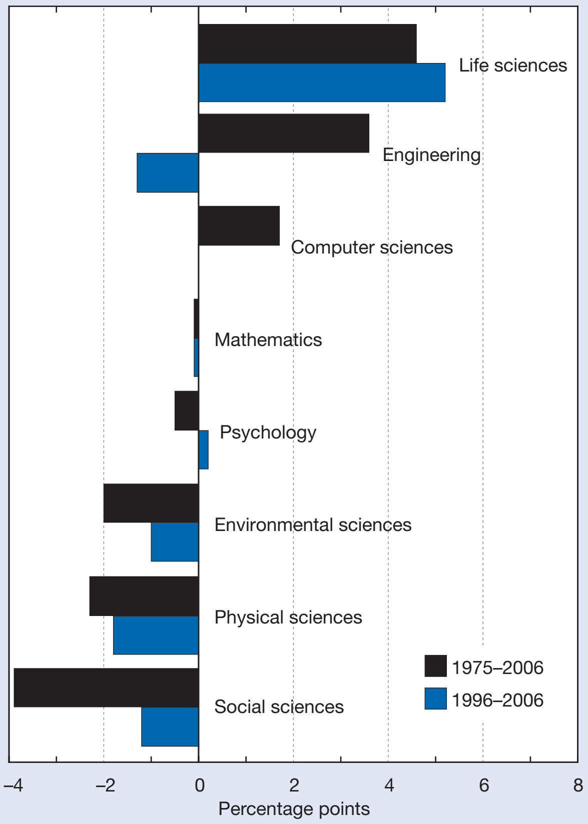
Figure 5-7
Changes in share of academic R&D in selected S&E fields: 1975–2006 and 1996–2006



NOTES: Fields ranked by change in share during 1975–2006, in descending order. Computer sciences' share identical in 1996 and 2006.

SOURCES: National Science Foundation, Division of Science Resources Statistics, Academic Research and Development Expenditures: Fiscal Year 2006; and WebCASPAR database, http://webcaspar.nsf.gov. See appendix table 5-4.

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The federally financed proportion of R&D spending declined in *all* of the broad S&E fields between 1975 and 1990 (appendix table 5-5).[9] However, since 1990, those declines have either stabilized or reversed, and the federal share reported in 2006 is higher than the 1990 share for all fields except mathematics, physical sciences, and sciences not elsewhere classified. Specifically, between 1998 and 2004, the period in which federal policies doubled the R&D budget of the National Institutes of Health (NIH), the broad fields of life sciences and psychology experienced the largest increases in their federally financed share of spending. During that period, the federal share for the life sciences increased from 57% to 64%, and the federal share for psychology increased from 67% to 75%.

Among the specific agency sources discussed in the next section, the Department of Health and Human Services (HHS), including NIH, provided the largest share of federal funding in FY 2006 ($17 billion), primarily in support of the medical and biological sciences (table 5-2). NSF provided the second largest amount of federal funding ($3.6 billion), with most (84%) going toward R&D in engineering and in the biological, computer, environmental, and physical sciences.

Federal Support of Academic R&D

The federal government continues to provide the majority of the funding for academic R&D.[10] 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. Infrastructure support is often provided through user facilities in federal laboratories, such as those supported by the Department of Energy (DOE). Examining and documenting the funding patterns of the key funding agencies is important to understanding both their roles and that of the federal government overall. For a discussion of a major federal program with the objective of improving the geographical distribution of federal obligations for academic R&D, see sidebar, "EPSCoR: The Experimental Program to Stimulate Competitive Research."

Top Agency Supporters

Six agencies are responsible for most of the federal obligations for academic R&D, providing an estimated 95% of the $25 billion obligated in FY 2007 (appendix table 5-6). NIH provided an estimated 63% of total federal financing of academic R&D in 2007. An additional 13% was provided by NSF; 8% by the Department of Defense (DOD); 5% by the National Aeronautics and Space Administration (NASA); 3% by DOE; and 2% by the USDA.[11] 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).

Total federal obligations for academic R&D in constant 2000 dollars, as well as those for DOE, NASA, NIH, and NSF, peaked in 2004 at $22.3 billion. Between 1990 and 2004, NIH's funding of academic R&D increased most rapidly, with an estimated average annual growth rate of 6.4% per year in constant 2000 dollars, increasing its share of federal funding from 52% to 63%. NASA and NSF experienced the next highest annual rates of growth during this period: 4.5% and 4.2%, respectively. Between 2004 and 2007, total obligations in constant dollars declined by an estimated 2% per year, and the decline occurred in all six major funding agencies.

Table 5-2

Federally financed academic R&D expenditures, by source of funds and S&E field: FY 2006

(Millions of current dollars)

Field	All expenditures	Federal expenditures	DOD	DOE	HHS	NASA	NSF	USDA	All other agencies
All fields	47,760	30,033	2,718	1,118	17,052	1,047	3,567	869	2,922
Computer sciences	1,438	1,015	295	36	47	25	427	2	115
Environmental sciences	2,602	1,763	158	91	64	247	566	59	552
Life sciences	28,831	18,268	446	153	15,204	103	587	718	1,008
Agricultural sciences	2,794	881	16	20	66	13	100	483	181
Biological sciences	9,044	6,240	153	66	5,033	44	426	179	306
Medical sciences	15,808	10,434	255	48	9,546	41	46	38	449
Life sciences nec	1,186	713	22	19	559	5	16	18	73
Mathematical sciences	530	373	37	11	79	4	183	3	28
Physical sciences	3,823	2,705	324	393	490	326	805	8	241
Psychology	875	629	33	4	468	12	49	1	58
Social sciences	1,703	711	38	13	288	11	100	37	222
Engineering	7,076	4,236	1,325	406	357	306	771	37	615

nec = not elswhere classified

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 = U.S. Department of Agriculture

NOTES: Not all fields reported in this table. Agency detail may not add to total because some institutions did not break out federal expenditures by agency.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Research and Development Expenditures at Universities and Colleges, Fiscal Year 2006.

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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., 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 2005, NSF was the lead federal funding agency for academic research in the physical sciences (36% of total funding); mathematics (50%); the computer sciences (71%); and the earth, atmospheric, and ocean sciences (39%) (appendix table 5-9). DOD was the lead funding agency in engineering (30%). HHS was the lead funding agency in the life sciences (91%), psychology (99%), and the social sciences (48%). Within the S&E subfields, other agencies took the leading role: DOE in physics (49%), the USDA in the agricultural sciences (99%), and NASA in astronomy (63%), aeronautical engineering (73%), and astronautical engineering (87%).

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 major sources to fund their R&D projects, the relative importance of those sources differs substantially for these two types of institutions (figure 5-10; appendix table 5-10). In 2006, public institutions received state and local government funding for approximately 8% of their total R&D expenditures ($2.7 billion of their $32.4 billion total), whereas only 2% ($0.3 billion) of private institutions' total R&D spending ($15.4 billion) was financed by state and local government. Compared with public institutions (23%, or $7.4 billion), private academic institutions also funded a much smaller portion of their R&D from institutional sources in 2006 (11%, or $1.6 billion). However, the federal government provided 75% ($11.6 billion) of the R&D funds spent by private institutions in 2006, compared with only 57% ($18.5 billion) for public institutions. The larger amount of institutional funds used for R&D at public institutions may reflect 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).[12] (For a more detailed discussion of the composition of institutional funds for public and private academic institutions, see sidebar, "Composition of Institutional Academic R&D Funds.")

Both public and private institutions received approximately 5% of their R&D support from industry in 2006. The share of total R&D expenditures funded by all other sources was also fairly comparable between public and private institutions, at 6% and 7%, respectively.

EPSCoR: The Experimental Program to Stimulate Competitive Research

EPSCoR, the Experimental Program to Stimulate Competitive Research, is based on the premise that universities and their S&E faculty and students are valuable resources that can potentially influence a state's development in the 21st century in much the same way that agricultural, industrial, and natural resources did in the 20th century.

EPSCoR originated as a response to a number of stated federal objectives. Section 3(e) of the National Science Foundation Act of 1950, as amended, states that "it shall be an objective of the Foundation to strengthen research and education in the sciences and engineering, including independent research by individuals, throughout the United States, and to avoid undue concentration of such research and education." Even earlier, the 1947 Steelman report, Science and Public Policy, in discussing the formation of NSF, stated *"it is clear that a portion of the funds expended by the National Science Foundation should be used to strengthen the weaker, but promising, colleges and universities, and thus to increase our total scientific potential"* (emphasis added).

But EPSCoR did not officially begin at NSF until 1978, when Congress authorized the agency to conduct EPSCoR in response to broad public concerns about the extent of geographical concentration of federal funding of R&D. Eligibility for EPSCoR participation was limited to those jurisdictions that have historically received lesser amounts of federal R&D funding and have demonstrated a commitment to develop their research bases and to improve the quality of S&E research conducted at their universities and colleges.

The success of the NSF EPSCoR programs during the 1980s subsequently prompted the creation of EPSCoR and EPSCoR-like programs in six other federal agencies: the Departments of Energy, Defense, and Agriculture; the National Aeronautics and Space Administration; the National Institutes of Health; and the Environmental Protection Agency. In FY 1993, congressional direction precipitated the formation of the EPSCoR Interagency Coordinating Committee (EICC). A memorandum of understanding (MOU) was signed by officials of the seven agencies with EPSCoR or EPSCoR-like programs agreeing to participate in the EICC. The major objective of the MOU focused on improving coordination among and between the federal agencies in implementing EPSCoR and EPSCoR-like programs consistent with the policies of participating agencies. The participating agencies agreed to the following objectives:

- ♦ Coordinate federal EPSCoR and EPSCoR-like programs to maximize the impact of federal support while eliminating duplication in states receiving EPSCoR support from more than one agency.
- ♦ Coordinate agency objectives with state and institutional goals, where appropriate, to obtain continued nonfederal support of science and technology (S&T) research and training.
- ♦ Coordinate the development of criteria to assess gains in academic research quality and competitiveness and in S&T human resource development.
- ♦ Furthermore, as members of the EICC, the agencies agreed to exchange information on pending legislation, agency policies, and relevant programs related to S&T research and training and, when appropriate, to provide responses on issues of common concern.

EPSCoR seeks to increase the R&D competitiveness of an eligible state through the development and utilization of the S&T resources residing in its major research universities. It strives to achieve its objective by (1) stimulating sustainable S&T infrastructure improvements at the state and institutional levels that significantly increase the ability of EPSCoR researchers to compete for federal and private sector R&D funding, and (2) accelerating the movement of EPSCoR researchers and institutions into the mainstream of federal and private sector R&D support.

In FY 2006, the seven EICC agencies spent a total of $353.4 million on EPSCoR or EPSCoR-like programs, up from $79.1 million in 1996, a more than fourfold increase (table 5-3). However, the Environmental Protection Agency discontinued issuing separate EPSCoR program solicitations in FY 2006, and NASA, which has 2-year money, planned for FY 2006 awards but had not yet made its selections. Twenty-seven states, the U.S. Virgin Islands, and the Commonwealth of Puerto Rico currently participate in the combined agency EPSCoR and EPSCoR-related programs, although not every state is included in each agency's set of EPSCoR states (table 5-4).

(continued on next page)

Table 5-3

EPSCoR and EPSCoR-like program budgets, by agency: FY 1996–2006

(Millions of dollars)

Agency	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
All agencies	79.1	80.9	74.1	91.0	129.7	209.2	270.7	353.9	351.5	365.7	353.4
DOD	18.6	16.2	18.0	19.0	24.0	18.7	15.7	15.7	8.4	11.4	11.5
DOE	6.5	6.3	6.8	6.8	6.8	7.7	7.7	11.7	7.7	7.6	7.3
EPA	NA	2.5	2.5	2.5	NA	NA	NA	NA	2.5	2.4	0.0
NASA	5.0	4.6	5.0	5.0	8.9	9.2	8.8	9.2	8.6	10.8	0.0
NIH	2.2	1.9	5.0	10.0	40.0	100.0	160.0	210.0	214.0	222.0	220.0
NSF	35.7	38.4	36.8	47.7	50.0	73.6	78.5	87.9	93.3	92.9	96.6
USDA	11.1	11.0	NA	NA	NA	NA	NA	19.3	17.0	18.6	18.0

NA = not available

DOD = Department of Defense; DOE = Department of Energy; EPA = Environmental Protection Agency; EPSCoR = Experimental Program to Stimulate Competitive Research; NASA = National Aeronautics and Space Administration; NIH = National Institutes of Health; NSF = National Science Foundation; USDA = U.S. Department of Agriculture

NOTES: EPA discontinued issuing separate EPSCoR program solicitations in FY 2006. NASA plans for FY 2006 awards, but no selections yet made. NASA has 2-year money.

SOURCES: 1998–2006 data for DOE, NASA, NIH, NSF, and USDA provided by agency EPSCoR representatives (USDA 2003–05 data from agency website); 2004–06 data for EPA taken from DOE website, EPSCoR Funding by Agency; 2000–06 data for DOD from DOD news releases; 1996–97 data for all agencies and 1998 and 1999 data for DOD and EPA from National Science Board, Science and Engineering Indicators 2000, table 6-1.

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Table 5-4

EPSCoR and EPSCoR-like program budgets, by agency and state: FY 2006

(Thousands of dollars)

State	DOD	DOE	NASA	NIH	NSF	USDA
Alabama	0	685	442	0	5,437	1,142
Alaska	981	0	0	3,669	3,518	0
Arkansas	350	135	538	7,305	2,956	3,971
Connecticut	0	0	314	0	0	0
Delaware	0	0	0	10,131	4,962	281
Hawaii	0	0	0	4,304	6,083	770
Idaho	0	375	633	7,109	3,450	0
Kansas	450	135	442	14,085	4,980	0
Kentucky	0	0	825	15,135	3,901	1,523
Louisiana	0	462	564	20,637	6,523	764
Maine	0	0	529	8,178	3,542	200
Mississippi	0	132	258	9,103	3,695	0
Montana	838	455	588	9,303	4,091	0
Nebraska	1,110	265	825	11,682	4,388	0
Nevada	772	740	825	7,622	4,020	0
New Hampshire	424	0	0	4,646	403	0
New Jersey	0	0	0	0	0	2,679
New Mexico	0	135	0	7,329	3,558	0
North Dakota	468	923	250	6,740	3,237	801
Oklahoma	1,236	350	622	15,727	5,690	1,462
Puerto Rico	574	375	449	3,484	743	0
Rhode Island	400	0	0	11,182	3,306	0
South Carolina	500	660	425	11,613	5,205	1,034
South Dakota	570	125	637	6,833	2,510	201
Tennessee	829	140	0	0	1,726	0
U.S. Virgin Islands	0	0	0	0	894	0
Vermont	1,179	0	633	10,255	828	1,041
West Virginia	350	855	422	9,343	3,374	1,208
Wyoming	482	140	543	4,571	3,601	923

DOD = Department of Defense; DOE = Department of Energy; EPSCoR = Experimental Program to Stimulate Competitive Research; NASA = National Aeronautics and Space Administration; NIH = National Institutes of Health; NSF = National Science Foundation; USDA = U.S. Department of Agriculture

NOTES: FY 2005 NASA data; NASA plans for FY 2006 awards, but no selections yet made. The Environmental Protection Agency discontinued issuing separate EPSCoR program solicitations in FY 2006, so no state level data available for 2006. DOE state level data do not add to total because $193,000 allocated to technical support and not distributed to states.

SOURCE: Data provided by agency EPSCoR representatives.

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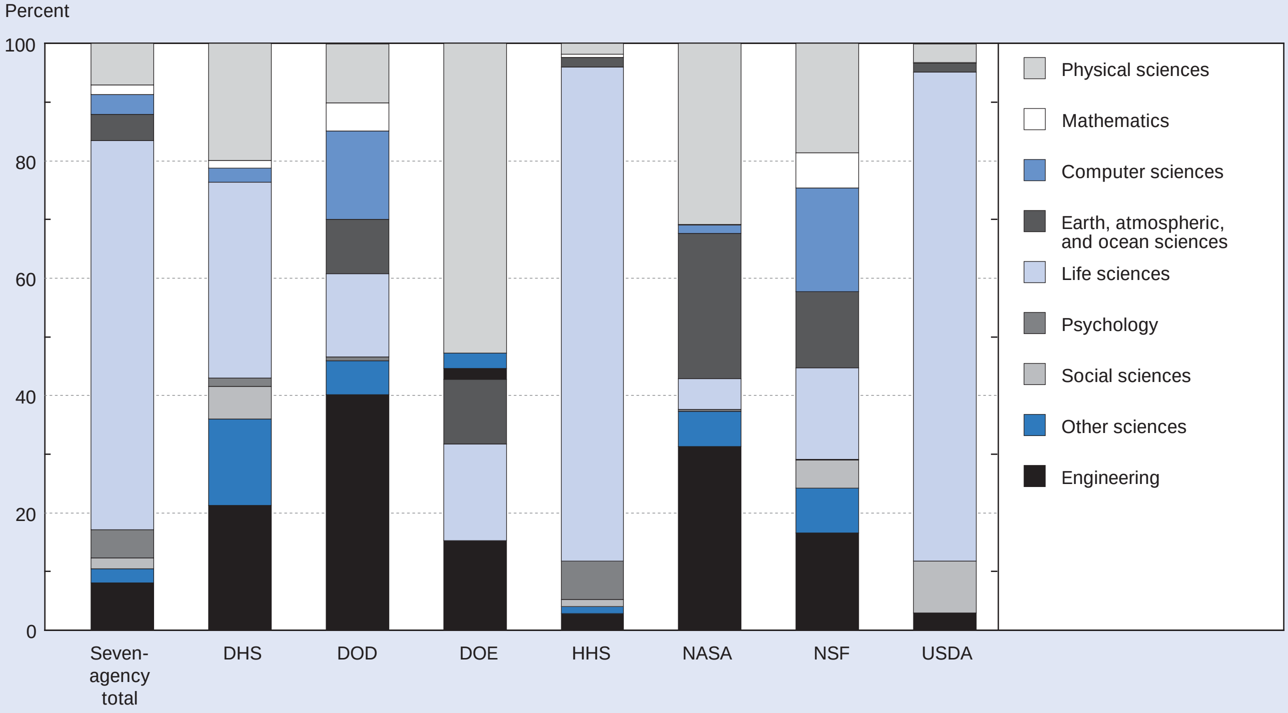
Figure 5-8
Federal agency academic research obligations, by field: FY 2005



DHS = Department of Homeland Security; 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 = U.S. 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 2005, 2006, and 2007 (forthcoming). See appendix table 5-8.

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Distribution of R&D Funds Across Academic Institutions

Of the 650 institutions that reported R&D expenditures of at least $150,000 in 2006, the top 20 in terms of total R&D expenditures accounted for 30% of total academic R&D spending. The top 100 institutions accounted for 80% of all academic R&D expenditures in 2006. Appendix table 5-11 presents a detailed breakdown of the distribution among the top 100 institutions.

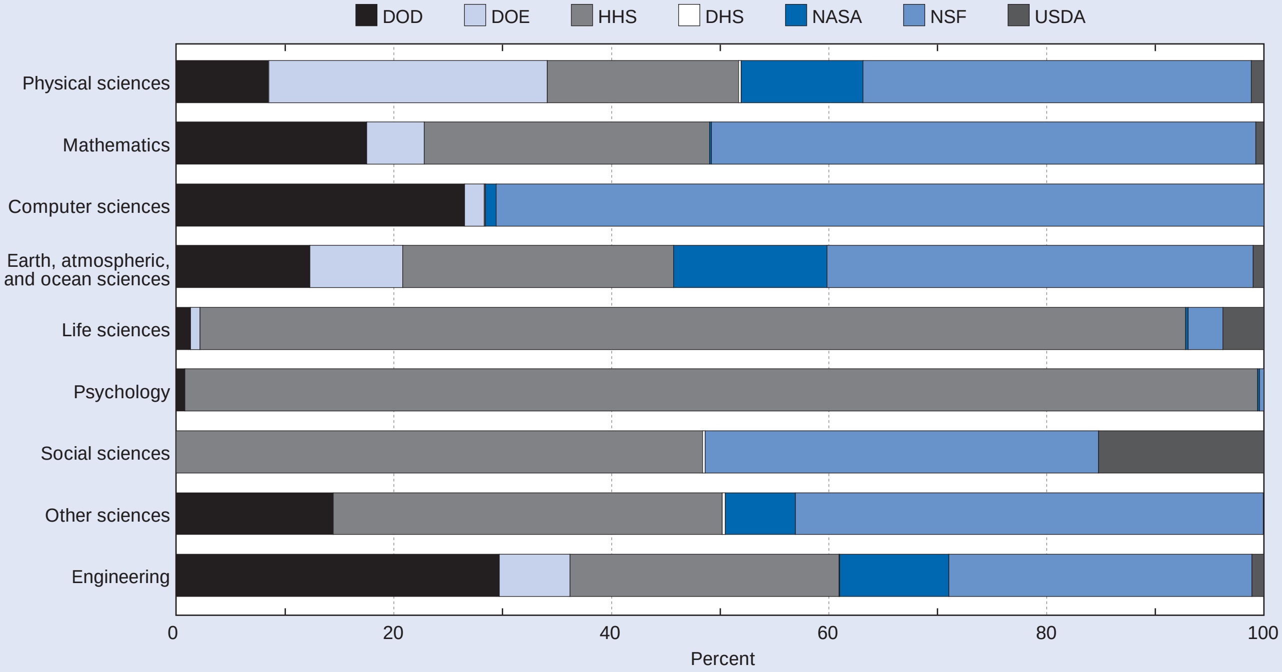
The concentration of academic R&D funds among the top 100 institutions has stayed relatively constant over the past two decades (figure 5-11). In 1986, institutions not in the top 100 accounted for 17% of the nation's total academic R&D expenditures. This percentage increased to 20% in 1993 and remained at that level through 2006. The share held by the top 10 institutions has also fluctuated narrowly (between 17% and 20%) throughout this 20-year period.

It should be noted that the composition of the universities in each of these groups is not the same over time; mobility occurs between groups as universities increase or decrease their R&D activities. Three of the top 10 institutions in 1986 were not in the top 10 in 2006, and 5 of the top 20 institutions in 1986 were not in the top 20 in 2006. The next section points to an increasing number of academic institutions receiving federal support for their R&D activities between 1972 and 2005.

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 1971 and 1994, when it reached a peak of 902 institutions. Between 1995 and 2005, the number of institutions receiving federal support fluctuated between 789 and 891 (figure 5-13).[13] Both the growth through 1994 and the fluctuations since then almost exclusively affected institutions that were not classified as having very high or high research activity by the Carnegie Foundation for the Advancement of Teaching. The number of such institutions receiving federal support almost doubled between 1971 and 1994, rising from 375 to 707. It then dropped to 593 in 1999 before beginning to rise again over the past several years (appendix table 5-12). These institutions' share of federal support also increased between 1971 and 2005, from 11% to 18%.

Figure 5-9
Major agency field shares of federal academic research obligations: FY 2005



DHS = Department of Homeland Security; 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 = U.S. 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 2005, 2006, and 2007 (forthcoming). See appendix table 5-9.

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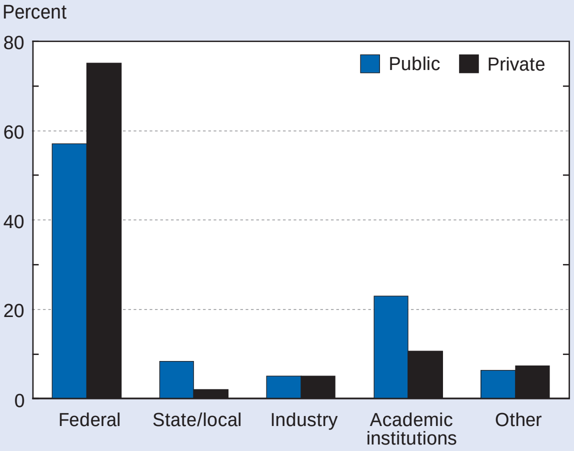
Figure 5-10
Sources of academic R&D funding for public and private institutions: 2006



SOURCES: National Science Foundation, Division of Science Resources Statistics, Academic Research and Development Expenditures: Fiscal Year 2006; and WebCASPAR database, http://webcaspar.nsf.gov. See appendix table 5-10.

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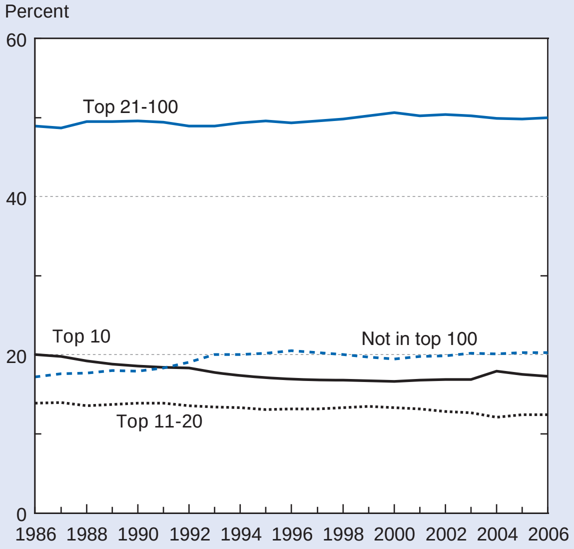
Figure 5-11
Share of academic R&D, by rank of university and college academic R&D expenditures: 1986–2006



SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Research and Development Expenditures at Universities and Colleges, special tabulations (2007). See appendix table 5-11.

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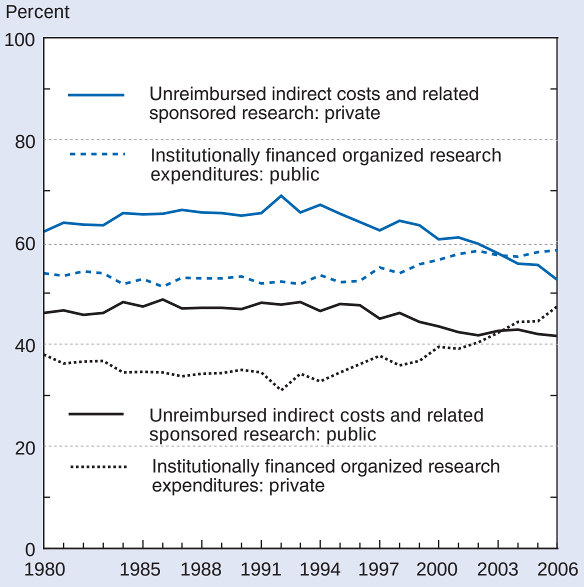
Composition of Institutional Academic R&D Funds

In 2006, academic institutions committed a substantial amount of their own resources to R&D: roughly $9.1 billion or 19% of all funding for academic R&D. The share of institutional support for academic R&D at public institutions (23%) was greater than that at private institutions (11%) (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 53% to 69% of private institutions' own R&D funds were designated for unreimbursed indirect costs plus cost sharing, compared with 42% to 49% of public institutions' own funds (figure 5-12).

Figure 5-12
Components of institutional R&D expenditures for public and private academic institutions: 1980–2006



SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Research and Development Expenditures at Universities and Colleges, special tabulations (2007).

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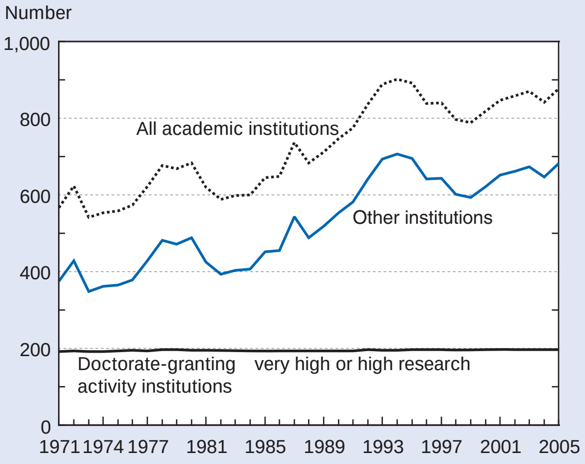
Figure 5-13
Academic institutions receiving federal R&D support, by selected Carnegie classification: 1971–2005



NOTE: Institutions designated by 2005 Carnegie classification code. Other institutions include all institutions except very high and high research activity institutions. For information on these institutional categories, see chapter 2 sidebar, Carnegie Classification of Academic Institutions, and The Carnegie Classification of Institutions of Higher Education, http://www.carnegiefoundation.org/classifications/index.asp, accessed 17 August 2007.

SOURCES: National Science Foundation, Division of Science Resources Statistics, Federal Science and Engineering Support to Universities, Colleges, and Nonprofit Institutions: FY 2005 (forthcoming); and Integrated Science and Engineering Resources Data System (WebCASPAR), http://webcaspar.nsf.gov.

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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.

Expenditures

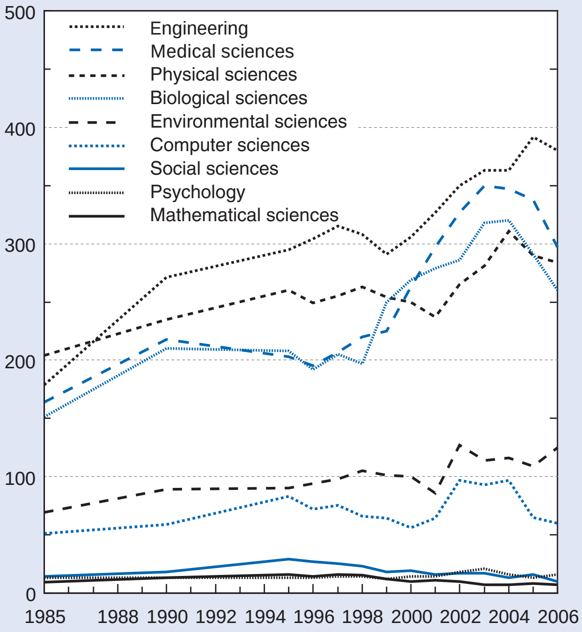
In 2006, about $1.8 billion in current funds was spent for academic research equipment. About 83% of these expenditures were concentrated in three fields: the life sciences (41%), engineering (24%), and the physical sciences (18%) (appendix table 5-13). After more than doubling in constant 2000 dollars between 1985 and 2004, equipment expenditures in the life sciences subfields of medical and biological sciences declined in 2005 and 2006. Engineering equipment expenditures also doubled between 1985 and 2005 but declined in 2006 (figure 5-14).

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 share of federal funding for research equipment varies significantly by field.

Figure 5-14
Current fund expenditures for research equipment at academic institutions, by field: 1985–2006

Constant 2000 dollars (millions)



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 2006; and WebCASPAR database, http://webcaspar.nsf.gov. See appendix table 5-13.

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In 2006, sociology received federal funding for 29% of its research equipment expenditures. In contrast, federal funding accounted for 82% of equipment expenditures in the field of astronomy (appendix table 5-14). The share of total expenditures for research equipment funded by the federal government fluctuated between 56% and 64% during the 1985–2006 period.

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 steadily since reaching a peak of 7% in 1985. By 2006, it had declined to 4% (appendix table 5-15). R&D equipment intensity in 2006 was highest in the physical sciences (9%) and certain engineering subfields (about 8% in both mechanical and metallurgical/materials engineering). The field of computer sciences experienced the most significant decline in research equipment intensity between 1985 and 2006, falling from 13% to 5%, which may reflect strong declines in equipment prices in this technology area and growth in capability of more general-purpose infrastructure.[14]

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.

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).

How the relationship between cyberinfrastructure and traditional bricks and mortar infrastructure will develop is unknown. For example, access to high-quality research facilities may become available to researchers located at institutions where traditional research space has not been available. Some institutions have begun conducting 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[15] continued to expand their stock of research space in FY 2005, but at a significantly slower rate than the previous 2-year period (table 5-5). Institutions reported a 7% increase in the amount of research space between FY 2003 and FY 2005, for a total of approximately 185 million net assignable square feet (NASF).[16] The size of this increase was more similar to the rates of previous biennial increases than to the 11% increase between FY 2001 and FY 2003, which was the highest biennial increase since the survey began collecting data.

In FY 2005, research space increased in all S&E fields except the earth, atmospheric, and ocean sciences, which experienced a 3% decline. Additionally, for the first time in more than a decade, the amount of research animal space declined.

Two of the three fields of science that experienced the largest percentage of increase in research space in FY 2003 again had the largest percentage of increase in FY 2005: the computer sciences and medical sciences. From a relatively modest base, the computer sciences had the largest increase

(32%), which resulted in 4.1 million NASF. In the decade between 1996 and 2005, space for the computer sciences grew by 105%.

During the same period, research space in psychology, the social sciences, mathematics, and the medical sciences also increased by more than 50%. However, except for the medical sciences, all of these fields also have the smallest amount of total space relative to the other fields. Between 1996 and 2005, the physical sciences and earth, atmospheric, and ocean sciences experienced the least amount of growth in research space.

Since survey inception, the greatest increases in research space have occurred in the biological sciences and medical sciences. The proportion of total space dedicated to these two fields has remained fairly stable from year to year, ranging between 38% and 42%. However, in 2005, the medical sciences surpassed the biological sciences in research space for the first time (39.7 million NASF versus 38.5 million NASF, respectively).

Construction of Research Space. Total new S&E research space being constructed in FY 2004–05 was also dominated by the biological and medical sciences. Sixty-four percent of newly built research space and 67% of construction funds were in the biological and medical sciences (tables 5-6 and 5-7). The trend continued in FY 2006–07. Fifty-four percent of all new construction and 57% of all expenditures for this construction are planned for these two fields.[17] However, whereas the largest percentage of new research space is planned for the biological and medical sciences, the physical and social sciences are expected to experience the largest rate of increase, about 200%.

Institutions anticipated a decline in the amount of newly constructed research space in the earth, atmospheric, and ocean sciences in FY 2006–07. This follows an absolute decline in space in this field during the previous 2-year period. The field of earth, atmospheric, and ocean sciences is the only one that experienced a decline in NASF since FY 2003–05 and the only field that anticipated a decline in new construction in FY 2006–07.

Total dollars invested in new construction of research space declined in FY 2005 for the first time in a decade, by 17% to $6.1 billion (table 5-7). This decline may be temporary, however, as institutions anticipate an increase in FY 2006–07 in funds expended for planned new construction. Even with the decline, however, total dollars for construction of new research space almost doubled between FY 1999 and FY 2005.

As a share of total expenditures for new construction, only the biological and medical sciences experienced an increase between FY 1987–88 and FY 2004–05, from 23% to 33% for the biological sciences and from 25% to 34% for the medical sciences. Psychology and mathematics remained about the same while all other fields experienced a decline. Institutions estimated that by FY 2006–07, the share of new construction for the biological sciences would decline to 29% and the share for the medical sciences to 28%. The share of total expenditures for research space in the earth, atmospheric, and ocean sciences ($69 million) was estimated to decline to less than 1%. The largest percentage point increase in share of funds for new construction in FY 2006–07 was estimated for the physical sciences (from 7% to 10%).

Table 5-5

S&E research space in academic institutions, by field: FY 1988–2005

(Millions of net assignable square feet)

Field	1988	1990	1992	1994	1996	1998	1999	2001	2003	2005
All fields	112	116	122	127	136	143	148	155	172.7	185.1
Agricultural sciences	18	21	20	20	22	25	24	27	26.4	26.8
Biological sciences	24	27	28	28	30	31	31	33	36.0	38.5
Computer sciences	1	1	2	2	2	2	2	2	3.1	4.1
Earth, atmospheric, and ocean sciences	6	6	7	7	7	8	8	8	8.9	8.6
Engineering	16	17	18	21	22	23	24	26	27.4	28.9
Mathematics	1	1	1	1	1	1	1	1	1.5	1.6
Medical sciences	19	20	22	23	25	25	26	28	34.9	39.7
Physical sciences	16	16	16	17	18	18	19	19	20.4	21.0
Psychology	3	3	3	3	3	3	4	4	4.4	4.8
Social sciences	3	3	3	3	4	5	3	5	5.7	6.3
Other sciences	4	2	2	2	2	3	3	3	3.8	4.9
Animal research space	NA	NA	9	11	12	12	13	NA	16.7	16.5

NA = not available

NOTES: Animal research space listed separately and also included in individual field totals. NA indicates years question not asked. Detail may not add to total because of rounding.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Science and Engineering Research Facilities, Fiscal Years 1988–2005.

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Table 5-6
New construction of S&E research space in academic institutions, by field and time of construction: FY 2004–07
(Millions of square feet)

Field	Construction started FY 2004–05		Construction planned to start FY 2006–07	
	Institutions (number)	Total NASF	Institutions (number)	Total NASF
All fields	167	10.2	172	13.7
Agricultural sciences	26	0.4	23	0.5
Biological sciences	84	3.2	77	3.4
Computer sciences	18	0.3	14	0.5
Earth, atmospheric, and ocean sciences	26	0.3	14	0.1
Engineering	50	1.5	47	1.9
Mathematics	8	*	7	0.1
Medical sciences	57	3.3	54	4.0
Physical sciences	32	0.5	43	1.5
Psychology	14	0.2	10	0.2
Social sciences	12	0.1	11	0.3
Other sciences	12	0.3	23	1.2
Animal research space	64	1.2	54	1.0

* = >0 but <50,000 NASF

NASF = net assignable square feet

NOTES: Animal research space listed separately and also included in individual field totals. Detail may not add to total because of rounding.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Science and Engineering Research Facilities, Fiscal Year 2005.

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Table 5-7
Costs for new construction of S&E research space in academic institutions, by field: Selected years, FY 1986–2007
(Millions of dollars)

Field	1986–87	1988–89	1990–91	1992–93	1994–95	1996–97	1998–99	2002–03	2004–05	2006–07
All fields	2,051	2,464	2,976	2,812	2,768	3,110	3,222	7,388.7	6,109.9	7,903.4
Agricultural sciences	150	152	175	210	150	273	224	142.3	171.5	135.6
Biological sciences	463	577	832	633	614	582	781	1,944.7	2,022.0	2,327.9
Computer sciences	61	65	40	47	46	21	75	338.4	122.0	314.6
Earth, atmospheric, and ocean sciences	57	82	170	123	33	172	149	194.2	121.6	69.2
Engineering	430	388	395	286	575	332	416	1,055.3	890.8	1,079.8
Mathematics	2	8	12	10	2	9	13	9.3	15.6	20.3
Medical sciences	505	648	807	999	647	1,043	881	2,256.0	2,075.0	2,183.6
Physical sciences	182	401	430	337	426	381	419	782.4	398.9	756.1
Psychology	23	25	36[a]	16	42	77	49	73.3	91.7	108.2
Social sciences	38	48	NA	44	112	75	55	148.4	78.9	150.7
Other sciences	139	70	79	106	122	145	159	444.4	121.9	757.5
Animal research space	NA	NA	NA	NA	NA	NA	223	731.9	660.0	742.9

NA = not available, question not asked

[a] Psychology and social sciences not differentiated in questionnaire item for FY 1990–91.

NOTES: Animal research space listed separately and also included in individual field totals. Question on construction costs not asked on FY 2001 survey; therefore, no data reported. Only construction projects costing >$250,000 for a single field reported on FY 2003 and FY 2005 surveys; construction projects costing >$100,000 reported in previous cycles. 2006–07 data estimates of planned research space. Detail may not add to total because of rounding.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Science and Engineering Research Facilities, Fiscal Years 1988–2005.

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Source of Funds. Institutions use one or more sources to fund their capital projects, including the federal government, state or local governments, and the institutions' own funds (appendix table 5-16).[18] The federal government's share of total construction funding, never a large proportion, reached its smallest proportion (5%) of total construction funds in FY 2002–03 (figure 5-15).[19] Concurrently, the institutional share of construction funds generally increased during this time and reached its highest share, 63%, in FY 2002–03.

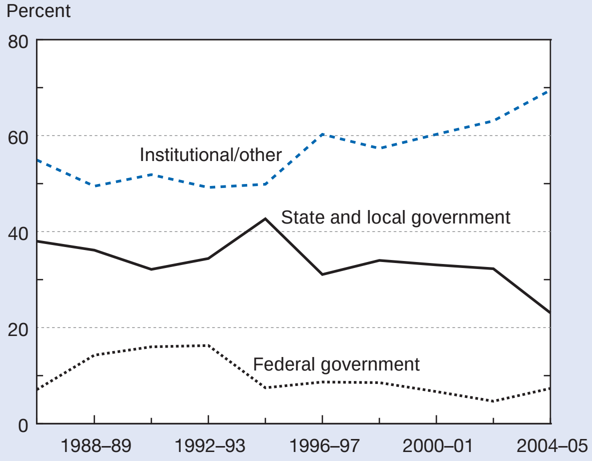
Between FY 2002–03 and FY 2004–05, the federal share increased for the first time since FY 1994–95, rising from 5% to 7%. During the same period, the share of construction funds from state and local governments decreased by 9 percentage points to 23% in FY 2004–05. This was the largest percentage point decline in the state and local share since FY 1986–87, except for the 2-year period from FY 1994 to FY 1996, when the decrease was also 9 percentage points. Institutions generally accommodated this decrease in state and local funds by increasing the institutional share of funds and decreasing their total expenditures. During FY 2004–05, the institutional share rose to the highest percentage of total funds for construction (69%) since FY 1986–87. During this period, the institutional share of funds expended on repair/renovation also increased to its highest percentage since FY 1986–87.

Cyberinfrastructure: Networking

Networking resources are a key component of cyberinfrastructure.[20] Networks allow 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.[21]

Figure 5-15

Source of funds for new construction of S&E research space: 1986–87 to 2004–05



NOTE: Data extrapolated for 2000–01 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 5-16.

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All academic institutions today have connections to the *commodity Internet* (Internet1), the network commonly known as the Internet. Although Internet connections are used for many purposes (e-mail, buying books from the campus bookstore, transfer of databases), conducting research can require greater network capabilities than other activities.

One common indicator of network capability is bandwidth, or speed. A network's bandwidth can affect the amount and type of research activity accomplished through the network. The greater the amount of bandwidth, the more capable the network is in handling both large amounts of data and communication traffic and more demanding or sophisticated communications. Although a slow network connection might well be able to transmit scientific articles, accessing scientific instruments and databases located thousands of miles away demands (among other requirements) higher bandwidth.

Internet Bandwidth. In FY 2005, 43% of academic institutions reported the total of their commodity internet (Internet1) and Abilene (often called Internet2) bandwidth to be

Table 5-8

Bandwidth to commodity Internet (Internet1) and Abilene (Internet2) at academic institutions: FY 2005 and 2006

(Percent distribution)

Bandwidth	FY 2005	FY 2006
All bandwidth	100	100
<1.6 mb	2	1
1.6–9 mb	3	2
10 mb	1	*
11–45 mb	23	18
46–99 mb	16	13
100 mb	3	4
101–155 mb	9	10
156–622 mb	18	17
623–999 mb	3	4
1–2.5 gb	15	20
2.6–9 gb	4	5
10 gb	*	1
>10 gb	2	4
Other	*	*
Institutions (number)	449	449

* = >0 but <0.5%

gb = gigabits/second; mb = megabits/second

NOTES: Abilene is a high-performance backbone network that enables the development of advanced Internet applications and the deployment of leading-edge network services to member colleges, universities, and research laboratories across the country. Detail may not add to total because of rounding. FY 2006 data estimated.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Science and Engineering Research Facilities, Fiscal Year 2005.

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greater than 155 megabits (table 5-8). Twenty-one percent reported bandwidth of 1 gigabit or greater. The percentage of institutions with total bandwidth of 1 gigabit or faster is estimated to increase about 9 percentage points in FY 2006 to 30%.

High-Performance Network Connections. In addition to their Internet1 connections, institutions may also be connected to one or more high-performance networks. By FY 2005, the majority of institutions had connected to Abilene, a high-performance network dedicated to research led by a consortium of universities, governments, and private industry; only 5% of doctorate-granting institutions did not have an Abilene connection. By FY 2006, 76% of all institutions anticipated having a connection, a 17% increase since FY 2003. Furthermore, 32% of those anticipating Abilene connections in FY 2006 also anticipated Abilene bandwidth of 1 gigabit or faster.

Institutions may also be connected to the National Lambda Rail, a national fiber optic infrastructure supporting multiple networks for the research community. In just 1 year, the number of institutions connected to the National Lambda Rail is expected to increase by 200%, from 10% with connections in FY 2005 to 31% in FY 2006.[22] Finally, about 13% of institutions anticipated being connected to at least one federal government high-performance network, such as NASA's Research and Engineering Network (NREN) or DOE's Energy Sciences Network (ESnet), by FY 2006.

The majority of institutions (63%) obtained at least some of their bandwidth, whether Internet1 or high performance, through a consortium in FY 2005, and additional institutions anticipated doing so in FY 2006 (68%). All but one of the institutions reporting Internet1 connections of 1 gigabit or faster received their bandwidth through a consortium. Although institutions reported a variety of consortia, many are state and/or regional research and education networks. For example, the list of consortia includes the Metropolitan Research and Education Network (MREN), the Corporation for Education Network Initiatives in California (CENIC), Merit Network, and the New York State Education and Research Network (NYSERNet).

Internal Institutional Networks. Concurrent with increasing connection speeds to external networks such as Internet1, institutions are also increasing their internal network speeds (table 5-9). In FY 2003, the highest speed from one desktop to another was 100 megabits at 64% of institutions and 1–2.5 gigabits at 33%. By FY 2005, only 40% of institutions reported 100 megabits as their highest desktop-to-desktop speed, and 54% reported speeds of 1 gigabit or faster. In FY 2003, no institution had a speed greater than 2.5 gigabits, whereas 4% had speeds at least this fast in FY 2005; more than 14% of institutions estimated that their highest desktop-to-desktop speed would be at least this fast in FY 2006.

Table 5-9

Highest desktop-to-desktop speed on an academic institution's internal network: FY 2003, 2005, and 2006

(Percent distribution)

Connection speed	FY 2003	FY 2005	FY 2006
All connection speeds	100	100	100
<1.6 mb	*	0	0
1.6–9 mb	0	0	0
10 mb	2	*	0
11–45 mb	0	*	*
46–99 mb	0	2	1
100 mb	64	40	28
101–155 mb	*	*	*
156–622 mb	*	1	1
623–999 mb	0	3	3
1–2.5 gb	33	50	53
2.6–9 gb	0	1	2
10 gb	0	3	11
>10 gb	0	*	1
Other	0	0	0
Institutions (number)	425	449	449

* = >0 but <0.5%

gb = gigabits/second; mb = megabits/second

NOTE: Detail may not add to total because of rounding. FY 2006 data estimated.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Science and Engineering Research Facilities, Fiscal Years 2003 and 2005.

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Doctoral Scientists and Engineers in Academia

The role of research in U.S. universities is both to create new knowledge and to educate students who will become the future generations of researchers and teachers (Association of American Universities 2006). Doctoral scientists and engineers in academia, and in particular faculty in U.S. colleges and universities, are an important aspect of academic R&D, as they generally engage in both research and teaching. The focus of this section is on the research aspects of doctoral scientists and engineers in academia. Teaching aspects of faculty employment are more thoroughly covered in chapter 2.

This section examines trends in employment and research activity of doctoral scientists and engineers in U.S. universities and colleges, with special attention paid to faculty in research universities. Research universities have a disproportionate influence on the U.S. academic R&D enterprise. Research institutions, although few in number, are the leading producers of S&E bachelor's, master's, and doctoral degree recipients (see chapter 2) and the doctorate-granting source of more than three-quarters of faculty with S&E doctorates (NSF/SRS 2006). These institutions also conduct more than

80% of academic R&D (as measured by expenditures) and produce the bulk of both academic articles and patents (see section "Outputs of S&E Research: Articles and Patents" later in this chapter).

Trends in Academic Employment of Doctoral Scientists and Engineers

Academic employment of S&E doctorate holders reached a record high of 274,200 in 2006 (appendix table 5-17).[23] However, long-term growth in the number of these positions between 1973 and 2006 was slower than in either business or government. Employment in the academic sector slowed in the 1990s, especially at research universities, and growth over the past three decades was slower than in the business and government sectors (table 5-10; figure 5-16). As a result, the share of all S&E doctorate holders employed in academia dropped from about 55% to 45% during the 1973–2006 period (table 5-11). 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 2006, more than half of recent doctorate holders were employed in academia.

All Academic S&E Doctoral Employment

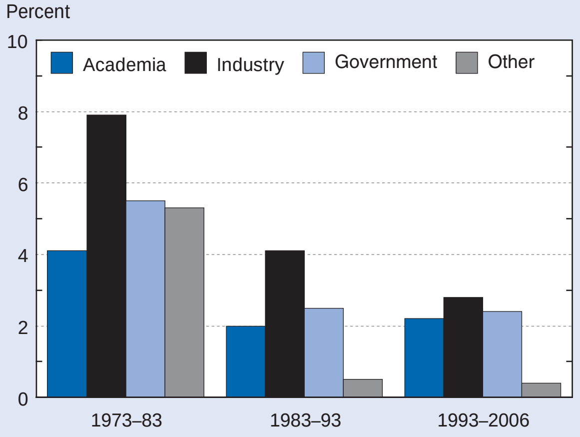
Growth in academic employment was stronger for life scientists than for other scientists and engineers. In engineering and many other science fields, growth in academic employment slowed in the early 1990s, but increased from 1995 to 2006 (figure 5-17; appendix table 5-17).

Trends in academic employment of S&E doctorate holders suggest continual movement away from the full-time faculty position as the academic norm (figure 5-18). Although academic employment of S&E doctorate holders grew from 118,000 in 1973 to 274,200 in 2006 (appendix table 5-17), during this period, full-time faculty positions increased more slowly than postdoc and other full- and part-time positions.

Table 5-12 shows the resulting distribution of academic employment of S&E doctorate holders. The full-time faculty share was 72% of all academic employment in 2006, down from 88% in the early 1970s. These employment trends, particularly during the 1993–2006 period, occurred as real spending for academic R&D rose by 73%, retirement of faculty who were hired during the 1960s increased, and academic hiring of young doctorate holders showed a modest rebound.[24]

Nonfaculty ranks (i.e., full- and part-time adjunct faculty, lecturers, research associates, administrators, and postdocs) increased from 41,400 in 1993 to 76,600 in 2006. This 85% increase stood in sharp contrast to the 15% rise in the number of full-time faculty. Both the full-time nonfaculty and part-time components grew between 1993 and 2006. The number of postdocs rose more slowly during most of this period, remaining at 16,000–19,000 from 1995 to 2003 before increasing to about 23,000 in 2006.[25] 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 almost 6% in 2006 (appendix table 5-17).

Figure 5-16
Average annual growth rate for employment of S&E doctorate holders: 1973–2006



SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations (preliminary data for 2006).

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Table 5-10
Average annual growth rate for employment of S&E doctorate holders in U.S. economy: 1973–2006
(Percent)

Sector	1973–2006	1973–83	1983–93	1993–2006
All sectors	3.3	5.4	2.5	2.2
Academia	2.7	4.1	2.0	2.2
Industry	4.7	7.9	4.1	2.8
Government	3.4	5.5	2.5	2.4
Other	1.9	5.3	0.5	0.4

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations (preliminary data for 2006).

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Table 5-11
S&E doctorate holders employed in academia, by years since doctorate: Selected years, 1973–2006
(Percent)

Years since doctorate	1973	1983	1993	2006
All employed doctorate holders	54.8	48.4	45.9	45.4
≤3	55.2	48.0	50.5	57.3
4–7	55.8	44.9	47.0	51.1
>7	54.2	49.4	45.0	42.9

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations (preliminary data for 2006).

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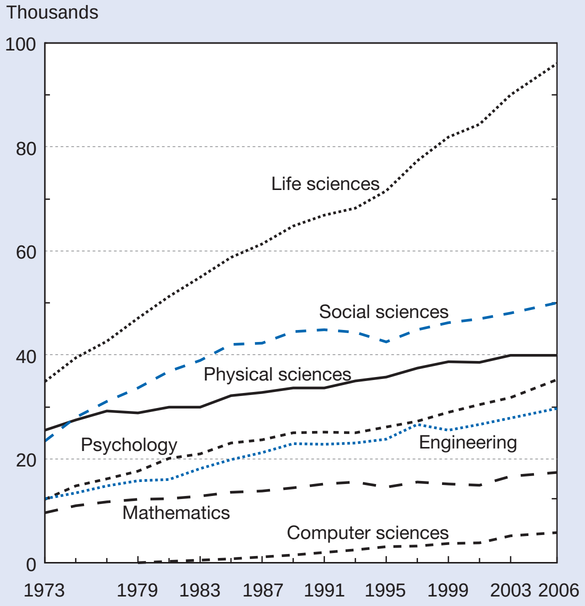
Figure 5-17
S&E doctorate holders employed in academia, by degree field: 1973–2006



NOTES: Physical sciences include earth, atmospheric, and ocean sciences.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations (preliminary data for 2006). See appendix table 5-17.

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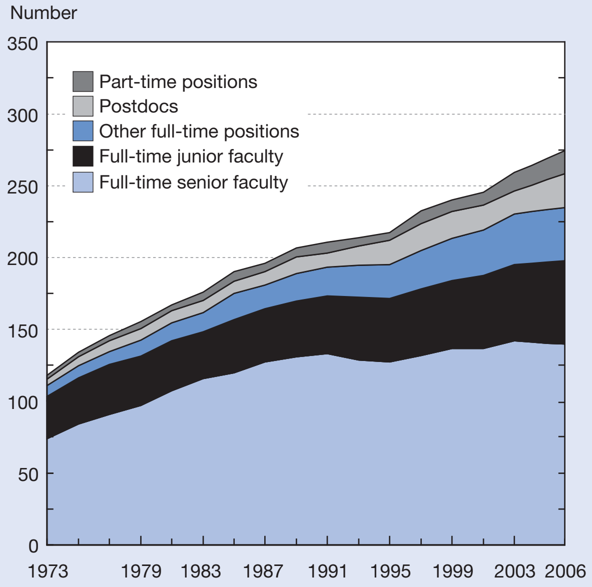
Figure 5-18
S&E doctorate holders, by type of academic appointment: 1973–2006



NOTES: Senior faculty includes full and associate professors; junior faculty includes assistant professors and instructors. Other full-time positions include nonfaculty positions such as research associates, adjunct appointments, lecturers, and administrative positions. Part-time employment excludes those employed part time because they are students or retired.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations (preliminary data for 2006). See appendix table 5-17.

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Public universities account for almost two-thirds of S&E doctorate holders employed in academic institutions and an even higher fraction of full-time S&E faculty. Within private research universities, postdocs make up a larger fraction of S&E doctorate holders (22%) than they do within public research universities (12%) (appendix table 5-18).

Women in the Academic Doctoral S&E Workforce

The academic employment of women with S&E doctorates rose sharply between 1973 and 2006, 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 eightfold during this period, from 10,700 in 1973 to an estimated 90,700 in 2006 (appendix table 5-19), as compared with about a 71% increase for men.

This increase is reflected in the rising share of women among S&E doctorate holders in academic positions. In 2006, women constituted 33% of all academic S&E doctoral employment and 30% of full-time faculty, up from 9% and 7%, respectively, in 1973. Roughly similar percentages of male and female doctoral S&E faculty are employed in re-

Table 5-12

S&E doctorate holders employed in academia, by involvement in research and position: Selected years, 1973–2006

Position/involvement in research	1973	1983	1993	2006
	Thousands			
All academic employment	118.0	176.1	213.8	274.2
Research primary/secondary activity	82.3	104.7	150.1	184.4
	Percent distribution			
All academic employment	100.0	100.0	100.0	100.0
Full-time faculty	87.6	84.3	80.6	72.1
Postdocs	3.5	4.7	6.2	8.5
Other positions	8.9	11.0	13.1	19.4
Research primary/secondary activity	100.0	100.0	100.0	100.0
Full-time faculty	87.5	83.0	81.1	73.4
Postdocs	4.9	7.1	8.9	11.9
Other positions	7.6	9.9	10.0	14.8

NOTES: Research includes basic or applied research, development, and design. Full-time faculty includes full, associate, and assistant professors plus instructors. Other positions include full-time nonfaculty, such as research associates, adjunct positions, lecturers, administrative positions, and part-time positions. Part-time employment excludes those employed part time because they are students or retired. Detail may not add to total because of rounding.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations (preliminary data for 2006). See appendix tables 5-17 and 5-26.

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search institutions (table 5-13). 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, mathematics, and computer sciences.

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 2006. In 2006, women constituted 19% of full professors, 34% of associate professors, and 42% of junior faculty, the latter slightly higher than their share of recently earned S&E doctorates (figure 5-19; appendix table 5-19; see also “Doctoral Degrees by Sex” in chapter 2). These trends reflect the recent arrival of significant numbers of women doctorate holders in full-time academic faculty positions. (For a more complete discussion of the role of women, see NSF/SRS 2007c.)

Table 5-13

S&E doctorate holders employed in academia, by sex, race/ethnicity, and Carnegie institution type: 2006

(Percent distribution)

Institution type	All S&E doctorate holders	Female	Male	Asian, non-Hispanic	White, non-Hispanic	Under-represented minority
All institutions	100.0	100.0	100.0	100.0	100.0	100.0
Doctorate-granting universities—very high research activity	42.6	41.9	42.9	51.3	41.8	34.7
Other doctorate-granting institutions	17.6	15.6	18.6	15.9	17.6	20.3
Master’s colleges and universities	17.6	18.0	17.4	12.4	18.2	20.9
Medical schools/medical centers	5.3	6.7	4.7	7.3	5.1	4.6
Baccalaureate colleges	7.7	8.0	7.6	3.2	8.5	8.2
Two-year institutions	3.6	3.8	3.5	1.8	3.8	4.2
Other	5.5	6.0	5.3	8.0	4.9	7.1

NOTES: Institutions designated by 2005 Carnegie classification code. For more information on these institutional categories, see chapter 2 sidebar, “Carnegie Classification of Academic Institutions” and The Carnegie Classification of Institutions of Higher Education, http://www.carnegiefoundation.org/classifications/index.asp, accessed 25 May 2007. Underrepresented minority includes blacks, Hispanics, and American Indians/Alaska Natives.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients 2006, special tabulations (preliminary data).

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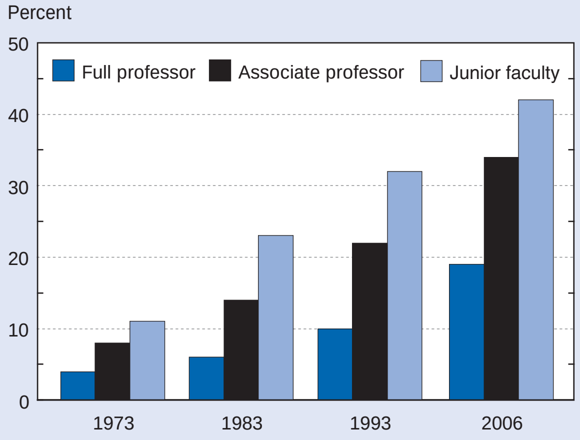
Figure 5-19
Share of doctoral S&E faculty positions held by women, by rank: Selected years, 1973–2006



NOTE: Junior faculty includes assistant professors and instructors.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations (preliminary data for 2006).

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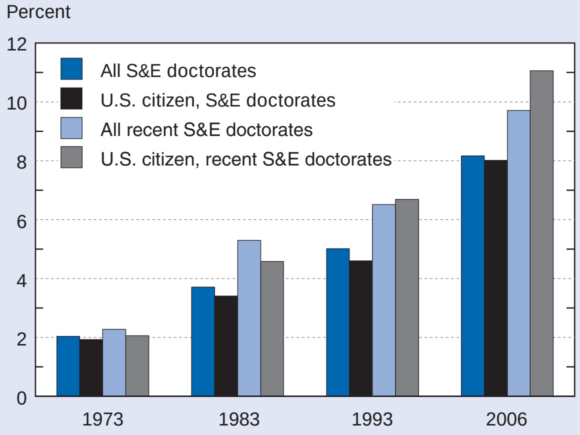
Underrepresented Minorities in Academic Doctoral Workforce

The Census Bureau's demographic projections have long indicated an increasing prominence of minority groups, especially Hispanics, 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. 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 5-20).[26] 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 2006, up from about 2% in 1973. However, among recent doctorate holders, they represented 10% of total academic employment (figure 5-20).

Underrepresented minorities constituted a smaller share of total employment at research universities than at other academic institutions throughout this period (table 5-13). Notably, a lower percentage of black S&E faculty than of other S&E faculty are employed at research universities and a higher percentage are employed at comprehensive universities, especially historically black colleges and universities (NSF/SRS 2006). Underrepresented minorities are concentrated in different fields than whites or Asians. Compared with whites, blacks tended to be relatively concentrated in the social sciences and were relatively less represented in the physical sciences, the life sciences, and engineering. The field distribution of Hispanic degree holders is similar to that of white degree holders. (For a more complete discussion of the role of underrepresented minorities, see NSF/SRS 2007c.)

Figure 5-20
Share of underrepresented minorities among S&E doctorate holders employed in academia, by citizenship status and years since degree: Selected years, 1973–2006



NOTES: Underrepresented minorities include blacks, Hispanics, and American Indians/Alaska Natives. Recent doctorate holders earned degrees within 3 years of survey. Denominator always refers to set of individuals defined in legend.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations (preliminary data for 2006).

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Asians/Pacific Islanders in Academic Doctoral S&E Workforce

Asians/Pacific Islanders more than tripled their employment share in the S&E academic doctoral workforce between 1973 and 2006, increasing from 4% to 14% (appendix table 5-20). However, a distinction needs to be made between those who are U.S. citizens and those who are not because the latter group constituted 45% of this group's doctorate holders in the academic S&E workforce in 2006.[27] 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 9% in 2006, a magnitude of growth similar to that of underrepresented minorities. 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. Although the Asian/Pacific Islander share of all recent S&E doctorate holders employed in academia rose from 5% in 1973 to 28% in 2006, the share of those who are U.S. citizens increased from 1% to 7% (figure 5-21).

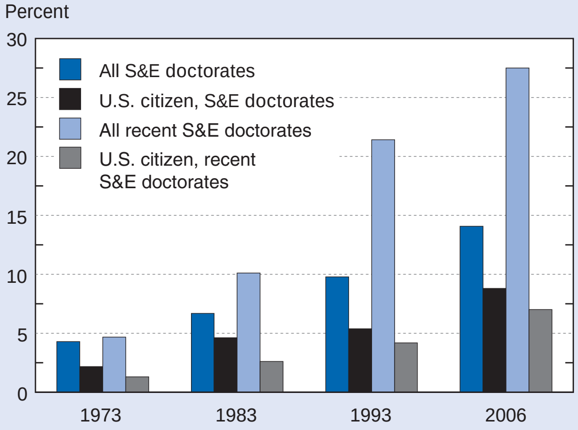
Compared with whites, Asians/Pacific Islanders are more heavily represented in engineering and computer sciences and represented at very low levels in psychology and social sciences. This finding holds both for U.S. citizens and for all Asians/Pacific Islanders. In 2006, Asians/Pacific Islanders constituted 29% of academic doctoral computer scientists and 27% of engineers (appendix table 5-20). Whether or not they are U.S. citizens, Asians/Pacific Islanders represent a larger percentage of total employment at research universities than at other academic institutions (table 5-13).

Whites in Academic Doctoral S&E Workforce

The relative prominence of whites, particularly white males, in the academic S&E doctoral workforce diminished between 1973 and 2006 (figure 5-22). In 2006, whites constituted 78% of the academic doctoral S&E workforce, compared with 91% in 1973 (table 5-14; appendix table 5-20); the share of white males also declined during this period, from about 83% to 52%. The decline in the shares of whites and white males who recently received their doctorates was even greater, from 91% to 63% and from 80% to 35%, respectively. Part of the decline is due to the increasing numbers of women, underrepresented minorities, and Asians/Pacific Islanders. However, the decline in share is not the whole story. During the 1990s and through 2006, the absolute number of white males in the academic doctoral S&E workforce who recently received their doctorates remained virtually unchanged.

Figure 5-21

Share of Asians/Pacific Islanders among S&E doctorate holders employed in academia, by citizenship status and years since degree: Selected years, 1973–2006



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 (preliminary data for 2006).

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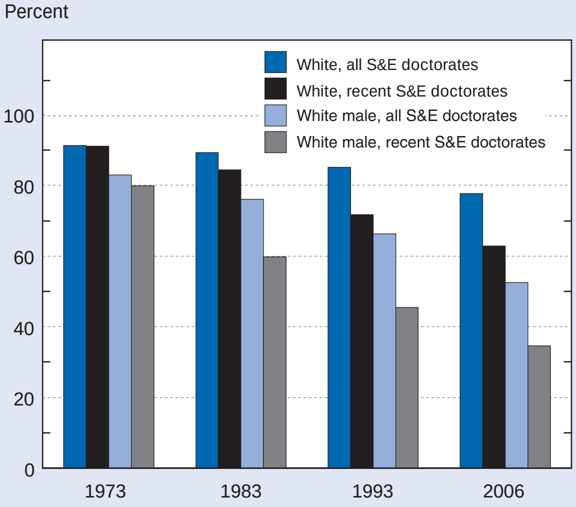
Figure 5-22

Share of all whites and white males among S&E doctorate holders employed in academia, by years since degree: Selected years, 1973–2006



NOTES: 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 (preliminary data for 2006).

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Foreign-Born S&E Doctorate Holders

Much of the discussion in this chapter is of academic employment of S&E doctorate holders with U.S. doctorates. Because many foreign-born S&E doctorate holders in U.S. academic institutions did not earn their doctorate in the United States, the data in this section are taken from the Department of Education's National Survey of Postsecondary Faculty, which, although it has a smaller sample size and thus less detail by field and other employment characteristics, has information on faculty with non-U.S. doctorates.

Full-time doctoral S&E faculty are increasingly foreign born. In 2003, 28% of all full-time doctoral S&E faculty and 33% of full-time doctoral faculty in research institutions in the United States were foreign born, up from 21% and 25%, respectively, in 1992 (appendix table 5-21). In the physical sciences, mathematics, computer sciences, and engineering, 47% of full-time doctoral S&E faculty in research institutions were foreign born, up from 38% in 1992.

The Aging Professoriate and Trends in Retirement

From 1993 to 2003, retirement rates among doctoral scientists and engineers employed in academic institutions remained relatively stable, despite the application of the Age Discrimination in Employment Act of 1967 to colleges and universities in 1994.[28] The act, which prohibits mandatory retirement on the basis of age, raised questions about the

Table 5-14
White and white male S&E doctorate holders employed in academia, by years since degree: Selected years, 1973–2006

	1973		1983		1993		2006	
Group	Thousands	Percent	Thousands	Percent	Thousands	Percent	Thousands	Percent
All S&E doctorate holders	118.0	100	176.3	100	213.8	100	274.2	100
White	107.7	91	157.4	89	181.8	85	213.0	78
Male	97.8	83	134.1	76	141.8	66	143.9	52
Recent S&E doctorate holders	25.0	100	20.5	100	25.1	100	33.9	100
White	22.8	91	17.3	84	18.0	72	21.3	63
Male	20.0	80	12.3	60	11.4	45	11.7	35

NOTES: 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 (preliminary data for 2006).

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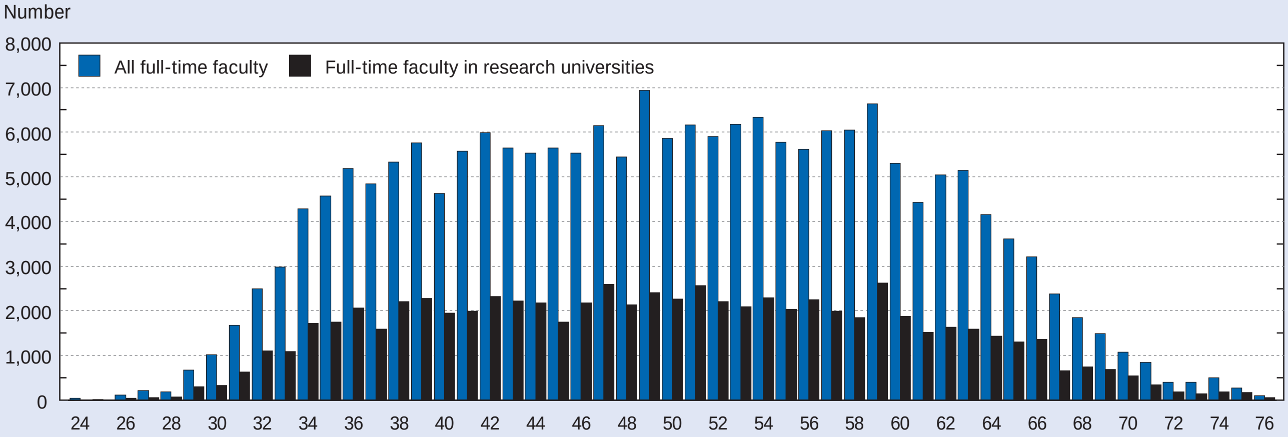
consequences for higher education of an aging professoriate, including fewer academic employment opportunities for new doctorate holders (NRC 1991). Among S&E doctorate holders ages 56–75 whose most recent employment was in the education sector, the percentage who were retired changed little between 1993 and 2003 (NSF/SRS 2008), despite the elimination of mandatory retirement.

Although retirement rates changed little, the age distribution of academic S&E doctorate holders has changed over the past several decades (appendix table 5-22), the percentage of those who are age 65 or older having increased. Full-time S&E faculty employed in research universities account for about 40% of full-time S&E faculty ages 65 and older (figure 5-23). They also have a slightly greater propensity to work longer than faculty in other institutions: 8% of full-time S&E faculty in research universities are ages 65 and older, compared with 6% of those in master's colleges and universities (appendix table 5-23).

Recent S&E Doctorate Holders

Trends in academic employment patterns of those with recently awarded S&E doctorates show a decrease in the share of recent doctorate holders in full-time faculty positions and an increase in postdocs (figure 5-24; appendix table 5-24). Between 1973 and 2006, the share of recent doctorate holders hired into full-time faculty positions fell from 74% to 38%. Conversely, the overall share of recent S&E doctorate holders who reported being in postdoc positions rose from 13% to 46%. After increasing throughout the 1990s, the share of recent S&E doctorate holders in postdoc positions declined from 1999 to 2003 before rising to a new peak in

Figure 5-23
Age distribution of S&E doctorate holders employed in U.S. academic institutions: 2006



NOTES: Research universities are doctorate-granting universities with very high research activity. Institutions designated by 2005 Carnegie classification code. See chapter 2 sidebar, Carnegie Classification of Academic Institutions, and The Carnegie Classification of Institutions of Higher Education, http://www.carnegiefoundation.org/classifications/index.asp, accessed 25 May 2007.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, 2006, special tabulations (preliminary data).

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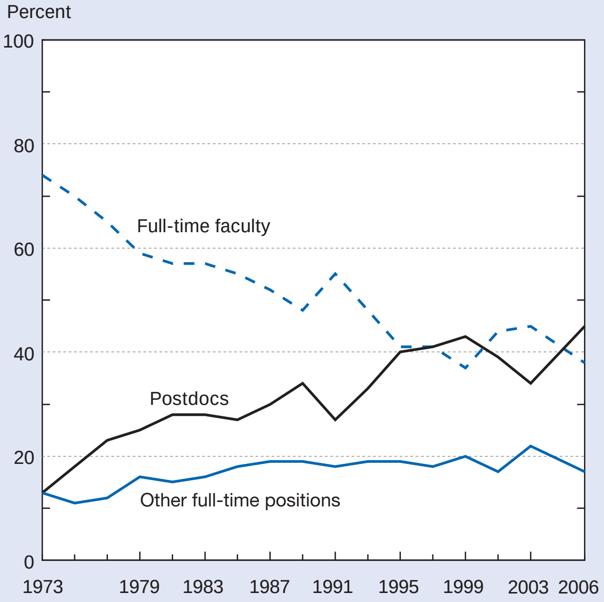
Figure 5-24
S&E doctorate holders with recent degrees employed at academic institutions, by type of position: 1973–2006



NOTES: Recent doctorate holders earned degrees within 3 years of survey. Full-time faculty includes full, associate, and assistant professors plus instructors. Other full-time positions include nonfaculty appointments such as research associates, adjunct appointments, lecturers, and administrative positions. All positions not shown.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations (preliminary data for 2006). See appendix table 5-24.

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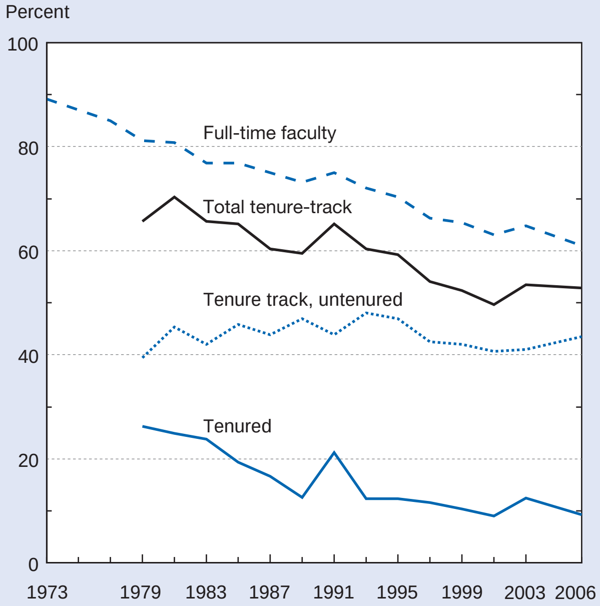
2006. Recent S&E doctorate holders who entered academic employment at research universities were more likely to be in postdoc than in faculty positions (appendix table 5-25). (See the discussion of postdocs in chapter 3, “Science and Engineering Labor Force,” for more information, including reasons for accepting a postdoc position and short-term career trajectory.)

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 61% had faculty rank in 2006, compared with 89% in 1973 (appendix table 5-24). A little more than half of these doctorate holders were in tenure-track positions in 2006, with about 9% already tenured (figure 5-25).

Figure 5-25
Faculty and tenure-track status of S&E doctorate holders employed in academia 4–7 years after receiving degree: 1973–2006



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 (preliminary data for 2006). See appendix table 5-24.

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Academic Researchers

This section examines the number and characteristics of academic S&E doctorate holders for whom research is either a primary or secondary work activity. Note that estimates of the *total* number of academic researchers would include S&E faculty and postdocs as well as research assistants (see chapter 2, appendix tables 2-8 and 2-35) and nondoctoral, nonfaculty research staff. In addition, many other students, both graduate and undergraduate, are also likely to be involved in research activities during the course of their graduate education.

Research as Either Primary or Secondary Work Activity

From 1973 to 2006, the number of academic S&E doctorate holders reporting research as their primary or secondary work activity showed greater growth than the number reporting teaching as their primary or secondary activity. The former group increased from 82,300 in 1973 to 184,400 in 2006, and the latter group increased from 94,900 to 164,000 (appendix table 5-26).[29]

The life sciences accounted for much of this trend, with researchers growing from 26,000 to 67,100 and teachers from about the same base (25,300) to 45,800 (figure 5-26). 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 and engineering.

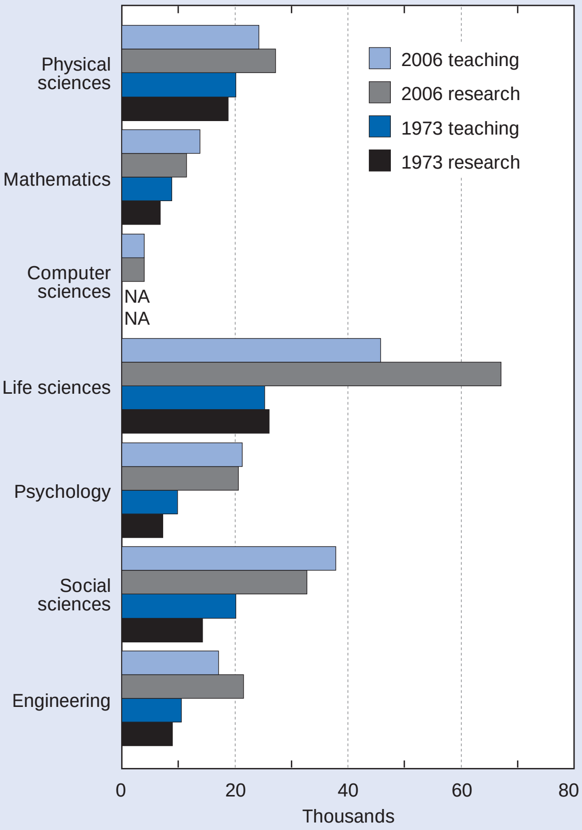
Relative to all S&E doctoral employment, the number of academic S&E doctorate holders reporting research as either their primary or secondary activity declined between 1973 and 1977; was relatively constant at about 60% from

1977 to 1985, when R&D funds grew relatively slowly; then rose again in 1987 to about 74%, dropped to about 70% in 1993, remained relatively constant at that level until 2003, and dropped slightly in 2006 (appendix tables 5-17 and 5-26). Table 5-15 shows the trends in research involvement by field, and table 5-16 indicates that the distribution across fields of S&E doctorate holders who report research as their primary or secondary work activity is quite similar to that of all S&E doctorate holders.

Research universities employ about 43% of all S&E doctorate holders employed in academic institutions and more than half of those whose primary or secondary work activity is research. They also employ about 76% of S&E postdocs, almost all of whom have research as a primary or secondary work activity (appendix table 5-27).

Figure 5-26

S&E doctorate holders employed in academia with research or teaching as primary or secondary work activity, by degree field: 1973 and 2006



NA = not available

NOTE: Research includes basic or applied research, development, or design. Physical sciences include earth, atmospheric, and ocean sciences.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, 1973 and 2006, special tabulations (preliminary data for 2006). See appendix table 5-26.

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Time Spent in Research

In 2003, full-time doctoral S&E instructional faculty spent about 27% of their time in research, 52% of their time teaching, and 20% of their time engaged in other activities. The average percentage of time spent in research did not change between 1992 and 2003, but the average percentage of time spent in teaching increased (appendix table 5-28). In 2003, faculty who taught only graduate students spent a higher percentage of their time in research than faculty who taught only undergraduates, and faculty in research institutions spent a higher percentage of their time in research than faculty in nonresearch institutions.

The fraction of full-time doctoral S&E instructional faculty engaged primarily in research increased during the past decade (appendix table 5-29). In 2003, 26% of full-time doctoral S&E instructional faculty were so engaged, compared with 20% in 1992. The fraction engaged primarily in teaching dropped during the past decade, from 61% in 1992 to 53% in 2003. This drop occurred in S&E and non-S&E fields and among doctoral and nondoctoral faculty. Relatively few nondoctoral faculty are engaged in research.

Table 5-15

S&E doctorate holders employed in academia reporting research as primary or secondary activity, by degree field: Selected years, 1973–2006

(Percent)

Degree field	1973	1983	1993	2006
All fields	69.7	59.5	70.2	67.3
Physical sciences	73.7	64.9	71.4	68.1
Mathematics	70.1	55.8	61.3	65.9
Computer sciences	NA	80.0	80.0	69.9
Life sciences	74.5	69.8	76.0	69.8
Psychology	59.8	50.0	59.6	58.3
Social sciences	61.1	45.8	66.0	65.4
Engineering	72.6	61.9	75.8	72.3

NA = not available

NOTES: Research includes basic or applied research, development, and design. Physical sciences include earth, atmospheric, and ocean sciences.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations (preliminary data for 2006). See appendix tables 5-17 and 5-26.

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Table 5-16

S&E doctorate holders employed in academia reporting research as primary or secondary work activity, by degree field: 2006

(Percent distribution)

Degree field	All academic employment	Research primary/ secondary activity
All fields	100.0	100.0
Physical sciences	14.6	14.7
Mathematics	6.3	6.2
Computer sciences	2.1	2.2
Life sciences	35.1	36.4
Psychology	12.9	11.2
Social sciences	18.2	17.7
Engineering	10.8	20.5

NOTES: Research includes basic or applied research, development, and design. Physical sciences include earth, atmospheric, and ocean sciences. Detail may not add to total because of rounding.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients 2006, special tabulations (preliminary data). See appendix tables 5-17 and 5-26.

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Government Support of Academic Doctoral Researchers

Academic researchers rely on the federal government for a substantial share (more than 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 5-30 shows the percentage of academic S&E doctorate holders who received federal support for their work during the period 1973–2006, 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 2006, 47% of all S&E doctorate holders in academia and 58% of those for whom research was a primary or secondary activity reported federal government support (appendix table 5-30). As table 5-17 shows, for S&E as a whole and for many broad fields, the likelihood of receiving federal support in 2006 was either the same as it was 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 2006, this percentage ranged from about 58% in the life sciences and 56% in the physical sciences to 23% in the social sciences (table 5-17; appendix table 5-30).

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, and in 1985, it was to 1 month. However, 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 2006 surveys, which again used an entire reference year.

The discussion in this edition of *Indicators* generally compares data for 2006 with data for 1991. 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.

Table 5-17

S&E doctorate holders employed in academia reporting receipt of federal support in previous year, by degree field: Selected years, 1973–2006

(Percent)

Degree field	1973	1983	1991	2006
All fields	44.5	39.8	48.5	46.9
Physical sciences	47.3	46.5	57.0	56.3
Mathematics	26.9	30.1	34.5	34.8
Computer sciences	NA	44.6	49.4	43.9
Life sciences	59.3	60.0	65.5	57.9
Psychology	37.5	30.1	34.7	36.3
Social sciences	25.5	23.7	28.4	23.1
Engineering	53.5	54.7	63.2	58.7

NA = not available

NOTES: 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 supported by government. In other years, question pertains to work conducted over course of year. Physical sciences include earth, atmospheric, and ocean sciences.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations (preliminary data for 2006). See appendix table 5-30.

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Full-time faculty and other full-time doctoral employees received federal support less frequently than postdocs. In 2006, about 46% of full-time faculty, 47% of other full-time employees, and 71% 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 5-30).

NSF and NIH Support for Young Investigators

The share of all NSF grants awarded to new principal investigators (PIs) remained relatively constant from 2002 to 2006, at roughly 27%–28%, while the number of proposal submissions from both new and prior investigators increased and the funding rate both per PI and per proposal decreased. Although the number of new PIs awarded NSF grants remained relatively stable (about 5,300) for the past 5 years, the PI funding rate (based on any award to a PI in a 3-year period) declined, from 30% in 2000–02 to 24% in 2004–06. The number of prior PIs receiving NSF funding also remained relatively stable (about 11,300) for the past 5 years, and the PI funding rate declined, from 54% in 2000–02 to 47% in 2004–06. These success rates based on PIs are somewhat higher than success rates based on proposals, as many investigators submit multiple proposals. When funding rates are calculated based on the number of proposals submitted, the proposal success rate between 2002 and 2006 declines from 19% to 15% for new PIs and from 32% to 26% for prior PIs.

The trend at NIH was similar: the number of new investigators remained stable over time and the funding rate for both new and prior PIs declined in recent years. However, the percentage of all competing Research Project (R01) equivalent awardees who were new awardees declined from 12% in 1980 to 7% in 2005. The average age of new doctoral investigators receiving their first NIH research grant rose from 37 in 1979 to 42 in 2002 (NRC 2005). The proportion of NIH research grant recipients under age 40 dropped from 50% in 1980 to 17% in 2003. Responding to this trend, NIH created the Pathway to Independence award in 2006, which combines funding for up to 2 years of training in a postdoc position and up to 3 years for independent research as a faculty member. The hope is that these awards will be an incentive for universities and colleges to create new positions for these investigators and that the awards will help new investigators win R01 research grants (Kaiser 2006).

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. In 2006, S&E doctorate holders with recently earned doctorates (i.e., doctorates earned within 3 years of the survey) who were in full-time faculty positions were less likely to receive federal support than those in postdoc or other full-time positions (appendix table 5-31). For full-time faculty, the percentage reporting federal support in 2006 was lower for those with recently earned doctorates than for the academic S&E doctoral workforce as a whole (appendix tables 5-30 and 5-31). (See sidebar, "NSF and NIH Support for Young Investigators.") It should be pointed out that these 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.

In 2006, about half of those with recently earned doctorates received federal support, with 30% of those in full-time faculty positions, 51% of those in other full-time positions, and 69% of those in postdoc positions (appendix table 5-31). As with all academic doctorate holders, younger researchers were less likely to report federal support in 2006 than in 1991. The share of postdocs with federal support was relatively low (less than 60%) in some fields (e.g., the social sciences and mathematics) and higher in others (e.g., computer sciences, physical sciences, and engineering).

Table 5-18

S&E doctorate holders employed in academia 4–7 years after receiving degree reporting receipt of federal support in previous year, by degree field: Selected years, 1973–2006

(Percent)

Degree field	1973	1983	1991	2006
All fields	47.1	50.1	57.4	47.2
Physical sciences	44.8	66.2	67.2	57.6
Mathematics	29.0	39.8	28.3	32.0
Computer sciences	NA	43.5	66.2	44.8
Life sciences	59.7	67.1	70.6	57.5
Psychology	37.8	32.3	38.8	35.9
Social sciences	29.0	28.1	36.6	21.5
Engineering	50.7	64.3	73.2	63.7

NA = not available

NOTES: 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 supported by government. In other years, question pertains to work conducted over course of year. Physical sciences include earth, atmospheric, and ocean sciences.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations (preliminary data for 2006). See appendix table 5-31.

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Among full-time faculty and postdocs in 2006, 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, those who had received their doctorate 4-7 years earlier were also less likely to receive support in 2006 than in 1991 (table 5-18; appendix table 5-31).

Outputs of S&E Research: Articles and Patents

Chapter 2 of this volume and the previous section of this chapter discuss the outputs of S&E research and education in terms of human capital. This section examines additional indicators of the output of academic S&E research: articles published in the world's S&E literature and patents received by U.S. academic institutions. In addition, licensing activities, royalties, and startups associated with university research are also discussed.

Published, peer-reviewed articles have traditionally been the means by which scientists and engineers report the results of their research and gain status in their fields. According to sociologist Robert K. Merton,

> The institutional conception of science as part of the public domain is linked with the imperative for communication of findings. Secrecy is the antithesis of this norm; full and open communication its enactment. The pressure for diffusion of results is reinforced by the institutional goal of advancing the boundaries of knowledge and by the incentive of recognition which is, of course, contingent upon publication. (Merton, 1973, p. 274; see also de Solla Price 1978)

This section uses data on S&E articles to indicate world S&E knowledge production by country and by selected regions and/or groupings of countries related by geography, cultural ties, language, or political factors. Coauthorship of articles by researchers in different departments, different institutions, and different countries and regions illustrates the increasing trend of collaboration in research, both within and across countries and regions.

Citation of research articles indicates, albeit imperfectly, the relative importance of previously published research findings to future research; consequently, patterns in citation are also discussed in this section. Citation patterns, including trends in highly cited research articles, are contrasted with trends in total publication of articles.

The discussion of research outputs concludes with indicators of the flow of knowledge from academically based research to intellectual capital embodied in patents awarded to academic institutions, along with related other indicators.

S&E Article Output

The number of S&E articles in the dataset analyzed in this chapter totaled 10.6 million for the period 1988–2005.[30] In the past 10 years, the total world S&E article output as contained in the Science Citation Index (SCI) and Social Sciences Citation Index (SSCI) (see sidebar, "Bibliometric Data and Terminology") grew at an average annual rate of 2.3% (table 5-19). This reflects increases in both the number of articles per journal (from 117 in 1988 to 139 in 2005) and the total number of journals (from 4,093 in 1988 to 4,906 in 2005). Scientists and engineers in institutions in the member states of the European Union authored or coauthored one-third of the world total in 2005,[31] followed by the United States with 29% and by 10 Asian countries (hereafter "Asia-10") with 20% (figure 5-27; table 5-19).[32]

Trends in Country and Regional Authorship

Although S&E authors from some 200 countries are represented among the articles discussed in this section, these authors are concentrated in a relatively small number of countries (see sidebar, "Distribution of Publication Data"). Authors from one country, the United States, dominated global article output in 2005 with 29% of the total, followed by Japan with 8% and the United Kingdom, Germany, and China with 6% each.

Previous editions of *Indicators* and other studies (e.g. NSF/SRS 2007a) reported steadily increasing investments in S&E education and research infrastructure, especially in Asia. As these investments matured and led to increased R&D in those countries, authorship by scientists and engineers in those countries also increased, as did their success in getting articles published in international peer-reviewed journals. Differences in recent rates of growth in article production are striking. Among Asian countries/economies that produce a major number of articles (defined here as more than 10,000 articles in 2005), average annual growth rates between 1995 and 2005 were highest in China, at 17%, and South Korea, at 16% (table 5-19). Taiwan's article output grew rapidly as well, at 9% per year. These high rates of growth in S&E article authorship contrast with much slower rates for the world as a whole (2.3%) and for countries with mature S&E infrastructures such as the United States (0.6%) and the countries of the European Union (1.8%). Russia's change in article output was negative over the 10-year period.

The 10-year change rate shown in table 5-19 obscures changes in S&E article output trends that occurred within the period. The growth rate of world output increased from 2.2% on average annually between 1995 and 2000 to 2.4% between 2000 and 2005 (appendix table 5-34). Between 1995 and 2000, U.S. article output was flat at best. This flattening of U.S. article output was the focus of a special NSF study that explored the dimensions of this trend (Bell 2007; Hill et al. 2007; Javitz et al. 2007). Between 2000 and 2005, the U.S. output again turned positive, increasing to an average annual growth rate of 1.3%, more than the 1.1% annual rate of the European Union and less than the 6.3% of the Asia-10 for the same period.

Even among nations with moderate S&E article production (defined as between 1,000 and 10,000 articles in 2005), a few stand out for increasing their publication over the past decade.

Bibliometric Data and Terminology

The article counts, coauthorship data, and citations discussed in this section are derived from S&E articles, notes, and reviews published in a set of the world's most influential scientific and technical journals tracked by Thomson Scientific in the Science Citation Index and Social Sciences Citation Index (http://scientific.thomson.com/products/categories/citation/). The data presented here derive from a database prepared for NSF by ipIQ, Inc., formerly CHI Research, Inc., under a license agreement. The data exclude letters to the editor, news stories, editorials, and other content whose central purpose is not the presentation or discussion of scientific data, theory, methods, apparatus, or experiments.

These data are not strictly comparable with those presented in editions prior to *Science and Engineering Indicators 2004,* 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 journals and articles in the world.

For each new year of data, ipIQ reviews the list of journals and updates the master journal file as necessary as new journals appear and old journals no longer appear or are incorporated into new ones. In other words, the S&E journal literature analyzed for these indicators is always evolving as research and publication evolve. The number of journals analyzed by NSF from SCI/SSCI was 4,093 in 1988 and 4,906 in 2005; over the entire period, some 6,760 journals were reflected in the data. 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.

Except where noted, *author,* as used here, means *departmental or institutional author.* Articles are attributed to countries or sectors by the country or sector of the institutional address(es) given in the article bylines at the time of publication. If the institutional affiliation 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. An article is considered coauthored only if it shows different institutional affiliations or different departments of the same institution. Multiple listings of the same department of an institution are considered as one institutional author. The same logic applies to cross-sector and international collaboration.

Two methods of counting articles based on attribution are used: fractional and whole counts (Gauffriau and Larsen 2005). 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.

Several changes introduced in this edition of *Indicators* improve the usefulness of the data discussed here but also inhibit comparison with data from the same source used in previous editions.

- Previous editions reported data based on the year an article entered the database ("tape year"), not on the year it was published ("publication year"). In this edition, data in section one *only* ("S&E Article Output") are reported by publication year through 2005 as contained in the 2006 database or tape year. Publication data in the remaining sections ("Coauthorship and Collaboration," "Trends in Output and Collaboration Among U.S. Sectors," and "Trends in Citation of S&E Articles") are reported by tape year as contained in the 2005 database or tape year. Tables and figures refer the reader to which data are reported.
- Breakouts of broad fields of science were adjusted to more closely align with field taxonomies used in other chapters and more commonly recognizable in other NSF/SRS databases and publications. As in previous editions, journals were assigned to 1 of 134 subfields, but these subfields were regrouped into 13 new broad fields (appendix table 5-32). Furthermore, a group of journals in "professional fields" reported on in previous editions has been deleted altogether, resulting in slightly reduced totals overall but a more appropriate concept of science, engineering, or technology journals and articles.
- Finally, the country/economy breakouts were updated to parallel more closely discussions elsewhere in this edition (appendix table 5-33).

Table 5-19
S&E article output, share of world total, and change rate, by major S&E article-producing region/country/economy: 1995–2005

	1995		2005		
Region/country/economy	Number	Share (%)	Number	Share (%)	Average annual change (%)
World	564,645	100	709,541	100	2.3
United States	193,337	34.2	205,320	28.9	0.6
European Union	195,897	34.7	234,868	33.1	1.8
France	28,847	5.1	30,309	4.3	0.5
Germany	37,645	6.7	44,145	6.2	1.6
Italy	17,880	3.2	24,645	3.5	3.3
Netherlands	12,089	2.1	13,885	2.0	1.4
Spain	11,316	2.0	18,336	2.6	4.9
Sweden	9,287	1.6	10,012	1.4	0.8
United Kingdom	45,498	8.1	45,572	6.4	0.0
Other Western Europe	13,199	2.3	22,333	3.1	5.4
Other former USSR	22,871	4.1	17,822	2.5	-2.5
Russia	18,603	3.3	14,412	2.0	-2.5
Asia-10	76,182	13.5	144,767	20.4	6.6
China	9,061	1.6	41,596	5.9	16.5
India	9,370	1.7	14,608	2.1	4.5
Japan	47,068	8.3	55,471	7.8	1.7
South Korea	3,803	0.7	16,396	2.3	15.7
Taiwan	4,759	0.8	10,841	1.5	8.6
Near East/North Africa	9,476	1.7	13,839	2.0	3.9
Central/South America	9,521	1.7	20,395	2.9	7.9
Other	39,371	7.0	44,826	6.3	1.3
Australia	13,125	2.3	15,957	2.2	2.0
Canada	23,740	4.2	25,836	3.6	0.8

USSR = Union of Soviet Socialist Republics

NOTES: Major S&E article producers = >10,000 articles in 2005. Article counts from set of journals covered by Science Citation Index (SCI) and Social Sciences Citation Index (SSCI). Articles classified by year of publication and assigned to region/country/economy on basis of institutional address(es) listed on article. 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. See appendix table 5-33 for all countries/economies included in each region. Detail does not add to total because countries omitted.

SOURCES: Thomson Scientific, SCI and SSCI, http://scientific.thomson.com/products/categories/citation/; ipIQ, Inc.; and National Science Foundation, Division of Science Resources Statistics. See appendix table 5-34.

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In the Middle East, Iran's article output grew at 25% a year, although its output was less than 3,000 in 2005 (table 5-20). In Europe, Turkey[33] and Portugal stand out for their rapid growth (16% and 11%, respectively), as do Thailand and Singapore in Asia (14% and 12%, respectively). Brazil stood out in South America with an 11% annual growth rate.

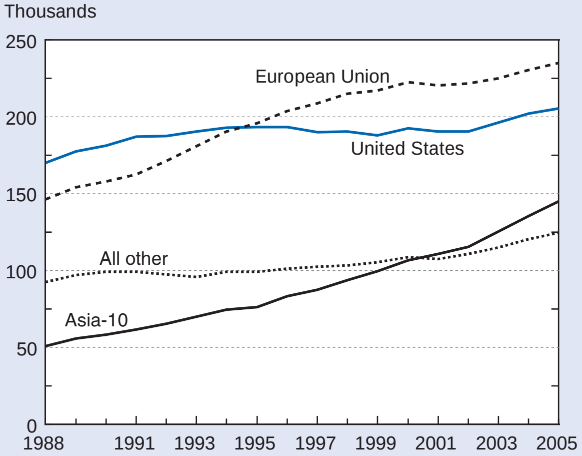
Trends in Country Rank by S&E Field

Figure 5-28 emphasizes that a few countries dominate the world's authorship of S&E articles, and, as noted in the previous discussion, growth rates vary widely across countries. So which countries dominate article authorship by field of S&E, and how are these rankings changing as a result of countries' different rates of growth in publishing?[34]

In a comparison of the top producers of S&E articles in 1995 and 2005, two patterns are evident: (1) U.S. scientists and engineers authored more S&E articles across all fields than authors in any other single country in both 1995 and 2005, and (2) overall, the top 20 article-producing countries were similar in both years (table 5-21). Four countries (the United States, Japan, the United Kingdom, and Germany) were the leading countries across all of S&E in both 1995 and 2005, and their ranks did not change over the period. Three countries among the top 20 producers of S&E articles in 2005 were not in that rank in 1995: South Korea, Brazil, and Turkey. Other notable changes in the ranks of top-producing countries were as follows:

- China's high rates of annual growth in S&E article production resulted in its movement from 14th to 5th place in overall S&E article authorship, to 2nd place in engineering and chemistry, and to 3rd place in physics and mathematics. China moved up in rank of authorships in other fields as well.

Figure 5-27
S&E article output, by major S&E publishing region/country: 1988–2005



NOTES: Article counts from set of journals covered by Science Citation Index (SCI) and Social Sciences Citation Index (SSCI). Articles classified by year of publication and assigned to region/country/economy on basis of institutional address(es) listed on article. 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. See appendix table 5-33 for countries/economies included in each region.

SOURCES: Thomson Scientific, SCI and SSCI, http://scientific.thomson.com/products/categories/citation/; ipI , Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

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- South Korea improved its overall rank from 22nd in 1995 to 10th in 2005, with its highest rank (4th) in engineering. It made gains in other fields as well.
- Taiwan moved up in rank overall and in all fields shown except mathematics.
- India failed to demonstrate the fast growth of other Asia-10 countries and lost rank in some fields.
- Brazil and Turkey gained rank across all fields shown.
- Russia, whose growth rate was negative over the period, lost rank across all fields.

Distribution of Publication Data

The publication data used in this section are characterized by many data points, of which only a small number have high value and therefore account for a significant proportion of all the data.* For example, of the 179 countries with a 2005 publication record in the database, 23 accounted for 90% of the 710,000 articles published that year (figure 5-28).

The United States produces 29% of the world total of the articles analyzed in this section, exerting a dominant influence throughout the broad indicators reported here. A middle tier of 12 countries, each of which produces between 2% and 8% of the world total, accounts for another 49% overall. Six countries, each with between 1% and 2% of the world total, account for 8% of the total. The remaining 158 countries together account for the remaining 14% of the world total. Among the lowest tier of countries in terms of total output are countries considered "mature" in S&E, such as Poland, Belgium, Israel, Singapore, and New Zealand.

In each of the sections based on publication records (outputs, international coauthorship, citation rates), an effort was made to limit the amount of data to avoid overwhelming the reader. Data cutoff points are defined where appropriate. The underlying assumption of these cutoffs is that some data may be of interest to a particular country or an academic researcher but not important to the overall world trends. Nevertheless occasional note is made to specific countries in the flat end of the distribution shown in figure 5-28 when needed.

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*Data with these properties belong to a related group of distributions collectively referred to as "power law distributions" (Adamic 2000). Such distributions have traditionally been studied in linguistics, economics, geosciences, and other fields and today commonly appear in studies of the Internet.

Coauthorship and Collaboration

In addition to the increasing volume of the world's S&E published literature discussed in the previous section, another trend was an increase in the number of S&E articles with authors from different institutions. A related and even stronger trend, increases in the number of internationally coauthored S&E articles, was widely noted in previous editions of *Indicators.*[35] The following discussion begins with consideration of broad trends for the world as a whole, moves to regional patterns, and ends with a discussion of country-level trends, including selected country-to-country coauthorship patterns and indexes of international collaboration. (Indicators of cross-sector coauthorship, available only for the United States, are examined below in the section "Trends in Output and Collaboration Among U.S. Sectors.")

Indicators of world S&E article output discussed in the previous section show a growing world article output, with just a few dozen countries producing the predominant proportion of all articles. Within that trend lie three additional patterns of interest: a growing tendency for articles to list multiple authors, authors from more than one institution, and authors from more than one country.

Previous editions of *Indicators* used coauthorship data as an indicator of collaboration among scientists and discussed possible underlying drivers for increased collaboration, including scientific advantages of knowledge and instrument sharing, decreasing costs of travel and communication, national policies, and so forth (NSB 2006). Katz and Martin

Table 5-20
S&E article output, share of world total, and change rate, by medium S&E article-producing country: 1995 and 2005

Country	1995		2005		Average annual change (%)
	Number	Share (%)	Number	Share (%)	
World	564,645	100	709,541	100	2.3
Iran	279	0.1	2,635	0.4	25.2
Turkey	1,715	0.3	7,815	1.1	16.4
Thailand	340	0.1	1,249	0.2	13.9
Singapore	1,141	0.2	3,609	0.5	12.2
Portugal	990	0.2	2,910	0.4	11.4
Brazil	3,436	0.6	9,889	1.4	11.2
Slovenia	434	0.1	1,035	0.1	9.1
Greece	2,058	0.4	4,291	0.6	7.6
Mexico	1,937	0.3	3,902	0.5	7.3
Chile	889	0.2	1,559	0.2	5.8
Ireland	1,218	0.2	2,120	0.3	5.7
Czech Republic	1,955	0.3	3,169	0.4	5.0
Argentina	1,967	0.3	3,058	0.4	4.5
Poland	4,549	0.8	6,844	1.0	4.2
Hungary	1,764	0.3	2,614	0.4	4.0
Austria	3,425	0.6	4,566	0.6	2.9
Belgium	5,172	0.9	6,841	1.0	2.8
Norway	2,920	0.5	3,644	0.5	2.2
New Zealand	2,442	0.4	2,983	0.4	2.0
Switzerland	7,220	1.3	8,749	1.2	1.9
Egypt	1,388	0.2	1,658	0.2	1.8
Finland	4,077	0.7	4,811	0.7	1.7
Denmark	4,330	0.8	5,040	0.7	1.5
Israel	5,741	1.0	6,309	0.9	0.9
South Africa	2,351	0.4	2,392	0.3	0.2
Ukraine	2,516	0.4	2,105	0.3	-1.8

NOTES: Medium S&E article producers = >1,000 and <10,000 articles in 2005. Article counts from set of journals covered by Science Citation Index (SCI) and Social Sciences Citation Index (SSCI). Articles classified by year of publication and assigned to region/country/economy on basis of institutional address(es) listed on article. 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. Detail does not add to total because countries omitted.

SOURCES: Thomson Scientific, SCI and SSCI, http://scientific.thomson.com/products/categories/citation/; ipIQ, Inc.; and National Science Foundation, Division of Science Resources Statistics. See appendix table 5-34.

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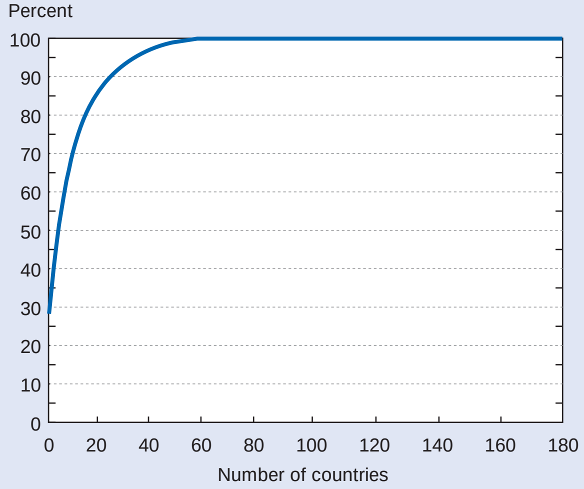
(1997) and Bordons and Gómez (2000) analyze limitations of coauthorship as an indicator of research collaboration, but other researchers have continued to conduct studies of S&E research collaboration using such data (Adams et al. 2005; Gómez, Fernández, and Sebastián 1999; Lundberg et al. 2006; Wuchty, Jones, and Uzzi 2007; Zitt, Bassecoulard, and Okubo 2000). The coauthorship data used in this section as indicators of collaboration in S&E research are presented with knowledge of neither the motive(s) underlying the collaboration nor the nature of the collaboration that actually occurred.[36] They should be seen as broad indicators of a secular trend in the S&E publishing record that reflects changes in the way S&E research is conducted and reported in today's world.

Article Author Names and Institutions

Indicators of the extent of these changes are shown in figure 5-29, which depicts the annual number of S&E articles published worldwide relative to the number of author names[37] and different institutions that appear in article bylines. Between 1988 and 2005, the number of S&E articles, notes, and reviews grew by 60% and both the number of institutions and the number of author names more than doubled. The number of author names per article for S&E overall increased from 3.1 in 1988 to 4.5 in 2005, and this growth occurred in all of the broad S&E fields (table 5-22). Growth on this indicator was slower in mathematics and the social sciences, and more rapid in physics and the medical sciences.

A slightly different indicator, coauthored articles, has also increased steadily. *Coauthored articles* are defined as S&E articles with more than one institutional address in the byline. ("Institution" here may refer to different departments or units within the same institution; multiple listings of the same department or unit are counted as one institutional author.) Adams and colleagues (2005) offer several hypotheses that might explain growing collaboration, including special-

Figure 5-28
Worldwide output of S&E articles, by number of article-producing countries: 2005



NOTES: Article counts from set of journals covered by Science Citation Index (SCI) and Social Sciences Citation Index (SSCI). Articles classified by year of publication.

SOURCES: Thomson Scientific, SCI and SSCI, http://scientific.thomson.com/products/categories/citation/; ipI , Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix table 5-34.

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ization by researchers and a consequent increase in division of labor; decreases over time in the cost of collaboration (and of international collaboration) due to the Internet; and increases in the sharing of large research resources like instruments and large datasets. They also argue that increases in the division of labor of scientists on a team lead to increases in scientific productivity. On the other hand, Cummings and Kiesler (2005, 2007) report high coordination costs in studies of two large U.S. government programs that sought to foster collaboration.

Coauthored articles grew from 40% of the world's S&E articles in 1988 to 61% in 2005 (figure 5-30). This growth has two parts: (1) coauthored articles that list only domestic institutions in the byline, and (2) articles that list institutions from more than one country, that is, internationally coauthored articles, which may also have multiple domestic institutional authors as well. The remainder of this section focuses on these internationally coauthored articles.

Coauthorship From a Regional Perspective

Use of the same region/country categories as in "S&E Article Output" above shows changes in the patterns of interregional coauthorship.[38] Over the period 1995–2005, interregional coauthorship increased as a percentage of total article output for the United States (from 17% to 27%), the European Union (from 18% to 26%), and the Asia-10 (from

Table 5-21
Rank in S&E article output, by country/economy and selected S&E broad field: 1995 and 2005

	All fields		Engineering		Chemistry		Physics		Geosciences		Mathematics		Biological sciences		Medical sciences	
Country/economy	1995	2005	1995	2005	1995	2005	1995	2005	1995	2005	1995	2005	1995	2005	1995	2005
U.S.	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Japan	2	2	2	3	2	3	2	2	5	3	8	7	3	2	3	3
UK	3	3	3	5	6	8	6	7	2	2	4	5	2	3	2	2
Germany	4	4	4	6	3	4	3	4	6	5	3	4	4	4	4	4
China	14	5	8	2	11	2	7	3	15	7	9	3	20	7	21	11
France	5	6	6	7	5	6	5	5	4	6	2	2	5	5	5	7
Canada	6	7	5	8	10	12	9	12	3	4	5	10	6	6	7	6
Italy	8	8	10	10	8	10	8	8	9	9	6	6	7	8	6	5
Spain	11	9	15	12	9	9	11	11	11	10	10	8	11	9	11	10
South Korea	22	10	13	4	15	11	15	9	35	19	24	12	29	13	31	14
Australia	9	11	12	14	14	17	17	18	7	8	11	13	8	10	9	9
India	12	12	9	11	7	7	10	10	13	12	17	21	14	12	19	20
Russia	7	13	7	13	4	5	4	6	8	11	7	9	9	18	22	28
Netherlands	10	14	14	18	13	16	14	17	10	13	13	16	10	11	8	8
Taiwan	18	15	11	9	17	14	20	13	23	15	20	20	22	19	20	16
Sweden	13	16	16	19	18	21	18	19	12	18	15	18	12	14	10	12
Brazil	23	17	25	16	25	15	21	15	24	16	19	15	19	15	24	17
Switzerland	15	18	19	21	16	18	13	16	16	14	16	19	13	16	12	15
Turkey	34	19	26	17	29	20	37	25	29	21	44	27	34	24	25	13
Poland	19	20	18	20	12	13	12	14	27	29	14	14	25	23	28	26

UK = United Kingdom

NOTES: Countries initially ranked on 2005 total article output. Article counts from set of journals covered by Science Citation Index (SCI) and Social Sciences Citation Index (SSCI). Articles classified by year of publication and assigned to country/economy on basis of institutional address(es) listed on article. 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. China includes Hong Kong.

SOURCES: Thomson Scientific, SCI and SSCI, http://scientific.thomson.com/products/categories/citation/; ipIQ, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

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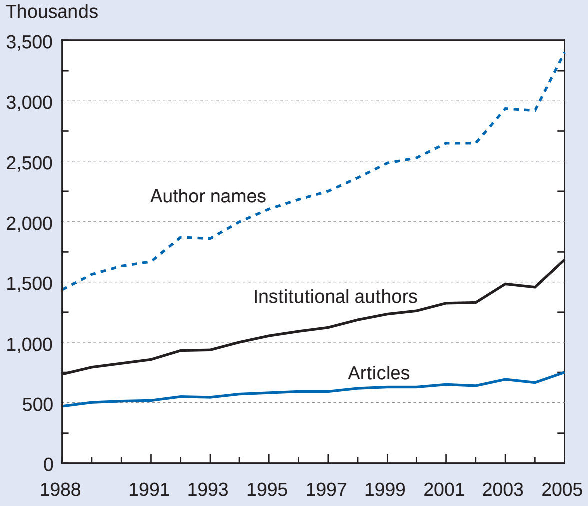
Figure 5-29
Worldwide S&E articles, institutional authors, and author names: 1988–2005



NOTES: Article counts from set of journals covered by Science Citation Index (SCI) and Social Sciences Citation Index (SSCI). Articles classified by year of publication. Author name counted each time it appears in data set. Authors assigned to institution on basis of institutional address listed on article; authors from separate departments each counted as individual institutional author; multiple authors from same department of institution considered as one institutional author.

SOURCES: Thomson Scientific, SCI and SSCI, http://scientific.thomson.com/products/categories/citation/; ipIQ, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

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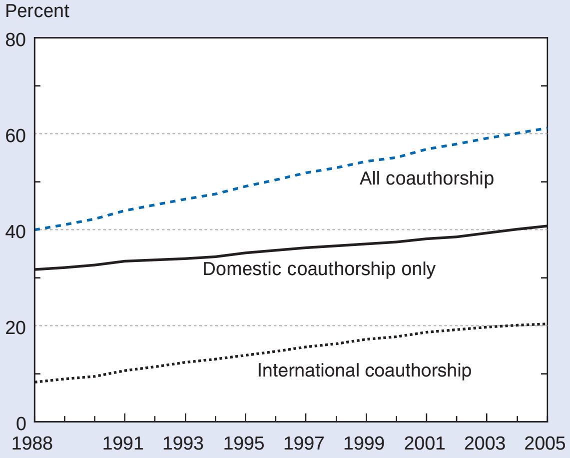
Figure 5-30
Share of worldwide S&E articles coauthored domestically and internationally: 1988–2005



NOTES: Article counts from set of journals covered by Science Citation Index (SCI) and Social Sciences Citation Index (SSCI). Articles classified by year they entered database, rather than year of publication, and assigned to region/country/economy on basis of institutional address(es) listed on article. Articles on whole-count basis, i.e., each collaborating institution or country credited one count. Internationally coauthored articles may also have multiple domestic coauthors.

SOURCES: Thomson Scientific, SCI and SSCI, http://scientific.thomson.com/products/categories/citation/; ipIQ, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

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Table 5-22
Authors per S&E article, by field: 1988 and 2005

Field	1988	2005
All fields	3.1	4.5
Engineering	2.5	3.6
Astronomy	2.5	5.0
Chemistry	3.1	4.1
Physics	3.3	5.4
Geosciences	2.4	3.7
Mathematics	1.5	1.9
Computer sciences	1.9	2.8
Agricultural sciences	2.7	4.0
Biological sciences	3.3	4.9
Medical sciences	3.6	5.3
Other life sciences	2.0	3.1
Psychology	2.1	2.9
Social sciences	1.4	1.8

NOTE: Articles classified by year they entered database rather than year of publication.

SOURCES: Thomson Scientific, Science Citation Index and Social Sciences Citation Index, http://scientific.thomson.com/products/categories/citation/; ipIQ, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

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16% to 19%) (table 5-23). As a percentage of the world's interregionally coauthored articles, the shares of articles with a U.S. or European Union institutional author declined slightly, giving way to a rise in the share of articles with an institutional author from the Asia-10 (from 22% in 1995 to 28% in 2005). The other regions identified in table 5-23 tend to have a less-developed S&E infrastructure, and scientists and engineers in those regions tend more often to coauthor articles with colleagues in the more scientifically advanced regions/countries. For example, 41% of all S&E articles with an institutional author from the Near East/North Africa (which includes Israel) had an author from another region, as did 59% of S&E articles with an institutional author from Sub-Saharan Africa (which includes South Africa). The following sections look more closely at coauthorship patterns of specific countries and country pairs.

Coauthorship Patterns From an International Perspective

When the region-level data discussed in the previous section are disaggregated to the country level, a richer picture of international S&E article coauthorship emerges. Table 5-24 displays the international coauthorship rates of countries that had institutional authors on at least 1% or more of

Table 5-23

Interregional collaboration on S&E articles: 1995 and 2005

(Percent)

	Share region's/ country's total article output		Share world's interregional articles	
Region/country	1995	2005	1995	2005
United States	17	27	60	57
European Union	18	26	66	65
Other Western Europe	41	44	12	12
Asia-10	16	19	22	28
Other Asia	51	66	1	1
Other former USSR	22	42	10	9
Near East/ North Africa	36	41	7	7
Central/ South America	39	40	8	9
Sub-Saharan Africa	41	59	4	3
Other	27	40	20	21

USSR = Union of Soviet Socialist Republics

NOTES: Interregionally coauthored articles have at least one collaborating institution from indicated region/country and an institution from outside that region/country. Article counts from set of journals covered by Science Citation Index (SCI) and Social Sciences Citation Index (SSCI). Articles classified by year they entered database, rather than year of publication, and assigned to region/country/economy on basis of institutional address(es) listed on article. Articles on whole-count basis, i.e., each collaborating country/economy credited one count. See appendix table 5-33 for countries/economies included in each region. Detail adds to >100% because articles may have authors from more than two countries/ economies.

SOURCES: Thomson Scientific, SCI and SSCI, http://scientific.thomson.com/products/categories/citation/; ipIQ, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

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the world's internationally coauthored S&E articles in 2005. The sheer number of U.S. coauthored articles dominates these measures, accounting for 44% of the world total. As discussed in the sidebar "Distribution of Publication Data," a relatively small number of countries account for a large proportion of the world's internationally coauthored articles. But a country's number of internationally coauthored articles (i.e., its "size") is not a reliable predictor of the propensity of that country's scientists to engage in international coauthorship (Narin, Stevens, and Whitlow 1991). Countries of very different article output volumes (e.g., the United Kingdom with 28,000 internationally coauthored articles and Finland with 3,400) show similar rates of international coauthorship (44% and 48%, respectively). In contrast, the number of Japan's internationally coauthored articles is similar to Italy's, but Japan's international coauthorship rate (23%) is well below Italy's (43%).

Narin and colleagues (1991) concluded that "the direction of international coauthorship is heavily dependent on linguistic and historical factors." Coauthorship data suggest intriguing "preferences" at the national level (Glänzel and Schubert 2005; Schubert and Glänzel 2006) based on the geography, cultural relations, and language of particular pairs or sets of countries, and these preferences have been evolving over time (Glänzel 2001). Some researchers have focused on the growing S&E article output and international coauthorship of particular countries mentioned in the previous section, for example, Korea (Kim 2005), China (Zhou and Leydesdorff 2006), and Turkey (Uzun 2006).

International Coauthorship With the United States

When authors of S&E articles from U.S. institutions collaborate with authors from abroad, in which countries are these authors likely to be located? Table 5-25 lists the 30 countries whose institutions appeared on at least 1% or more of U.S. internationally coauthored articles in 2005. U.S. authors are most likely to coauthor with colleagues from Germany (13.5%), the United Kingdom (13.4%), and Canada (11.9%).

Readers may note the asymmetry between the columns of data in table 5-25: each country's share of coauthorship in U.S. internationally coauthored articles is lower than the U.S. share of that country's international articles.[39] To some extent, the asymmetry may simply reflect the dominating effect of the size of U.S. S&E across the globe, including the number of publishing scientists and engineers (see sidebar, "Distribution of Publication Data"). For example, scientists and engineers from Canada may relatively more often collaborate with scientists and engineers in the United States (52%) than the reverse (12%) simply because there are more scientists and engineers in the United States than in Canada.[40] Canada and the United States are also close geographically and linguistically, and these factors may reinforce the size effect of the United States. Likewise, the difference in the rates of coauthorship between the United States and Israel (53% for Israel with the United States versus 3% for the United States with Israel) may reflect historical and ethnic factors in addition to the size effect of the United States. The discussion in the next section shows how removing the effect of size identifies specific country pairs of strong coauthorship across the world.

International Collaboration in S&E

In developing indicators of international collaboration between countries and across regions, researchers have developed statistical techniques that account for unequal sizes in countries' S&E article output and coauthorship patterns (Glänzel and Schubert 2004). One of the simplest of these techniques is used in calculating the *index of international collaboration* shown in table 5-26. A country-to-country index is calculated by dividing a country's rate of collaboration with another country by the other country's rate of international coauthorship (Narin, Stevens, and Whitlow 1991). For example, if 12% of country A's coauthored ar-

Table 5-24

International collaboration on S&E articles, by selected region/country/economy: 2005

(Percent)

Region/country/economy	Share country's/economy's total article output	Share world's internationally coauthored articles
United States	27	44
European Union		
Austria	57	3
Belgium	58	4
Czech Republic	52	2
Denmark	54	3
Finland	48	2
France	49	14
Germany	47	20
Greece	40	2
Hungary	56	2
Ireland	52	1
Italy	43	9
Netherlands	49	7
Poland	47	3
Portugal	54	2
Spain	42	7
Sweden	50	5
United Kingdom	44	19
Other Western Europe		
Norway	52	2
Switzerland	59	6
Turkey	19	1
Asia-10		
China	25	8
India	22	3
Japan	23	10
Singapore	41	1
South Korea	28	4
Taiwan	21	2
Other former USSR		
Russia	43	6
Ukraine	52	1
Near East/North Africa		
Israel	44	3
Central/South America		
Argentina	47	1
Brazil	35	3
Mexico	46	2
Sub-Saharan Africa		
South Africa	49	1
Other		
Australia	41	6
Canada	43	10
New Zealand	48	1

USSR = Union of Soviet Socialist Republics

NOTES: Internationally coauthored articles have at least one collaborating institution from indicated country/economy and an institution from outside that country/economy. Article counts from set of journals covered by Science Citation Index (SCI) and Social Sciences Citation Index (SSCI). Articles classified by year they entered database, rather than year of publication, and assigned to region/country/economy on basis of institutional address(es) listed on article. Articles on whole-count basis, i.e., each collaborating country/economy credited one count. Countries with <1% of international total omitted. See appendix table 5-33 for all countries/economies included in each region. Detail adds to >100% because articles may have authors from more than two countries/economies.

SOURCES: Thomson Scientific, SCI and SSCI, http://scientific.thomson.com/products/categories/citation/; ipIQ, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix table 5-35.

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Table 5-25

International coauthorship of S&E articles with the United States, by selected country/economy: 2005

(Percent)

Country/economy	U.S. share of country's/ economy's international articles	Country's/ economy's share of U.S.'s international articles
Germany	30.1	13.5
United Kingdom	31.5	13.4
Canada	52.1	11.9
Japan	39.8	9.1
France	25.7	8.5
China	39.9	7.5
Italy	33.0	7.2
Australia	35.2	4.8
South Korea	54.7	4.6
Netherlands	30.4	4.6
Spain	26.6	4.2
Switzerland	30.6	4.0
Russia	27.6	3.5
Sweden	27.8	3.2
Israel	52.5	3.0
Brazil	38.9	2.6
Belgium	23.0	2.2
Taiwan	55.5	2.2
India	36.2	2.1
Poland	27.0	1.9
Denmark	28.2	1.8
Mexico	42.8	1.6
Austria	23.3	1.5
Finland	26.7	1.4
Norway	30.8	1.3
Turkey	44.8	1.2
Greece	32.9	1.1
Argentina	33.8	1.0
New Zealand	32.8	1.0
Hungary	27.9	1.0

NOTES: Internationally coauthored articles have at least one collaborating institution from indicated country/economy and an institution from outside that country/economy. Article counts from set of journals covered by Science Citation Index (SCI) and Social Sciences Citation Index (SSCI). Articles classified by year they entered database, rather than year of publication, and assigned to region/country/economy on basis of institutional address(es) listed on article. Articles on whole-count basis, i.e., each collaborating country/economy credited one count.

SOURCES: Thomson Scientific, SCI and SSCI, http://scientific.thomson.com/products/categories/citation/; ipIQ, Inc.; and National Science Foundation, Division of Science Resources Statistics. See appendix table 5-35.

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Table 5-26

International collaboration on S&E articles, by selected region and country/economy pair: 2005

Region, country/economy pair	International collaboration index
North/South America	
Canada–U.S.	1.19
Mexico–U.S.	0.98
U.S.–Brazil	0.89
Argentina–Brazil	5.01
Mexico–Argentina	3.06
North Atlantic	
UK–U.S.	0.72
Germany–U.S.	0.69
France–U.S.	0.59
Canada–UK	0.72
Canada–France	0.66
Europe	
France–Germany	0.86
France–UK	0.83
Germany–UK	0.79
Spain–France	1.27
Italy–Switzerland	1.39
Norway–Denmark	4.64
Finland–Sweden	3.84
Sweden–Denmark	3.48
Pacific Rim	
Japan–U.S.	0.91
China–U.S.	0.91
South Korea–U.S.	1.25
Taiwan–U.S.	1.27
China–Canada	0.74
Japan–Canada	0.52
Asia/South Pacific	
China–Japan	1.56
South Korea–Japan	2.02
Australia–Singapore	1.72
Australia–China	1.07
Australia–New Zealand	4.23
India–Japan	1.31
India–South Korea	1.84

UK = United Kingdom

NOTES: International collaboration index is first country's rate of collaboration with second country divided by second country's rate of international coauthorship. Article counts from set of journals covered by Science Citation Index (SCI) and Social Sciences Citation Index (SSCI). Articles classified by year they entered database, rather than year of publication, and assigned to region/country/economy on basis of institutional address(es) listed on article. Articles on whole-count basis, i.e., each collaborating country/economy credited one count.

SOURCES: Thomson Scientific, SCI and SSCI, http://scientific.thomson.com/products/categories/citation/; ipIQ, Inc.; and National Science Foundation, Division of Science Resources Statistics. See appendix table 5-35.

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ticles are with country B, and country B produces 12% of internationally coauthored articles, the expected country-to-country collaboration index is 1 (12%/12%). Indexes greater than 1 represent greater than expected rates of coauthorship, and indexes less than 1 represent less than expected rates of coauthorship.

Table 5-26 lists the international collaboration index for selected pairs of countries. The indexes for all pairs of countries that produced at least 1% of all internationally coauthored articles in 2005 can be calculated from the data in appendix table 5-35. In North America, the Canada-United States index of 1.19 shows a rate of collaboration that is slightly greater than would be expected based solely on the number of internationally coauthored articles produced by each of these two countries. The United States-Mexico index of 0.98 is just about as would be predicted, whereas Mexico's collaboration with Argentina is much stronger than expected, at 3.06. In South America, the collaboration index of Argentina-Brazil, at 5.01, is one of the highest in the world.

None of the collaboration indexes between countries on opposite sides of the North Atlantic was as high as expected based on their total international collaboration. In Europe, collaboration patterns were mixed. Among the large publishing countries of Germany, the United Kingdom, and France, collaboration was less than expected. The indexes for France-Spain and Italy-Switzerland were somewhat higher than expected, and very strong rates of collaboration were evident throughout Scandinavia.

Cross-Pacific collaboration was rather weak between the United States and both China and Japan, but somewhat stronger than expected between the United States and both South Korea and Taiwan. Canada showed a lower tendency than the United States to coauthor with other Pacific Rim countries.

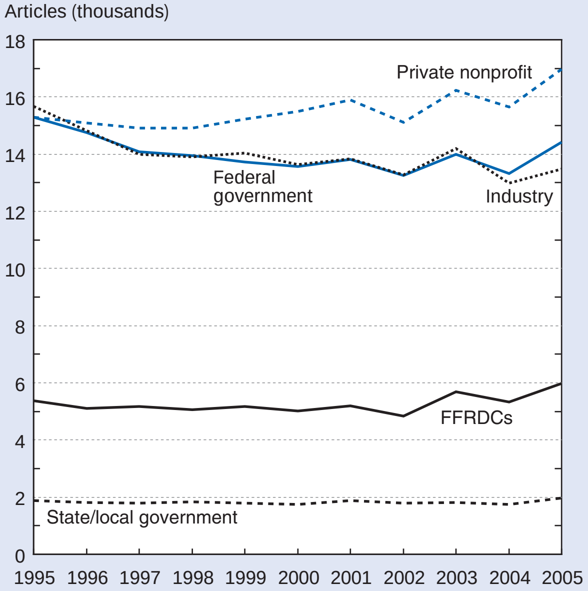
Collaboration indexes between the large article producers within the Asia-10 were generally higher than expected. Indexes for Japan-China and for Japan-South Korea were strong. Australia's collaboration with Singapore (1.72) and New Zealand (4.23) was particularly strong. India collaborated more than would be expected with Japan (1.31) and South Korea (1.84).

Trends in Output and Collaboration Among U.S. Sectors

S&E articles authored at academic institutions have traditionally accounted for just under three-fourths of all U.S. articles (appendix table 5-36). This section takes a closer look at nonacademic authorship, including output trends by sector and the extent of coauthorship, both between U.S. sectors and between U.S. sectors and authors abroad. (For a more detailed discussion of industry authorship, see "Industry Collaboration in Publications" in chapter 6.)

Figure 5-31

S&E article output of U.S. nonacademic sectors: 1995–2005



FFRDC = federally funded research and development center

NOTES: Article counts from set of journals covered by Science Citation Index (SCI) and Social Sciences Citation Index (SSCI). Articles classified by year they entered database, rather than year of publication, and assigned to sector on basis of institutional address(es) listed on article. Articles on fractional-count basis, i.e., for articles with collaborating institutions from multiple sectors, each sector receives fractional credit on basis of proportion of its participating institutions. Joint and unknown sectors omitted.

SOURCES: Thomson Scientific, SCI and SSCI, http://scientific.thomson.com/products/categories/citation/; ipl , Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix table 5-36.

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Article Output by Sector

Total annual publications by authors in U.S. nonacademic sectors changed little over the past decade (appendix table 5-36). Authorship by scientists and engineers in the federal government and in industry declined overall (figure 5-31). Articles with nonprofit institutional authors have trended upward, primarily due to increases in the medical sciences. State and local government authorship, dominated by articles in the medical and biological sciences, remained constant across the decade. The article output of federally funded research and development centers (FFRDCs) remained flat until 2002 but has recently shown increases. (See sidebar "S&E Articles From Federally Funded Research and Development Centers.")

Trends in Sector Coauthorship

The previous section on "Coauthorship and Collaboration" presented coauthorship data as an indicator of collaboration between and among U.S. and foreign scientists and engineers. This section considers coauthorship data as an indicator of collaboration at the sectoral level between U.S.

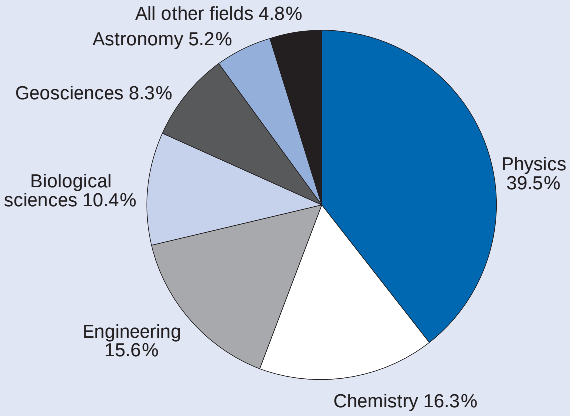
S&E Articles From Federally Funded Research and Development Centers

FFRDCs are research offices/laboratories sponsored by federal agencies and administered by universities, industry, or other nonprofit institutions. FFRDCs have specialized research agendas closely related to the mission of the sponsoring agency and may house large and unique research instruments not otherwise available in other research venues.

Although all of the broad fields of science considered in this chapter contain articles authored at FFRDCs, a handful of these fields dominates publication by this sector and points to their specialized research programs. Physics articles account for 40% of the FFRDC total (figure 5-32) but only 10% of the academic sector total (appendix table 5-36). Chemistry and engineering articles each account for another 16% of the FFRDC total.

Nine federal agencies (the Departments of Defense, Energy, Health and Human Services, Homeland Security, Transportation, and Treasury, the National Aeronautics and Space Administration, the Nuclear Regulatory Commission, and the National Science Foundation) sponsor some three dozen FFRDCs (NSF/SRS, 2007b), but the 16 centers sponsored by the Department of Energy dominate S&E publishing by this sector. Across all fields of S&E, DOE-sponsored labs accounted for 83% of the total for the sector in 2005. Scientists and engineers at DOE-sponsored FFRDCs published 96% of the sector's articles in chemistry, 95% in physics, and 90% in engineering (NSF, special tabulations).

Figure 5-32
S&E articles from FFRDCs, by field: 2005



FFRDC = federally funded research and development center

NOTES: Article counts from set of journals covered by Science Citation Index (SCI) and Social Sciences Citation Index (SSCI). Articles classified by year they entered database, rather than year of publication, and assigned to sector on basis of institutional address(es) listed on article. Articles on fractional-count basis, i.e., for articles with collaborating institutions from multiple sectors, each sector receives fractional credit on basis of proportion of its participating institutions. Detail does not add to total because of rounding.

SOURCES: Thomson Scientific, SCI and SSCI, http://scientific.thomson.com/products/categories/citation/; ipI , Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix table 5-36.

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institutional authors and between U.S. sectors and foreign institutions.[41] These data show that the growing integration of R&D activities, as measured by coauthorship, is occurring across the full range of R&D-performing institutions.

Between 1995 and 2005, coauthorship increased in all U.S. sectors and, most notably, between U.S. institutional authors in all sectors and non-U.S. authors. Authors in FFRDCs, industry, and private nonprofit institutions increased their coauthorship with foreign authors by 10 percentage points between 1995 and 2005 (table 5-27). Authors at FFRDCs reached the highest rate of collaboration with foreign authors, at 38%, followed by industry at 26%. Coauthorship with foreign authors increased by 9 percentage points for authors in the federal government and academia and by 5.5 percentage points for authors in state/local government.

The extent of coauthorship between U.S. sectors and authors from another country varied by broad field of science. Astronomy had the highest rate of international coauthorship in 2005, at 58%, well above the U.S. national average of 27% across all fields and all sectors (appendix table 5-37). Within astronomy, authors at FFRDCs, in the federal government, in academia, and in private nonprofit institutions increased their international coauthorship over the decade 1995–2005 at some of the highest rates compared with other S&E fields. The geosciences, mathematics, and physics also experienced higher than average growth in international coauthorship in most sectors.

U.S. cross-sectoral coauthorship increased between all sectors except FFRDCs and industry. The largest gains in all sectors were with coauthors in academia (by far the largest sector with the largest pool of potential S&E coauthors). State/local government, the sector with the highest percentage of articles with coauthors from academia in 1995, at 63%, also had the highest percentage in 2005, at 71%, followed by private nonprofit institutions at 62% and the federal government at 59% (table 5-27).

Within-sector coauthorship (e.g., FFRDC authors with authors from other FFRDCs) increased as well.[42] Starting from the highest base of within-sector coauthorship in 1995, at 36%, academic authors increased their coauthorship with authors from other academic institutions to 43% in 2005. FFRDC-FFRDC coauthorship, and private nonprofit/private nonprofit coauthorship both increased by more than 4 percentage points over the decade.

Except for the decline in coauthorship between FFRDCs and industry, the indicators presented in this section show steadily increasing integration between and among the different types of U.S. institutions that publish the results of

Table 5-27

U.S. article coauthorship, by sector, foreign coauthorship, and U.S. coauthor sector: 1995 and 2005

(Percent)

Year/sector	Foreign coauthor	U.S. coauthor sector: FFRDCs	Federal government	State/local government	Academic institutions	Industry	Private nonprofit
1995							
FFRDCs	28.2	12.7	7.1	0.2	44.5	8.7	3.3
Federal government	16.2	2.5	16.9	1.9	51.3	8.5	7.6
State/local government	9.9	0.6	13.5	12.8	63.2	8.0	15.3
Academic institutions	16.6	2.4	7.7	1.4	36.3	5.7	8.4
Industry	16.1	3.3	9.1	1.2	40.3	13.7	7.2
Private nonprofit	14.4	1.2	7.6	2.2	56.1	6.8	22.9
2005							
FFRDCs	38.3	16.9	8.2	0.3	54.3	6.9	4.2
Federal government	25.2	3.4	19.3	2.7	58.8	9.3	11.1
State/local government	15.3	0.8	16.9	15.6	70.6	10.3	19.3
Academic institutions	25.6	3.1	8.0	1.5	42.9	6.1	9.7
Industry	26.3	3.2	10.5	1.8	50.7	16.0	11.8
Private nonprofit	24.4	1.5	9.6	2.6	61.8	9.1	27.4
1995–2005 change (percentage points)							
FFRDCs	10.1	4.2	1.1	0.1	9.8	-1.8	0.9
Federal government	9.1	0.9	2.4	0.8	7.5	0.8	3.5
State/local government	5.5	0.2	3.4	2.8	7.5	2.3	4.0
Academic institutions	9.0	0.7	0.3	0.2	6.6	0.4	1.3
Industry	10.2	-0.1	1.4	0.6	10.3	2.3	4.6
Private nonprofit	10.0	0.3	2.0	0.5	5.6	2.3	4.6

FFRDC = federally funded research and development center

NOTES: Article counts from set of journals covered by Science Citation Index (SCI) and Social Sciences Citation Index (SSCI). Articles classified by year they entered the database, rather than year of publication, and assigned to sector on basis of institutional address(es) listed on article. Articles on whole-count basis, i.e., each collaborating country or sector credited one count. Articles from joint or unknown sectors omitted. Detail may add to >100% because articles may have authors from more than two sectors.

SOURCES: Thomson Scientific, SCI and SSCI, http://scientific.thomson.com/products/categories/citation/; ipIQ, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix table 5-37.

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R&D in the scientific and technical literature. The data in table 5-27 indicate that more of these coauthors have been from another department within an institution,[43] from another institution within the same sector, or from an institution in another sector. Growth in coauthorship has been particularly strong between U.S. authors in all sectors and authors in foreign institutions.

Trends in Citation of S&E Articles

When scientists and engineers cite the published results of previous research, they are formally crediting the influence of that research on their own work. Previous editions of *Indicators* presented data on the growing number of worldwide citations to foreign S&E literature. Like the indicators of international coauthorship discussed above, cross-national citations are evidence that S&E research is increasingly international in scope.

The indicators discussed here present a coherent picture of a world S&E literature dominated by the United States. At the same time, a decade of increases in the publication of research articles by a few dozen countries in Asia and Europe has chipped away at the U.S. share on a number of publication indicators. The following sections continue to explore this theme by contrasting worldwide research output trends with worldwide trends in highly cited S&E literature by field.

Citation Trends in a Global Context

Much of the world's S&E research literature is never cited in another article, although citation rates vary by field (appendix table 5-38).[44] Concomitant with changing shares of the world total of S&E research articles, shares of the world total of citations to these articles have also been changing. Appendix table 5-38 shows, for example, that between 1991–93 and 2001–03, the U.S. world share of S&E articles declined from 36% to 30%, while the European Union share grew from 33% to 35% and the Asia-10 share grew from 13% to 18%. Table 5-28 provides the parallel percentages for share of citations, showing a largely similar pattern: a decline for the United States from 50% to 41%, an increase for the European Union from 31% to 34%, and an increase for the Asia-10 from 8% to 13%. Figure 5-33 illustrates these changes. Other regions of the world remained relatively unchanged on these indicators during the period.

Trends in Highly Cited S&E Literature

Another indicator of performance of a national or regional S&E system is the share of its articles that are highly cited. High citation rates can indicate that an article has a greater impact on subsequent research than articles with lower citation rates.

Citation percentiles for 1995, 2000, and 2005 are shown by field and region/country in appendix table 5-38.[45] In appendix table 5-38, a region/country whose research influence is disproportionate to its output would have higher numbers of articles at higher citation percentiles, whereas a country whose influence was less than its output would suggest would have higher numbers of articles at lower citation percentiles. In other words, a country whose research has high influence would have higher shares of its articles in higher citation percentiles.

This is the case in every field for U.S. articles. Across the 11 years displayed in appendix table 5-38, the U.S. share of articles in the 99th percentile was higher than its share in the 95th percentile, and these were higher than its share in the 90th percentile, and so forth, even while the U.S. share of all articles was decreasing. In contrast, in every field shown in appendix table 5-38, the shares of European Union and Asia-10 articles in each percentile were inversely proportional to the citation percentiles, even as their share of all articles was increasing. Figure 5-34 displays these relationships for the United States, European Union, and Asia-10; only U.S. publications display the ideal relationship of consistently higher proportions of articles in the higher percentiles of article citations across the period.

These data are summarized in appendix table 5-39, which focuses only on the 99th percentile of article citations. As the U.S. share of all articles produced declined between 1995 and 2005, its share of articles in the 99th percentile (i.e., the top 1%) of cited articles also declined, particularly in some fields. The share of articles produced by the European Union and the Asia-10 increased over the same period, as did their shares of articles in the 99th percentile of cited articles.

However, when citation rates are normalized by the share of articles during the citation period to produce an index of highly cited articles, the influence of U.S. articles is shown to increase. Between 1995 and 2005, the U.S. index of highly cited articles increased from 1.73 to 1.83 (figure 5-35). During the same period, the European Union's index increased from 0.75 to 0.84 and the Asia-10's increased from 0.39 to

Table 5-28
Share of world citations of S&E articles, by major region/country: 1995, 2000, and 2005
(Percent)

Region/country	1995	2000	2005
United States	49.6	44.8	40.8
European Union	30.6	33.3	33.7
Other Western Europe	2.3	2.5	2.5
Asia-10	8.2	9.8	12.9
Other Asia	0.0	0.0	0.1
Other former USSR	1.0	1.0	0.8
Near East/North Africa	1.0	1.1	1.2
Central/South America	0.7	1.0	1.5
Sub-Saharan Africa	0.3	0.3	0.3
Other	6.3	6.3	6.1

USSR = Union of Soviet Socialist Republics

NOTES: Article counts from set of journals covered by Science Citation Index (SCI) and Social Sciences Citation Index (SSCI). Articles classified by year they entered database, rather than year of publication, and assigned to region/country/economy on basis of institutional address(es) listed on article. 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. Citation counts based on 3-year period with 2-year lag, e.g., citations for 1995 are references made in articles in 1995 data tape to articles in 1991–93 data tapes. See appendix table 5-33 for countries/economies included in each region.

SOURCES: Thomson Scientific, SCI and SSCI, http://scientific.thomson.com/products/categories/citation/; ipIQ, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

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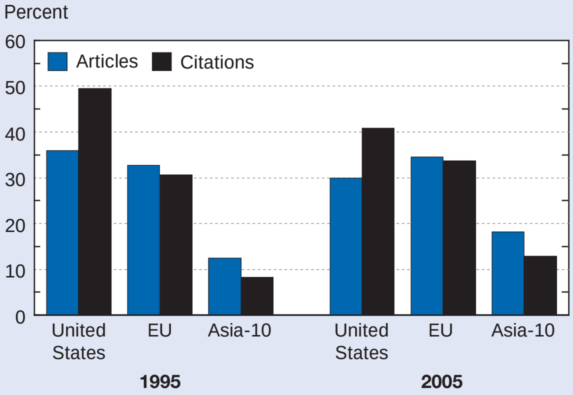
Figure 5-33
S&E articles and citations in all fields, by selected region/country: 1995 and 2005



EU = European Union

NOTES: Share of all articles based on 3-year period. Article counts from set of journals covered by Science Citation Index (SCI) and Social Sciences Citation Index (SSCI). Articles classified by year they entered database and assigned to region/country/economy on basis of institutional address(es) listed on article. Articles and citations 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. Citation data based on year article entered database. Citation counts based on 3-year period with 2-year lag, e.g., citations for 1995 are references made in articles in 1995 data tape to articles in 1991–93 data tapes. See appendix table 5-33 for countries/economies included in EU and Asia-10.

SOURCES: Thomson Scientific, SCI and SSCI, http://scientific.thomson.com/products/categories/citation/; ipI , Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix table 5-39 and table 5-28.

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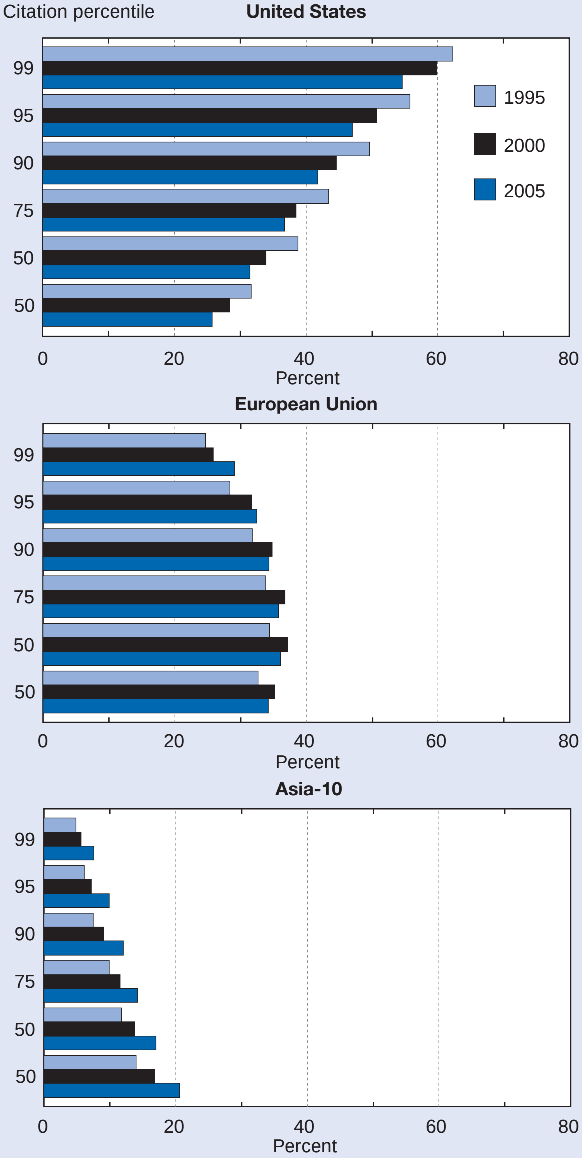
Figure 5-34
United States, European Union, and Asia-10 share of cited papers, by citation percentile: 1995, 2000, and 2005



NOTES: Article counts from set of journals covered by Science Citation Index (SCI) and Social Sciences Citation Index (SSCI). Articles classified by year they entered database, rather than year of publication, and assigned to region/country/economy on basis of institutional address(es) listed on article. 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. See appendix table 5-33 for countries/economies included in European Union and Asia-10. Citation counts based on 3-year period with 2-year lag, e.g., citations for 1995 are references made in articles in 1995 data tape to articles in 1991–93 data tapes. Percentiles approximate because of method of counting citations and always higher than stated.

SOURCES: Thomson Scientific, SCI and SSCI, http://scientific.thomson.com/products/categories/citation/; ipl , Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix table 5-38.

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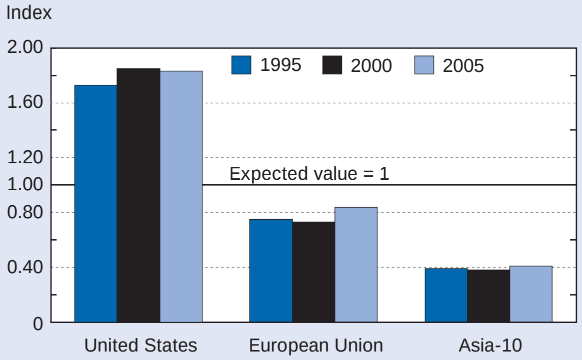
Figure 5-35
Index of highly cited articles, by selected region/country: 1995, 2000, and 2005



NOTES: Article counts from set of journals covered by Science Citation Index (SCI) and Social Sciences Citation Index (SSCI). Articles classified by year they entered database, rather than year of publication, and assigned to region/country/economy on basis of institutional address(es) listed on article. Citation data based on year article entered database. Citation counts based on 3-year period with 2-year lag, e.g., citations for 1995 are references made in articles in 1995 data tape to articles in 1991–93 data tapes. Index of highly cited articles is country/economy s share of world s top 1% cited articles divided by its share of world articles for the cited year window. See appendix table 5-33 for countries/economies included in European Union and Asia-10.

SOURCES: Thomson Scientific, SCI and SSCI, http://scientific.thomson.com/products/categories/citation/; ipl , Inc.; and National Science Foundation, Division of Science Resources Statistics. See appendix table 5-38.

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0.41. In other words, the United States had 83% more articles than expected in the 99th percentile of cited articles in 2005, while the European Union had 16% fewer than expected and the Asia-10 had 59% fewer than expected.[46]

The United States experienced notable gains on the index of highly cited articles in engineering, mathematics, and computer sciences (although with relatively low counts in the latter) and declines in chemistry and geosciences (appendix table 5-39). The European Union experienced gains on the index in astronomy, chemistry, and geosciences and reached expectation only in agricultural sciences. The Asia-10 achieved increases in a number of fields, including engineering, chemistry, physics, and geosciences, but did not progress in the biological or medical sciences. The Asia-10's index score nearest expectation was in mathematics, at 0.79.

Academic Patents, Licenses, Royalties, and Startups

Other indicators of academic R&D outputs reflect universities' efforts to capitalize on their intellectual property in the form of patents and associated activities.[47] Although some U.S. universities were granted patents much earlier, the majority did not become actively involved in the management of their own intellectual property until late in the 20th century.[48] The Bayh-Dole Act of 1980 gave colleges and universities ownership of income streams from patented discoveries that resulted from their federally funded research. To facilitate the conversion of new knowledge produced in their laboratories to patent-protected public knowledge that can be potentially licensed by others or form the basis for a startup firm, more and more research institutions established technology management/transfer offices.

Efforts to encourage links between university-based research and commercial exploitation of the results of that research have been widely studied by researchers. Mowery (2002) notes the strong growth in funding by NIH and the predominance of biomedical-related patenting by universities in the 1990s. Branstetter and Ogura (2005) identify a "bio-nexus" in patent-to-paper citations, and Owen-Smith and Powell (2003) explore the effects of an academic medical center as part of the "scientific capacity" of a research university. In a qualitative study of two research universities that would appear to have similar capacities, Owen-Smith and Powell (2001) examine the very different rates of invention disclosure of the two campuses. Stephan and colleagues (2007) found strong differences in patenting activity among university scientists by field of science; a strong relationship between publication activity and patenting by individual researchers; and patenting among university researchers restricted to a small set of the potential population.

The following sections discuss overall trends in university patenting through 2005 and related indicators.

University Patenting Trends

U.S. Patent and Trademark Office (USPTO) data show that patent grants to universities and colleges increased sharply from 1995 to about 2002, when they peaked at just under 3,300 patents per year, and then fell to about 2,700 in 2005 (appendix table 5-40).[49] (However, this decline contrasts with recent increases in the related indicators of invention disclosures and patent applications filed by academic institutions, which are discussed in the next section, "Patent-related activities and income.") The top R&D-performing institutions, with 95% of the total, dominate among universities and university systems receiving patent protection.[50] College and university patenting as a percentage of U.S. nongovernmental patents grew in the 1980s and 1990s from less than 2% to just under 5%, and then declined to about 4.2% by 2005 (figure 5-36).

The previous edition of *Indicators* noted that three biomedically related utility classes dominated university patenting in the 1980s and 1990s (NSB 2006, pp. 5-54 and 5-55). In 2005, these same three classes together accounted for more than one-third of all utility patents awarded to U.S. academic institutions: drug, bio-affecting and body treating compositions (15.4%); chemistry: molecular biology and microbiology (13.8%); and organic compounds (5.6%) (appendix table 5-41). Other medical and life sciences-related classes of patents, although smaller than the top three in number of patents awarded, also ranked high on the list of top patent utility classes awarded to universities.

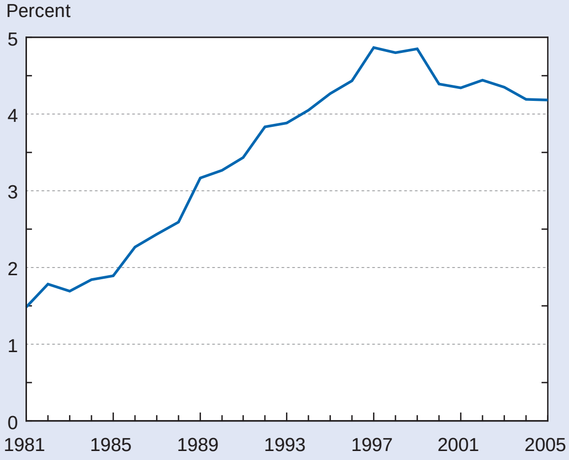
Patent-Related Activities and Income

In contrast to the USPTO-reported decline in the total number of patents awarded to U.S. universities and colleges in 2004 and 2005 (appendix table 5-40), data from the Association of University Technology Managers (AUTM) indicate continuing growth in a number of related activities. Invention disclosures filed with university technology management offices describe prospective inventions and are submitted before a patent application is filed. These grew from 13,700 in 2003 to 15,400 in 2005 (notwithstanding a small decline in respondent institutions to the AUTM survey over the same period) (appendix table 5-42). Likewise, new U.S. patent applications filed by the AUTM respondents also increased, from 7,200 in 2003 to 9,500 in 2004 and 9,300 in 2005 (appendix table 5-42).

Most royalties from licensing agreements accrue to relatively few patents and relatively few of the universities that hold them, and many of the AUTM respondent offices report negative income. (Thursby and colleagues [2001] note that the objectives of university technology management offices include more than royalty income.) At the same time, onetime payments to one university can complicate analysis of the overall trend in university income due to patenting. The *median* net royalty per university respondent to the AUTM surveys has both risen and fallen since 1996 but overall climbed from $440,000 in 1996 to $950,000 in 2005 (figure 5-37).

During the same period, the inventory of revenue-generating licenses and options across all AUTM respondent institutions increased, from 5,000 in 1996 to more than

Figure 5-36
U.S. academic share of patenting by U.S. private and nonprofit sectors: 1981–2005



NOTES: Patents issued by U.S. Patent and Trademark Office (USPTO) 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: USPTO, Technology Assessment and Forecast Report: U.S. Colleges and Universities, Utility Patent Grants, 1969–2005 (2007); and National Science Foundation, Division of Science Resources Statistics, special tabulations.

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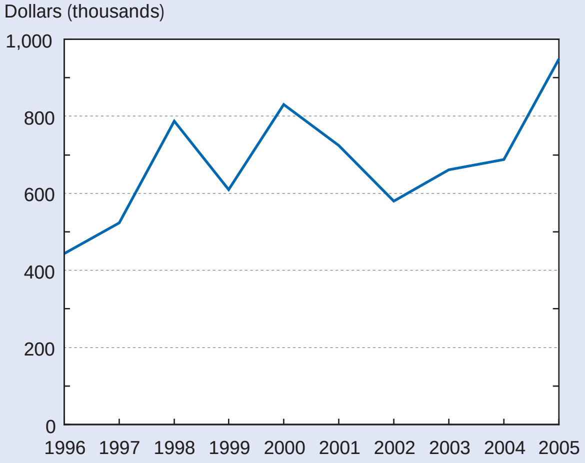
Figure 5-37
Median net royalties from academic patenting activities: 1996–2005



SOURCE: Association of University Technology Managers, AUTM Licensing Survey (various years).

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10,200 in 2005 (appendix table 5-42). New licenses and options executed grew steadily to more than 4,000/year in both 2004 and 2005. The annual number of startup companies established as a result of university-based inventions rebounded after 2 years of downturns in 2002 and 2003 to more than 400 in both 2004 and 2005.

Conclusion

U.S. universities and colleges continued to be important participants in U.S. R&D during the first decade of the 21st century, performing more than half the basic research nationwide and having a significant presence in applied research. Funding of academic R&D from all major sources and across all broad S&E fields continued to expand. Since 2000, average annual growth in R&D has been stronger for the academic sector than for any other R&D-performing sector. Both the overall academic S&E doctoral workforce and the academic research workforce have also continued to increase. Citation data indicate that U.S. scientific publications remain highly influential relative to those of other countries. However, the relative volume of U.S. article output has not kept up with the increasing outputs of the European Union and the Asia-10. In fact, the number of U.S. articles published in the world's leading S&E journals has only recently begun to increase again after being essentially level since the early to mid-1990s.

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 increasing between 2000 and 2004, the federal government's share of funding for academic R&D began to decrease in 2005 and again in 2006. In addition, for the first time since 1982, federal funding did not keep pace with inflation. 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 before rising again in both 2005 and 2006. The state and local share of support for academic R&D reached an all-time low in 2006. Research-performing universities have increased the amount of their own funds devoted to research every year since 1993.

The structure and organization of academic R&D have also changed. Research-performing colleges and universities continued to expand their stock of research space, particularly in the biological and medical sciences. However, spending on research equipment as a share of all R&D expenditures declined to an all-time low of 4.0% by 2006. 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 relative use of nonfaculty appointments. This shift has been marked by a substantial increase in the number of postdocs over a long period. These changes 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 risen.

A demographic shift in academic employment has also been under way, with increases in the proportion of women, Asians/Pacific Islanders, and underrepresented minorities in the S&E academic workforce. This shift is expected to continue into the future. Among degree holders who are U.S. citizens, white males have been 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.

Academic R&D is also becoming more international in a number of ways. U.S. academic scientists and engineers are collaborating extensively with colleagues in other countries: in 2005, more than one in four journal articles with a U.S. author also had at least one coauthor from abroad. The intimate linkage between research and U.S. graduate education, regarded as a model by other countries, helps to bring 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 full-time doctoral S&E faculty in research institutions approaching half the total in some fields.

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 between basic research, applied research, and development.

4. The academic R&D reported here includes separately budgeted R&D and related recovered indirect costs, as well as institutional estimates of unreimbursed indirect costs associated with externally funded R&D projects, including mandatory and voluntary cost sharing.

5. Federal grants and contracts and awards from other sources that are passed through state and local governments to academic institutions are credited to the original provider of the funds.

6. 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.

7. It also likely includes some amount of research funding from the above-named sources that universities are unable to accurately code for reporting to the Academic R&D Survey of Research and Development Expenditures at Universities and Colleges.

8. The medical sciences include fields such as pharmacy, neuroscience, oncology, and pediatrics. The biological sciences include fields such as microbiology, genetics, epidemiology, and pathology. These distinctions may be blurred at times because boundaries between fields often are not well defined.

9. In this section of the chapter and section, "Doctoral Scientists and Engineers in Academia," the broad S&E fields refer to the computer sciences, environmental sciences (sometimes referred to as "earth, atmospheric, and ocean sciences"), life sciences, mathematical sciences, physical sciences, psychology, social sciences, other sciences (those not elsewhere classified), and engineering. The more disaggregated S&E fields are referred to as "subfields." The third section, "Outputs of S&E Research: Articles and Patents," groups the broad fields and subfields slightly differently (see sidebar, "Bibliometric Data and Terminology" and appendix table 5-32).

10. The discussion of federal support for academic R&D in the previous section is based on reporting by performer, i.e., academic institutions. This section is based on reporting by funder—the government agencies that provide R&D support to academic institutions. Performing and funding series may differ for many reasons. For a more detailed discussion of the differences between these two sources, see chapter 4 sidebar, "Tracking R&D: Gap Between Performer- and Source-Reported Expenditures."

11. 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.

12. 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.

13. 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.

14. Part of the decline in R&D equipment intensity may be due to a threshold effect, i.e., institutions not reporting purchases of equipment under a certain dollar threshold. There is some evidence that the minimum dollar value at which purchases of research equipment are reported in the Survey of Research and Development Expenditures at Universities and Colleges has been increasing over the years, leading to some equipment that would have been reported in earlier years not being reported in more recent years.

15. 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.

16. Research space here is defined as the space used for sponsored R&D 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.

17. Some of this space will likely replace existing space and therefore will not be a net addition to existing stock.

18. Institutional funds may include operating funds, endowments, tax-exempt bonds and other debt financing, indirect costs recovered from federal grants/contracts, and private donations.

19. Some additional indirect federal funding may come through overhead on grants and/or contracts from the federal government. To the extent these funds are ultimately used for renovation or construction of facilities, they are reported as institutional funding because it is the institution that decides how they are spent.

20. Discussion of cyberinfrastructure is limited to networking because the Survey of Science and Engineering Research Facilities addresses only computing and networking capacity for research and instructional activities rather than all facets of cyberinfrastructure.

21. The "bricks and mortar" section of the Survey of Science and Engineering Research Facilities asks 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 cyberinfrastructure section of the survey, however, respondents were asked to identify all of their cyberinfrastructure resources, regardless of whether these resources were used for research.

22. There have been discussions of a possible merger of Abilene and National Lambda Rail.

23. 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 associates, and administrators; and part-time positions of all kinds. Academic employment is limited to those employed in 2-year or 4-year colleges or universities. 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.

24. It is impossible to establish causal connections among these developments with the data at hand.

25. These data include only U.S.-trained postdocs. The number of postdocs with temporary visas and presumed non-U.S. doctorates increased greatly in the 1990s. For data on trends in U.S.- and foreign-trained postdocs in U.S. academic institutions, see the discussion of postdocs in chapter 2. For more information on employment aspects of postdoctoral appointments, see the discussion of postdocs in chapter 3.

26. The inclusion or exclusion of those on temporary and permanent visas has little impact on the analysis (see figure 5-20).

27. 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.

28. 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.

29. This measure was constructed slightly differently in the 1980s and in the 1990s, starting in 1993, and is not strictly comparable across these periods. In the 1980s, the survey question asked the respondent to select the primary and secondary work activity from a list of activities. Beginning in 1993, respondents were asked on which activity they spent the most hours and on which they spent the second most hours. Therefore, the crossing over of the two trends between 1991 and 1993 could partly reflect a difference in methodology. However, the faster growth rate for researchers in both the 1973–91 and 1993–2006 periods means that changes in question wording cannot fully explain the observed trend. Because individuals may select both a primary and a secondary work activity, they can be counted in both groups.

30. The data in this edition of *Indicators* do not include articles from journals in professional fields. Thus the article counts reported here for past years will be slightly lower than counts reported in previous editions. See sidebar, "Bibliometric Data and Terminology."

31. European Union (EU) data include all member states as of 2007 (see appendix table 5-33 for a list of member countries); previous editions of *Indicators* considered a smaller set. Thus the larger world share of S&E articles accounted for by the European Union is in no small part a result of the expanded EU membership. However, see the discussion of growth rates by region and country later in this section.

32. The Asia-10 includes China (including Hong Kong), Japan, India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Thailand, and Taiwan.

33. Uzun (2006) describes 20 years of Turkish science and technology policies that underlie the expansion of its article output.

34. Another use of these data, showing within-country/within-region S&E article field distributions as an indicator of the region/country portfolio of S&E research, has been discussed in past editions of *Indicators*. Although countries and regions display somewhat different emphases in their research portfolios, these patterns are stable and change only slowly over time. See, for example, *Science and Engineering Indicators 2006,* figure 5-38 and appendix tables 5-44 and 5-45 (NSB 2006).

35. The reader is reminded that the data on which these indicators are based give the nationality of the institutional addresses listed on the article. Authors are not associated with a particular institution and may be of any nationality. Therefore the discussion in this section is based on the nationality of the institutions, not authors themselves and, for practical purposes, makes no distinction between nationality of institutions and nationality of authors.

36. Merton (1973, p. 409) points out the tension between the norms of priority and of allocating credit in science: "Although the facts are far from conclusive, this continuing change in the social structure of research, as registered by publications, seems to make for a greater concern among scientists with the question of 'how will my contribution be identified' in collaborative work than with the historically dominant pattern of wanting to ensure their priority over others in the field…It may be that institutionally induced concern with priority is becoming overshadowed by

the structurally induced concern with the allocation of credit among collaborators."

37. In this section only, author names refer to counts of individually listed authors of articles, not institutional authors. Since authors may appear on more than one article per year, they may be counted more than once. However, because NSF does not analyze individual author names, the extent of such multiple counting is unknown.

38. The coauthorship data discussed in this paragraph are restricted to coauthorship across the regions/countries identified in table 5-23; i.e., collaboration between or among countries of the European Union, for example, is ignored. *Intraregional* coauthorship is discussed in the following sections.

39. Readers are reminded that each country participating in an international coauthorship receives one full count for the article; i.e., for an article coauthored by the United States and Canada, both the United States and Canada receive a count of one. In the percentages discussed in this paragraph, the numerators for the country pairs are the same. The denominators vary, accounting for the different rates of coauthorship.

40. Readers are reminded that the *number* of coauthored articles between any pair of countries is the same; each country is counted once per article in these data. However, countries other than the pairs discussed here may also appear on the article.

41. Identification of the sector of the non-U.S. institution is not possible with the current data set.

42. Readers are reminded that coauthors from different departments in an institution are coded as different institutions.

43. See note 42.

44. This chapter uses the convention of a 3-year citation window with a 2-year lag, e.g., 2005 citation rates are from references in articles in the 2005 tape year to articles on the 2001, 2002, and 2003 tapes of the Thomson Scientific Science Citation Index and Social Sciences Citation Index databases. Analysis of the citation data shows that, in general, the 2-year citing lag captures the 3 peak cited years for most fields, with the following exceptions: in astronomy and physics the peak cited years are generally captured with a 1-year lag, and in computer sciences, psychology, and social sciences with a 3-year lag.

45. Percentiles are specified percentages below which the remainder of the articles falls, for example, the 99th percentile identifies the number of citations 99% of the articles failed to receive. Across all fields of science, 99% of articles failed to receive at least 21 citations. Matching numbers of citations with a citation percentile is not precise because all articles with a specified number of citations must be counted the same. Therefore, the citation percentiles discussed in this section and used in appendix table 5-38 have all been conservatively counted, and the identified percentile is in every case higher than specified, i.e., the 99th percentile is always >99%, the 95th percentile is always >95%, etc. Actual citations/percentiles per field vary widely because counts were cut off to remain in the identified percentile. Using this method of counting, for example, the 75th percentile for engineering contained articles with two citations, whereas the 75th percentile for biological sciences contained articles with 5–8 citations.

46. This pattern holds for even lower citation percentiles (e.g., the 95th or 90th).

47. The previous edition of *Indicators* discussed various factors that may have contributed to the rise in university patenting, including federal statutes and court decisions (see NSB 2006, p 5-51 through 5-53).

48. For an overview of these developments in the 20th century, see Mowery (2002).

49. It is unclear whether the recent downturn in patents granted to universities/colleges is a result of changes in processing at the U.S. Patent and Trademark Office (USPTO). For example, in its Performance and Accountability Report Fiscal Year 2006, USPTO reported an increase in overall applications from 2002 to 2006; a decrease in "allowed" patent applications; and an increase in average processing time from 24 to 31 months (USPTO 2006).

50. The institutions listed in appendix table 5-40 have been reported consistently by USPTO since 1982. Nevertheless some imprecision is present in the data. Several university systems are counted as one institution, medical schools may be counted with their home institution, and universities are credited for patents only if they are the first-name assignee on a patent; other assignees are not counted. Universities also vary in how they assign patents, e.g., to boards of regents, individual campuses, or entities with or without affiliation with the university.

Glossary

Abilene: A high-performance network dedicated to research led by a consortium of universities, governments, and private industry; often called Internet2.

Academic doctoral S&E workforce: Includes those with a U.S. doctorate in an S&E field employed in 2- or 4-year colleges or universities 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 associates, and administrators; and part-time positions of all kinds.

Academic institution: In the "Financial Resources for Academic R&D" section of this chapter, 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. Elsewhere in the chapter, this term encompasses any accredited institution of higher education.

Asia-10: Asia-10 includes China (including Hong Kong), India, Indonesia, Japan, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand.

Coauthored articles: In the "Outputs of S&E Research: Articles and Patents" section of this chapter, a paper is considered coauthored only if its authors have different institutional affiliations or are from separate departments of the same institution. See *institutional author*.

Cyberinfrastructure: Infrastructure based on distributed computer, information, and communications 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 (FFRDC): R&D-performing organization 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.

Fractional counting: A method of counting articles based on authorship attribution. Fractional counting divides the credit for an article with authors from more than one institution or country among the collaborating institutions or countries, based on the proportion of their participating departments or institutions. This method is generally used for article and citation counts.

Index of highly cited articles: A country's share of the world's top 1% of cited articles divided by its world share of articles during a given period.

Index of international collaboration: A country's rate of collaboration with another country divided by the other country's rate of international coauthorship.

Institutional author: Designation of authorship according to the author's institutional affiliation at the time of publication. Institutional authorship is used to determine the number of institutional authors an article has for purposes of article counts. Multiple authors from the same department of an institution are considered as one institutional author. See *fractional counting* and *whole counting*.

National Lambda Rail: A national fiber optic infrastructure supporting multiple networks for the research community.

Net assignable square feet (NASF): 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 a specific use, such as research or instruction. NASF is measured from the inside faces of walls.

Research space: The space used for sponsored R&D activities at academic institutions that is separately budgeted and accounted for.

Tape year: The year an article entered the publication database, which may be later than the year the article was published.

Underrepresented minority: Demographic category including blacks, Hispanics, and American Indians/Alaska Natives, groups considered to be underrepresented in academic institutions.

Whole counting: A method of counting articles based on authorship attribution. Whole counting assigns each collaborating institution or country one credit for its participation in an article. This method is generally used for coauthorship data.

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Chapter 6

Industry, Technology, and the Global Marketplace

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Highlights

Key Economic Indicators of National Competitiveness

Key economic indicators show that the U.S. economy continues to be a leading competitor among other advanced economies.

- Key economic indicators of national competitiveness, gross domestic product (GDP) growth, rising per capita income, and productivity growth, suggest that the United States continues to be very economically competitive. The United States has generally outperformed the European Union (EU) and Japan on these measures during the past two decades.
- China and India show higher productivity growth and per capita income growth than exhibited by the United States and other advanced economies. Despite these rapid gains, the absolute levels of productivity and per capita income remain far lower for China and India.

U.S. Technology in the Global Marketplace

The United States has a leading position in the market-oriented knowledge-intensive service industries that are key contributors to economic growth around the world.

- Market-oriented knowledge-intensive services—business, financial, and communications—are driving growth in the service sector, which now accounts for nearly 70% of global economic activity. Market-oriented knowledge-intensive services generated $12 trillion in gross revenues (sales) in 2005 and grew almost twice as fast as other services between 1986 and 2005.
- The United States is the leading provider of market-oriented knowledge-intensive services, responsible for about 40% of world revenues on a value-added basis (gross revenue sales minus the purchase of domestic and imported supplies and inputs from other industries) over the past decade. The U.S. world share of value added exceeds world share of both the EU and Asia in all three industries.
- Asia, ranked third compared with the United States and the EU, has shown a steady rise in its world value-added share over the past two decades. China and India are leading Asia's increase, primarily in communications.

High-technology manufacturing industries are key contributors to global manufacturing sector growth.

- Over the past 20 years, the rate of growth in world gross revenue in high-technology manufacturing industries was double that of other manufacturing industries. Asia has the largest high-technology manufacturing industry sector, followed by the United States and the EU, which ranks a distant third.
- The United States has the single largest value-added world share (35% in 2005) of any country in high-technology manufacturing industries. It is ranked first in three of the five high-technology industries (scientific instruments, aerospace, and pharmaceuticals) and is ranked second in the other two (communications equipment and office machinery and computers).
- China has made remarkable progress: its world share of high-technology manufacturing value added has more than quadrupled during the past decade. Estimates for 2005 show China accounting for 16% of world value added, making it the third-ranked country globally, just shy of Japan, whose world share in these industries fell sharply from 30% in 1989 to an estimated 16% in 2005.
- U.S. manufacturing has become more technology intensive, with the high-technology share of manufacturing industries increasing from 14% in 1990 to 24% in 2005. The high-technology share of China and India's manufacturing industries has also increased, suggesting that manufacturing output in lower-wage countries is also shifting toward technology-intensive goods.

U.S. Trade Balance in High-Technology Manufacturing and Technology Products

The U.S. trade balance in high-technology manufacturing industries and advanced products has declined.

- The U.S. world market share of exports by high-technology industries dropped from about 20% in the early 1990s to 12% in 2005, primarily because of losses in export share by U.S. industries producing communications equipment and office machinery and computers.
- The trend for China has been quite different. China's share has grown rapidly; its world market share of high-technology industry exports has more than doubled, from 8% in 1999 to an estimated 19% in 2005. Exports by China's high-technology industries surpassed those of Japan in 2001, the EU (excluding intra-EU exports) in 2002, and the United States in 2003. China has become the world's largest exporter.
- The reduction of U.S. industry's world export share has coincided with the decline in the U.S. trade balance in high-technology manufacturing industries that began in the late 1990s.
- The historically strong U.S. trade balance in advanced technology products exhibited a similar reduction, shifting from surplus to deficit starting in 2002. The overall U.S. trade deficit is largely driven by U.S. trade with Asian countries, especially China and Malaysia.

U.S. Royalties and Fees Generated From Intellectual Property

The United States continues to be a net exporter of intellectual property, primarily in manufacturing technology know-how and licensing of computer software.

- U.S. companies received $33 billion in net revenues generated by intellectual property from affiliated and unaffiliated foreign companies in 2005.
- The United States ran surpluses in manufacturing know-how and licensing of computer software with unaffiliated companies, largely driven by trade with Asia, the largest purchaser of U.S. intellectual property in these areas.

New High-Technology Exporters

Indicators that may be relevant to long-term high-technology export potential show that China is the highest ranked among the six large developing economies examined.

- China is the highest ranked high-technology exporter of the six large developing economies (the other economies are India, Russia, Mexico, Brazil, and Indonesia) according to its composite score in 2007. China was ranked fourth a decade ago, then moved to second in 1999 and first in 2002, overtaking India, the previous leader.
- Russia is ranked third of the larger developing economies in 2007, although this ranking has fluctuated over the last decade. Mexico, ranked fourth, improved its position compared with past cycles. Brazil, ranked fifth, continued a decade-long decline in its ranking.

S&E Publications in Peer-Reviewed Journals

U.S. S&E publications in peer-reviewed journals with at least one author from private industry declined in both absolute and relative terms between 1988 and 2005 (a period during which intensified, global competition emerged), and the share of such publications appearing in basic research journals has also declined during this period.

- Industry's share of overall U.S. S&E article output declined from just below 9% to about 6% between 1988 and 2005.
- After peaking at 26% in 1995, the percentage of S&E articles with an industrial author published in basic research journals declined to 22% by 2005.

Global Trends in Patenting

The United States continues to be the leading source of newly patented inventions compared with the EU and Asia. Asia's patenting activity is growing rapidly, however, especially in Japan, South Korea, and Taiwan.

- Inventors residing in the United States accounted for 53% of U.S. patent applications in 2005. Asia, the second-ranked source of U.S. patent applications, more than doubled its share from 13% two decades ago to 29% in 2005, led by growth from Japan, South Korea, and Taiwan. U.S. patent applications from China and India are also growing, although from a low level.
- U.S. inventors are also the leading source of economically valuable patents known as triadic patents. (Triadic patents include only those inventions for which patent protection is sought in all three major world markets: the United States, Europe, and Japan.)
- In 2005, the U.S. share of triadic patents was estimated at 37%, followed by the EU (30%) and Asia (28%). Asia's share of these more important, economically valuable patents has been flat, unlike its rising share of U.S. patent applications.
- U.S. inventors are the leading source of U.S. patents granted in two key technology areas: (1) information and communications technology (ICT) and (2) biotechnology. Asia is ranked second as a source of U.S. patent grants in ICT and third in biotechnology, and the EU is ranked third as a source in ICT and second in biotechnology.

U.S. High-Technology Small Businesses

High-technology small businesses are a key sector for developing, adopting, and diffusing new technologies in the U.S. economy. Two types of financing, angel and venture capital, are critical for the formation and growth of high-technology small businesses.

- High-technology small businesses employed 5 million workers in 2004, one-third of the total high-technology labor force. Service industries account for two-thirds of these workers, and manufacturing employs most of the remainder (31%).
- Angel investment plays an important role in the formation of high-technology companies. Angel investors financed 51,000 firms with $26 billion in 2006, an 11% increase compared with 2005. The top three technology areas receiving angel investment in 2006 were healthcare and medical devices, biotechnology, and computer software.
- Venture capital plays a key role in financing young high-technology firms that are expanding. Venture capitalists financed nearly 3,000 firms with $26 billion in 2006, 14% higher than 2005. Technology areas that received the largest share of venture capital investment were computer software (20%), biotechnology (18%), and communications (16%).

Introduction

Chapter Overview

This chapter focuses on industry's vital role in the nation's science and technology (S&T) enterprise and how the national S&T enterprise develops, uses, and commercializes S&T investments by industry, academia, and government.[1] Various indicators that track U.S. industry's national activity and standing in the international marketplace for technology products and services and technology development are discussed. Using public and private data sources, U.S. industry's technology activities are compared with those of other major regional economies, particularly the European Union (EU) and Asia.[2]

Past assessments showed the United States to be a leader in many technology areas. *Science and Engineering Indicators 2006* showed that advancements in information technologies (computers and communications products and services) drove the rising trends in new technology development and dominated technical exchanges between the United States and its trading partners. The chapter will examine whether the United States continues to be a leader in technology products and services and assess the competitiveness of the United States in the global economy.

Chapter Organization

This chapter leads off with a new section about how several key economic indicators that provide some perspective on trends in U.S. competitiveness compare with those of Europe, Japan, and the emerging economies of China and India. The chapter then examines the U.S. position in the global marketplace within the service and manufacturing industries, focusing on industries that have a particularly strong linkage to S&T. Because the service sector has become a key driver of global economic activity, considerable discussion is devoted to the U.S. global position in these industries.

Following this discussion, trends in the U.S. global position in production and trade of high-, medium-, and low-technology industries are examined and compared with trends in the EU and Asia. The U.S. trade position in advanced technology goods and intellectual property is also discussed. The chapter next presents indicators that may be useful for assessing the potential for countries to become more important exporters of high-technology products. For the first time, the chapter looks at trends in publishing output, as measured by articles by U.S. industry authors in peer-reviewed journals, to examine changes in one measure of the role of industry in the performance of research. This discussion is followed by analysis of U.S. inventiveness trends using data on U.S., European, and triadic patents. Trends in patenting by U.S. inventors are compared with those by European and Asian inventors, focusing on trends of two technologies: biotechnology and information and communications technology (ICT). Finally, the chapter looks at trends in high-technology-oriented U.S. small businesses that can have a particularly strong relationship to entrepreneurship in S&T. Data are presented on small businesses by technology area, employment, formation, and sources of financing.

Key Economic Indicators of U.S. Competitiveness

S&E and the technological innovations that emerge from R&D activities enable high-wage nations such as the United States to compete in today's highly competitive global marketplace. Many of the innovative new products found around the world, many of the inventions and manufacturing process innovations that improve worker productivity, and many of the transformative innovations that create not just new companies but new industries can be traced back to earlier national investments in S&E and R&D. Business application and marketing of these innovations make large contributions to national economic growth and support U.S. economic competitiveness in the marketplace at home and abroad (Okubo et al. 2006).[3]

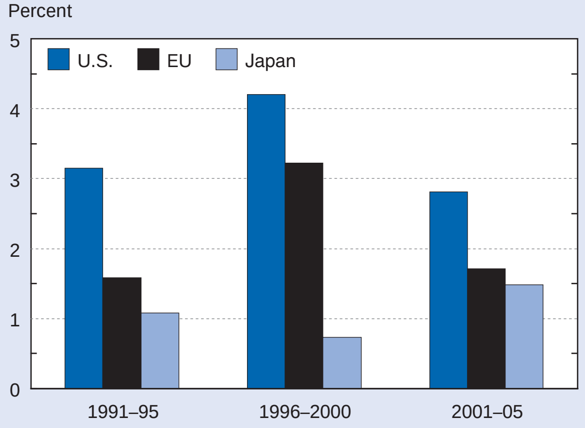
An international standard used to judge a nation's competitiveness rests on the ability of its industries to produce goods that sell in the marketplace while simultaneously maintaining, if not improving, the standard of living for its citizens (OECD 1996). Three macroeconomic indicators that help to measure this standard of national competitiveness are economic growth, standard of living, and productivity. Trends in these indicators for the United States are presented alongside those for the EU and Japan, which also rely on R&D and other S&E investments to support national competitiveness.

Trends in National Economic Growth, Standard of Living, and Labor Productivity

National Economic Growth

The U.S. economy, the largest of any nation, continues to be one of the fastest growing compared with other large, advanced economies (figure 6-1; appendix table 6-1). With the expansion of country membership, the EU has become an economic area slightly larger than the United States, $13.0 trillion versus $12.4 trillion on a purchasing power parity basis in 2005. (Purchasing power parity (PPP) is the exchange rate required to purchase an equivalent market basket of goods.) Both economies measured more than three times larger than that of Japan. Breaking down the past 15 years into three 5-year periods, the U.S. economy grew faster than either the EU or Japan during each of the three periods. U.S. gross domestic product (GDP) grew at an average annual rate of 3.2% from 1991 to 1995, by 4.2% from 1996 to 2000, and by 2.8% from 2001 to 2005 (figure 6-1). During 2005, the most recent year for which these internationally comparable data are available, U.S. GDP grew by 3.2%.

Figure 6-1
Average annual GDP growth for United States, EU, and Japan: 1991–2005



EU = European Union; GDP = gross domestic product

NOTES: GDP converted to U.S. dollars using 2002 purchasing power parities at 2005 price level. EU excludes Bulgaria and Romania.

SOURCE: Conference Board and Groningen Growth and Development Centre, Total Economy Database (January 2007), http://www.ggdc.net/dseries/totecon.shtml. See appendix table 6-1.

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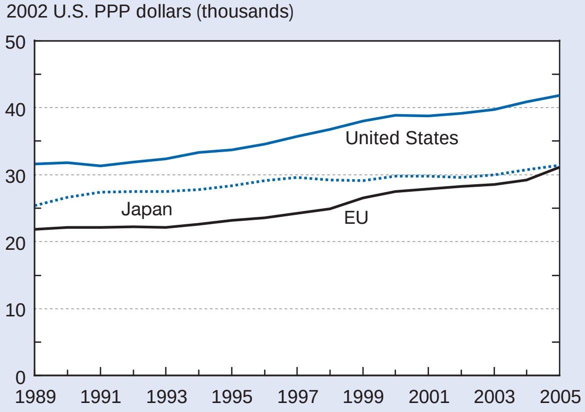
Figure 6-2
GDP per capita for United States, EU, and Japan: 1989–2005



EU = European Union; GDP = gross domestic product; PPP = purchasing power parity

NOTES: GDP converted to U.S. dollars using 2002 PPPs at 2005 price level. GDP per capita calculated using midyear population estimates. EU excludes Bulgaria and Romania.

SOURCE: Conference Board and Groningen Growth and Development Centre, Total Economy Database (January 2007), http://www.ggdc.net/dseries/totecon.shtml. See appendix table 6-1.

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Standard of Living

Faster growth of the U.S. economy, however, is due partially to more rapid population growth in the United States compared with the other two economies. Normalizing the value of all national economic activity (GDP) for population size provides a widely recognized measure of the national standard of living. During the same 15-year period discussed previously (1991–2005), U.S. GDP per capita increased each year except 2001, rising from $31,312 (inflation adjusted to PPP 2005 dollars) in 1991 to $41,824 in 2005 (figure 6-2; appendix table 6-1). GDP per capita in the EU was generally 25%–30% lower (in inflation adjusted to PPP dollars) than U.S. GDP per capita but followed a similar upward trend; 1993 was the EU's single year of declining GDP per capita. By comparison, during the same time period, Japan's standard of living grew much more slowly, experiencing several years of decline.[4]

Productivity of the United States and Other Advanced Economies

The high and rising standard of living enjoyed by the three advanced economies, the United States, the EU, and Japan, is influenced by the efficiency with which their resources (labor and capital) are employed, measured by labor or multifactor productivity. Labor and multifactor productivity are the change in GDP per unit of labor and combined unit of labor and capital, respectively.

Process innovations and the application of new capital equipment in the manufacturing process help to raise labor's productivity, allowing high-wage nations such as the United States to compete successfully in the global marketplace.

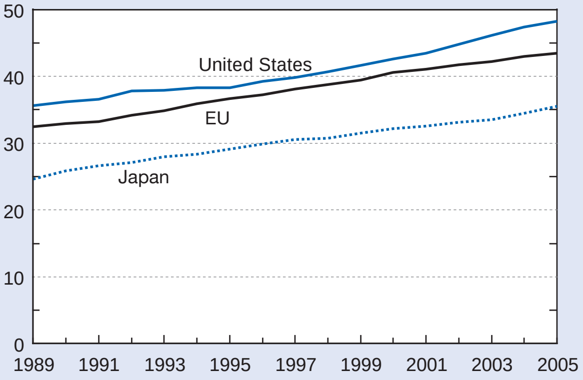
Labor productivity of the United States has exceeded that of the EU and Japan for at least several decades (figure 6-3; appendix table 6-2). Growth in U.S. productivity lagged behind that of the EU and Japan in the early 1990s, but rebounded in the latter half of the 1990s. U.S. productivity growth during this period has been attributed to the widespread diffusion of information technology (IT) throughout the economy.[5] The EU's and Japan's growth rates in productivity fell during the 1995–2000 period, and the EU's rate continued to decline from 2000 to 2005. As a result, the gaps between the levels of labor productivity of the United States, the EU, and Japan have widened over the past decade.

International Comparisons of Labor Compensation

Productivity growth can directly affect the level and growth of wages in a country. Existing data allow only limited international comparison. An international indicator of relative wages across economies is compensation costs (direct wages and benefits) for production workers in manufacturing, which measure whether gains in productivity and per capita GDP have been accompanied by an increase in labor compensation. These compensation data do not fully take into account cost-of-living differences across countries, however.

Figure 6-3
GDP per hour worked for United States, EU, and Japan: 1989–2005

2002 U.S. PPP dollars



EU = European Union; GDP = gross domestic product; PPP = purchasing power parity

NOTES: GDP converted to U.S. dollars using 2002 PPPs at 2005 price level. EU excludes Bulgaria and Romania.

SOURCE: Conference Board and Groningen Growth and Development Centre, Total Economy Database (January 2007), http://www.ggdc.net/dseries/totecon.shtml. See appendix table 6-2.

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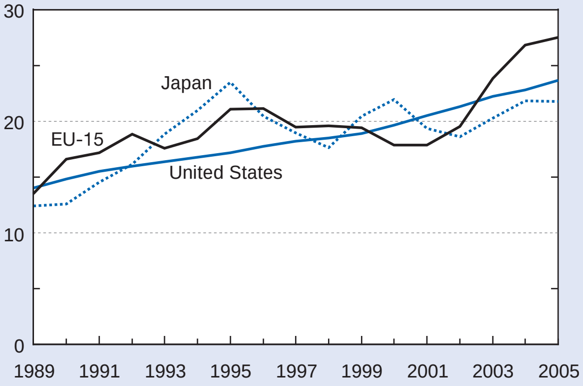
U.S. workers have enjoyed steady gains in compensation during the past decade and a half, coinciding with gains in U.S. productivity (figure 6-4; appendix table 6-3). The trend in compensation in the EU and Japan has been more volatile (in part reflecting fluctuations in exchange rates), but their levels are comparable to that of the United States. EU production workers generally fared better during this period than production workers in the United States and Japan, although this measurement does not adjust for differences in PPP within the three economies.

Data on wages and benefits for U.S. workers employed in broad sectors of the economy show that productivity growth has been accompanied by an increase in real wages and benefits paid to U.S. workers in private industry (table 6-1). Between 1989 and 2005, compensation for U.S. workers in the goods sector (manufacturing, construction, mining, and utilities) and the services sector (financial, retail, communications, and business) grew at 0.7% on an average annual basis adjusted for inflation. Compensation grew faster for white collar workers compared with blue collar workers in both sectors (table 6-1).

Judging from the measures discussed above, the United States continues to be highly competitive in the global marketplace. The U.S. economy continues to expand, finding demand for its products and services while maintaining relatively high compensation for U.S. workers and rising GDP per capita for its citizens.

Figure 6-4
Hourly compensation costs for manufacturing production workers for United States, EU-15, and Japan: 1989–2005

Current U.S. dollars



EU = European Union

NOTES: EU-15 includes member countries before enlargement in September 2004. Hourly compensation costs include direct wages and benefits. Wages in current dollars converted at market exchange rates of EU-15 and Japan.

SOURCES: Bureau of Labor Statistics, International Comparisons of Hourly Compensation Costs for Production Workers in Manufacturing (November 2006), http://www.bls.gov/news.release/ichcc.toc.htm, accessed 15 January 2007. See appendix table 6-3.

Science and Engineering Indicators 2008

Table 6-1
Average annual growth of real wages and benefits paid to U.S. workers and labor productivity, by selected economic sectors: 1989–2005

(Percent)

Sector	Annual growth/ productivity
Private industry	0.7
Goods sector	0.7
White collar	0.9
Blue collar	0.6
Services	0.7
White collar	0.8
Blue collar	0.5
Labor productivity (economywide)	1.8

NOTES: Productivity growth measured on basis of gross domestic product (GDP) per employee. GDP is 2005 U.S. dollars converted at 2000 purchasing power parities. Goods sector includes manufacturing, construction, mining, and utilities. Service sector includes financial, retail, communications, and business.

SOURCES: Conference Board and Groningen Growth and Development Centre, Total Economy Database (15 September 2006), http://www.ggdc.net/; and U.S. Bureau of Labor Statistics, Employment Cost Index, Historical Listing, Constant-dollar, 1975-2005, http://www.bls.gov/web/ecconst.pdf, accessed 25 June 2007.

Science and Engineering Indicators 2008

Rising Competitiveness of China and India

Economic growth in China and India has been rapid in recent years, and these two countries have increased their global market share, trade, and investment in many industries. Productivity and per capita income growth of these two countries, particularly China, appear to have been much more rapid in recent years than that of the United States and other advanced economies (table 6-2). Despite these apparently rapid gains, their absolute level of productivity and per capita income remain far lower than that of industrialized countries (see sidebar, "Measuring National Competitiveness of China and India").

U.S. Technology in the Global Marketplace

National investments in S&E, technological innovations developed from related activities, and R&D performed in all sectors of the economy, almost certainly play an important role in supporting U.S. competitiveness. This section of the chapter takes a closer look at both the industries that perform the bulk of R&D in the United States and recent trends of high-technology and lower-technology industry activity 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.

At least to some degree, S&T is important for growth and competitiveness of all industries. However, the Organisation for Economic Co-operation and Development (OECD) has identified 10 industries in services and manufacturing that have a particularly strong linkage to S&T:

- **Knowledge-intensive service industries.** Communications services, financial services, business services (including computer software development), education services, and health services (OECD 2001).[6] These five service industries incorporate sciences, engineering, and technology in either their services or the delivery of their services. Knowledge-intensive service industries are further divided into industries that are either largely market driven and known as market oriented (communications, financial, and business services) or are largely provided by the public sector (education and health services) (see sidebar, "U.S. Global Market Position in Education and Health Services").
- **High-technology manufacturing industries.** Aerospace, pharmaceuticals, computers and office machinery, communications equipment, and scientific (medical, precision, and optical) instruments.[7] These five science-based industries manufacture products while spending a relatively high proportion of their revenues on R&D.

This section presents revenue and trade data for the market-oriented knowledge-intensive services and high-technology manufacturing industries in 70 countries[8] (see sidebar, "Comparison of Data Classification Systems Used"). S&T is not exclusive to knowledge-intensive services and high-technology manufacturing; therefore this section will also examine the U.S. market position in other services and industries.

A critical issue is how to credit companies' output to industries and countries, given that production has become more global and dispersed across companies and industries. Companies increasingly use subsidiaries or contract other companies in a variety of industries located within and across national borders to help create their output.

Two measures are used in this chapter: *gross revenue* and *value-added revenue*, referred to as *value added*. Gross revenue is the value of the industry's shipments or services, equivalent to the industry's sales, including domestic and imported supplies and inputs from other industries. Gross revenue is an

Table 6-2
Selected economic and productivity indicators for United States, China, and India: 1995–2004

	Productivity growth (% average annual change)			GDP (US$)		
Country	1995–2004	1995–2000	2000–04	Per employee 2004	Per capita 2004	2004
United States	2.0	2.3	1.7	100	100	100
China	5.5	3.1	8.6	13	16	71
India	4.2	4.0	4.4	10	8	28

GDP = gross domestic product

NOTES: Productivity growth measured on basis of GDP per employee. GDP is U.S. dollars converted at 1990 purchasing power parities. China does not include Hong Kong.

SOURCE: Conference Board and Groningen Growth and Development Centre, Total Economy Database (September 2006), http://www.ggdc.net/dseries/totecon.shtml.

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Measuring National Competitiveness of China and India

The rapid economic advancement of China and India has sparked considerable interest and uncertainty about the measurement of their economies and productivity advancements. In the case of China, some scholars contend that official estimates of China's GDP, GDP per capita, and productivity growth have been overstated because of the difficulty and inaccuracy of estimating economic output within China's industry and service sectors.

Official estimates by the Chinese government and most international organizations suggest that labor productivity growth rates, as measured by real GDP per person employed, increased by an average of 7.3% between 1995 and 2004. Although a more conservative estimate by the Groningen Growth and Development Centre (GGDC) and The Conference Board (TCB) indicates an average productivity growth rate of 5.6% during the same period, this estimate also finds faster growth from 2000 to 2004 (8.6%) than official sources (7.6%) (table 6-2).

GGDC and TCB estimate that India's productivity growth averaged 4.4% during this period, as measured by GDP per employee (table 6-2). This is slower than China's growth, but significantly faster than the United States or other industrialized economies.

Despite uncertainties over the size of China's economy and its level of productivity, GGDC and TCB estimate that China's GDP and productivity are between 4 to 5 times higher on a purchasing power parity (PPP) basis than would be determined using China's official exchange rate. A PPP adjustment implies that China and India's GDP levels are about 71% and 28%, respectively, of the U.S. GDP level (table 6-2). China's and India's levels of productivity, however, remain far below that of the United States, estimated to be 13% and 10%, respectively, of U.S. 2004 levels.

U.S. Global Market Position in Education and Health Services

Many nations' governments serve as the primary provider of education and health 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 education and health services than for other service industries.

Education services include governmental and private educational institutions of all types that offer primary, secondary, and university education, as well as technical, vocational, and commercial schools. In 2005, fees (tuition) and income from education- and service-related operations amounted to $1.3 trillion in world value-added revenue (table 6-3; appendix tables 6-4 and 6-5). The U.S. education sector generated the most value added by far (41% in 2005), with the EU second (29%) and Asia third (14%). Asia's world share of education services revenues increased by 3 percentage points during the past decade, led by China and India. China's world share doubled from 3% to 6%, and India's share increased from 0.8% to 1.2%, coinciding with the rapid expansion in these countries of university-level enrollment and graduation of students in S&E and other fields. (See Chapter 2, section "Global Higher Education in S&E" for discussion about trends in S&E higher education in Asia and other countries.)

The United States, with arguably the least government involvement, has the largest health-service industry in the world, followed by the EU and Asia (table 6-3). In 2005, the U.S. health-service industry accounted for 38% of the $1.7 trillion in world revenue (value added) of the health-care sector, whereas the EU share was 29% and Asia's share was 19%.

Table 6-3
Value-added revenue and world share for selected service industries, by selected regions/countries: 1996, 2001, and 2005
(Percent)

Industry and region/country	1996	2001	2005
Education			
All regions/countries (2000 constant $trillion)	1.07	1.18	1.28
United States	40.0	39.8	40.6
EU	32.7	31.5	29.0
Asia	11.3	12.6	14.4
Health			
All regions/countries (2000 constant $trillion)	1.29	1.55	1.71
United States	40.5	36.5	38.4
EU	32.9	30.5	28.9
Asia	12.8	20.3	19.4

EU = European Union

NOTES: Value-added revenue excludes purchases of domestic and imported materials and supplies. EU excludes Cyprus, Estonia, Latvia, Lithuania, Malta, and Slovenia. Asia includes China, India, Indonesia, Japan, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. China includes Hong Kong.

SOURCE: Global Insight, Inc., World Industry Service database, special tabulations (15 April 2007).

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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	Data source	Data preparation
High-technology manufacturing industries	Industry shipments (sales), value-added exports, and imports in constant (2000) dollars	Industry by International Standard Industrial Classification	Aerospace, pharmaceuticals, office and computing equipment, communications equipment, scientific instruments	United Nations Commodity Trade Statistics and Global Insight, Inc.	Global Insight, Inc., proprietary special tabulations
Knowledge-intensive service industries	Industry production (revenues from services) in constant (2000) dollars	Industry by International Standard Industrial Classification	Business, financial, communication, health, education services	United Nations Commodity Trade Statistics and Global Insight, Inc.	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, and Japan patent offices)	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, European Patent Office, and Organisation for Economic Co-operation and Development (OECD)	U.S. Patent and Trademark Office and OECD
Angel capital	Funds invested by U.S. angel investors	Technology	Biotechnology, electronics, financial services, healthcare, industrial/energy, information technology, media, telecommunications	Center for Venture Research, University of New Hampshire	Center for Venture Research, University of New Hampshire
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	National Venture Capital Association	Thomson Financial Services, special tabulations

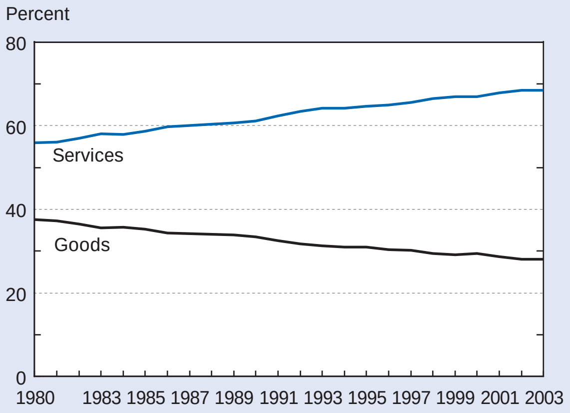
appropriate measure of the industry's impact on the national or global economy, because the industry's use of inputs boosts output in other domestic industries or countries.

Value added is gross revenue sales minus purchases of domestic and imported supplies and inputs from other industries. It is a more suitable indicator of an industry's direct contribution to the national economy because it excludes inputs from other industries and countries. In addition, value added adjusts for differences in the mix of labor, capital, and inputs used by an industry, which can vary across countries. The crediting of value-added output to regions or countries is imperfect, however, because a country receives credit on the basis of where the company reported the activity, which may be different from where the activity occurred.

Trade data are available for high-technology manufacturing industries but not market-oriented service industries. Trade data are on a gross-revenue basis, and country shares of world trade volume encompass inputs purchased from other industries and countries.

Another issue is classifying industries within a manufacturing or service category. In the data used here, companies are assigned to a single manufacturing or service industry on the basis of the largest share of the company's shipment of goods or delivery of services. This method of categorizing company activity is imperfect, because an industry classified as manufacturing may include services, and a company classified as being within a service industry may include manufacturing or directly serve a manufacturing company. Furthermore, the single industry classification is not a good measure for companies that have diversified activities in many categories of industries.

Figure 6-5
Services and goods shares of global economic activity: 1980–2003



NOTES: Services include wholesale and retail trade, hotels and restaurants, transportation, finance, real estate, education, health, and government. Goods include manufacturing, mining, construction, and utilities.

SOURCE: World Bank, World Development Indicators 2006, http://web.worldbank.org/WBSITE/E TERNAL/DATASTATISTICS/0,,contentMDK:20899413 pagePK:64133150 piPK:64133175 theSite PK:239419,00.html, accessed 25 June 2007.

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Global Trends in Market-Oriented Knowledge-Intensive Service Industries

The service sector has been growing faster than the manufacturing sector for at least two decades and is driving economic activity around the world (figure 6-5). The World Bank estimates that services constituted 68% of global economic activity in 2003 compared with a 56% share in 1980. Market-oriented knowledge-intensive services constitute a large and growing part of the service sector's output.[9] The worldwide gross revenue generated by market-oriented knowledge-intensive services more than doubled from $4.5 trillion in 1986 to $11.5 trillion in 2005, on a constant dollar basis (table 6-4).[10] Market-oriented knowledge-intensive service revenues grew at an average annual inflation-adjusted rate of 4.8% compared with 2.7% by other services during this 20-year period (table 6-4). In 1986, gross revenues of market-oriented knowledge-intensive services comprised 22% of all services; by 2005, their share had increased to 30%.

The United States, the EU, and Asia are the leading providers of market-oriented knowledge-intensive services, comprising nearly 90% of global value-added activity in 2005. The United States has the largest share among the three, responsible for about 40% of world service revenues on a value-added basis, a share that has remained constant for the past decade (figure 6-6; appendix tables 6-4 and 6-5). The EU is the next leading provider of high-technology services. Its share of world revenues, however, slipped from 26% in the mid-1990s to 25% in 2005 because of declines in service industry activity in Germany and Italy.

The third-leading provider of market-oriented knowledge-intensive services, Asia, shows a steady rise in world share over the past two decades (figure 6-6; appendix tables 6-4 and 6-5).[11] Over the past 10 years, Asia's world share rose by 2 percentage points to 22%. China, and to a lesser degree India, have driven the increase in Asia's world share. Between

Table 6-4
Global gross revenue of market-oriented knowledge-intensive and other service industries: Selected years, 1986–2005
(Trillions of 2000 constant dollars)

Industry	1986	1995	2000	2005	Average annual growth (%)
All service industries	20.24	27.52	33.06	38.49	3.3
Market-oriented knowledge-intensive services	4.54	6.86	9.44	11.52	4.8
Service industries not classified as market-oriented knowledge intensive	15.71	20.66	23.62	26.97	2.7
Market-oriented knowledge-intensive share of all services (%)	22.4	24.9	28.6	29.9	na

na = not applicable

NOTES: Knowledge-intensive services classified by Organisation for Economic Co-operation and Development and consist of business, financial, communications, education, and health services. Market-oriented knowledge-intensive services exclude education and health services. Gross revenue includes purchases of domestic and imported materials and inputs.

SOURCE: Global Insight, Inc., World Industry Service database, special tabulations (15 April 2007). See appendix tables 6-4 and 6-5.

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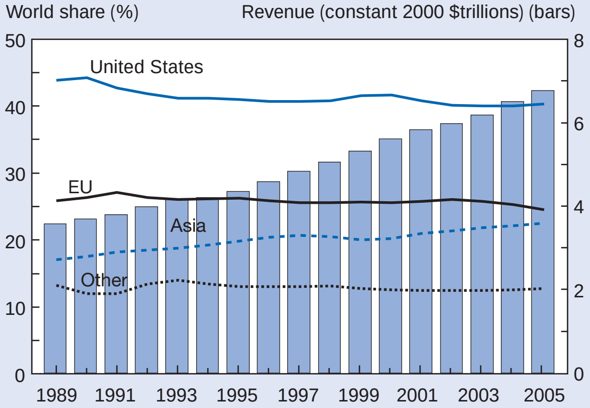
Figure 6-6
Value-added revenue and world share of market-oriented knowledge-intensive service industries, by selected regions/countries: 1989–2005



EU = European Union

NOTES: Knowledge-intensive services classified by Organisation for Economic Co-operation and Development and include business, financial, communications, education, and health services. Market-oriented knowledge-intensive services exclude education and health. Revenue on value-added basis, which excludes purchases of domestic and imported materials and inputs. EU excludes Cyprus, Estonia, Latvia, Lithuania, Malta, and Slovenia. Asia includes China, India, Indonesia, Japan, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. China includes Hong Kong.

SOURCE: Global Insight, Inc., World Industry Service database, special tabulations (15 April 2007). See appendix tables 6-4 and 6-5.

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1996 and 2005, China's growth in revenues was nearly twice the rate of the average for all of Asia, and its share of world revenues increased from 2.3% to 4.9%. India's revenues also grew considerably faster than Asia's average growth rate, although from a low level: India's world share rose from 0.7% to 1.1% during this period. Japan's revenues grew slower than the average rate for all of Asia, and its share of world revenues fell from 14.1% to 12.6% during this period.

U.S. Global Position in Market-Oriented Knowledge-Intensive Service Industries

The United States holds the leading position in all three industries that comprise market-oriented knowledge-intensive services (business, communications, and financial services) (table 6-5; appendix tables 6-4 and 6-5). The U.S. market is large and mostly open, which benefits U.S. industries in the global market in two important ways. First, supplying a domestic market with many consumers offers U.S. producers scale effects resulting from potentially large rewards for new ideas and innovations. Second, the relative openness of the U.S. market to foreign competitors in these three industries pressures U.S. producers to be innovative to maintain domestic market share.

Table 6-5
Global value-added revenue of market-oriented knowledge-intensive service industries and world share of selected regions: 1996 and 2005

Industry and region/country	1996	2005
Business		
Global revenue (2000 constant $trillions)	2.38	3.38
World share (%)		
United States	43.3	42.6
EU	28.2	29.3
Asia	17.1	16.9
Financial		
Global revenue (2000 constant $trillions)	1.61	2.28
World share (%)		
United States	36.9	37.6
EU	23.3	19.0
Asia	27.2	29.9
Communications		
Global revenue (2000 constant $trillions)	0.59	1.11
World share (%)		
United States	42.1	38.7
EU	22.7	22.2
Asia	16.2	22.6

EU = European Union

NOTES: Knowledge-intensive services classified by Organisation for Economic Co-operation and Development and consist of business, financial, communications, education, and health services. Market-oriented knowledge-intensive services exclude education and health services. Value-added revenue excludes purchases of domestic and imported materials and inputs. EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia. Asia includes China, India, Indonesia, Japan, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. China includes Hong Kong.

SOURCE: Global Insight, Inc., World Industry Service database, special tabulations (15 April 2007).

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Business Services

Business services, which include computer and data processing and commercial R&D, generated $3.4 trillion in 2005 as measured by value added, making this the largest knowledge-intensive industry (table 6-5; appendix tables 6-4 and 6-5). The United States has a leading position in this industry, and its share of global revenues (43% in 2005) has remained constant for the past decade. The EU and Asia rank second and third, respectively, in business services, and their world market shares have also remained essentially flat during this same period.

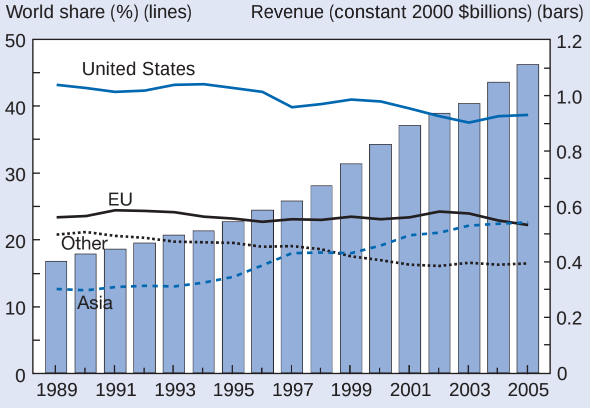
Financial Services

Financial services accounted for 34% of global value-added revenues generated by market-oriented knowledge-intensive service industries in 2005 (table 6-5; appendix tables 6-4 and 6-5). The United States is also a leader in this industry, with a world share of 38% in 2005, 1 percentage point higher than its share in 1996. Asia is ranked second in financial services, with a world share of 30% in 2005, 3 percentage points higher than its 1996 level. China's world share increased from 4% in 1996 to 8% in 2005. The EU ranked third in financial services, with a 19% share of world financial services industry revenues in 2005. Its share has declined by 4 percentage points over the past decade, primarily driven by declining revenues in industries within Germany and Italy.

Communications Services

The smallest of the knowledge-intensive industries ($1.1 trillion in 2005), communications services, is arguably the most technology driven. Provision of local and national communications services, however, is not fully open and competitive in many markets. In the United States, competition and new technologies have led to reductions in prices to consumers. In this industry, U.S. companies again hold a lead position, generating revenues equal to 39% of world value-added revenues in 2005 (figure 6-7; appendix tables 6-4 and 6-5). The U.S. world share in 2005, however, was 3 percentage points less than its share a decade ago. From 1996 to 2005, Asia's world market share jumped 6 percentage points, overtaking the EU in 2005 with a level of 23%. China and India drove Asia's ascent, with their communications industries averaging close to an annual average growth rate of 20% over the last decade. China and India's world shares more than doubled during this period, reaching 7% and 2%, respectively, in 2005. Japan's world share remained unchanged at 9%.

Figure 6-7
Global value-added revenue of communication services and world share of selected regions: 1989–2005



EU = European Union

NOTES: Revenue on value-added basis, which excludes purchased domestic and imported materials and inputs. EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia. Asia includes China, India, Indonesia, Japan, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. China includes Hong Kong.

SOURCE: Global Insight, Inc., World Industry Service database, special tabulations (15 April 2007). See appendix tables 6-4 and 6-5.

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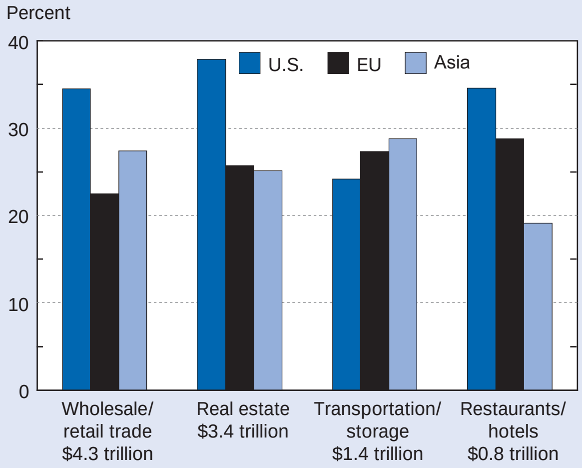
U.S. Global Position in Other Services

Commercially oriented services not classified as knowledge intensive include the wholesale and retail, restaurant and hotel, transportation, and real estate industries. These four industries incorporate S&T in their services or delivery of their services, but at a lower intensity compared with knowledge-intensive services. For example, inventory control incorporating IT technology has enabled the retail sector to cut costs and more precisely tailor and match inventory to meet customer demand.

The United States is leading in value added on a constant dollar basis within three of these four service industries: wholesale and retail, restaurant and hotel, and real estate (figure 6-8; appendix tables 6-6 and 6-7). The U.S. world market share has remained relatively constant during the past decade, although its position has changed in some industries. In the largest of these, wholesale and retail ($4.3 trillion in value added in 2005), the U.S. world share rose from 30% in 1996 to 35% in 2005, coinciding with the rapid rise of Wal-Mart and other retailers that compete aggressively on price and use sophisticated technology to manage their inventories.

Figure 6-8
Global value-added revenue and world share of selected service industries, by selected regions/ countries: 2005



EU = European Union

NOTES: Global revenue in 2005 of each sector shown in 2000 constant dollars. Revenue on value-added basis, which excludes purchases of domestic and imported materials and inputs. EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia. Asia includes China, India, Indonesia, Japan, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. China includes Hong Kong.

SOURCE: Global Insight, Inc., World Industry Service database, special tabulations (15 April 2007). See appendix tables 6-6 and 6-7.

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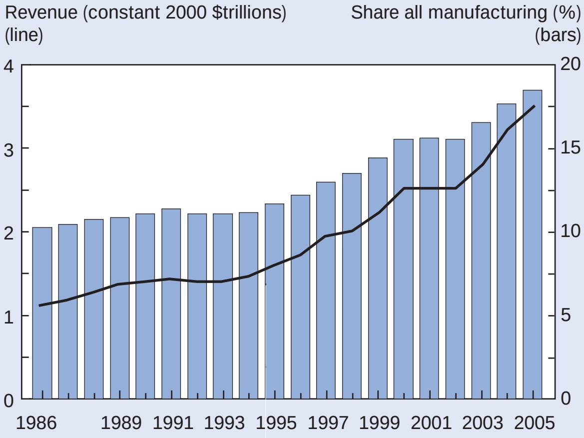
Importance of High-Technology Industries to Manufacturing

High-technology industries are driving growth in manufacturing activity worldwide. Between 1986 and 2005, high-technology manufacturing gross revenue rose from $1.1 trillion to $3.5 trillion in constant dollars (figure 6-9). Average annual growth during this 20-year period was 6%, more than double the rate for other manufacturing industries. In 2005, the high-technology share of all manufacturing output was 18% compared with 10% in 1986.

High-technology industries spend a relatively high proportion of their revenues on R&D compared with other manufacturing industries (table 6-6). R&D can lead to innovation, and companies that innovate tend to gain market share, create new product markets, and use resources more productively (NRC, Hamburg Institute for Economic Research, Kiel Institute for World Economics 1996; Tassey 2002).[12] High-technology industries also tend to develop high-value-added products, export more, and, on average, pay higher salaries than other manufacturing industries.[13] 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.

Figure 6-9
Global high-technology manufacturing industry gross revenue and share of all manufacturing industries: 1986–2005



NOTES: High-technology manufacturing industries classified by Organisation for Economic Co-operation and Development and include aerospace, communications equipment, office machinery and computers, pharmaceuticals, and scientific instruments. Revenue on gross basis, which includes purchases of domestic and imported materials and inputs.

SOURCE: Global Insight, Inc., World Industry Service database, special tabulations (15 April 2007).

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U.S. Global Position in High-Technology Manufacturing Industries

The United States, the EU, and Asia collectively dominate global activity in high-technology manufacturing industries (more than 90% of world activity), similar to their strong position in market-oriented knowledge-intensive services. U.S. high-technology manufacturers rank second, as measured by their share of world value added, compared with the EU and Asia (figure 6-10; appendix tables 6-8 and 6-9). After moving up sharply in the late 1990s, the U.S. share has remained essentially flat at 34%–35% since 2001. U.S. consumption of high-technology manufactured goods also exhibited a sharp increase in the late 1990s (see figure 6-11 in sidebar, "Consumption of High-Technology Manufactured Goods"). Asia has ranked first in high-technology manufacturing value added since 1987, with the exception of 2001. The United States, however, has the largest share of any country in high-technology industries since overtaking Japan in 1997.

The EU has a sizably smaller world share than the United States or Asia (figure 6-10; appendix tables 6-8 and 6-9), and its world share has fallen continuously from 25% in 1995 to 18% in 2005. Reduced manufacturing activity in four EU countries (Italy, the United Kingdom [UK], Germany, and Spain) led to the EU share's decline over the past 10 years.

Several Asian countries, mainly China and Japan, have had dramatic shifts in their market positions during the past two decades (table 6-7; appendix tables 6-8 and 6-9):

- Japan's share of world value added peaked in 1989 at 29%, nearly doubling its level in the early 1980s before declining steeply in the late 1990s. In 2005, Japan's high-technology manufacturers accounted for 16% of world value added. As a result of the decline in its world share, Japan's country ranking slipped from first to second.
- China's world share rose from 2% in the late 1980s to 4% by 1997, then accelerated sharply to reach 16% in 2005, just 0.1 percentage point below Japan's share. The fifth-ranked country by world share in 1998, China rose to third-ranked in 2005, overtaking the UK and Germany.
- South Korea's world share nearly doubled from 2% in 1993 to almost 4% in 2005. Its country ranking moved from 10th to 5th during this period, overtaking Italy, France, and the UK.
- India's world share, although doubling between 1989 and 2005, remained very small, at less than 0.5%.

High-Technology Industries and Domestic Production

Increasingly, manufacturers in countries with high standards of living and labor costs have moved their manufacturing operations to locations with lower labor costs. High-technol-

Table 6-6

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	2,423	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/54/0,3343,en_2649_201185_21573686_1_1_1_1,00.html.

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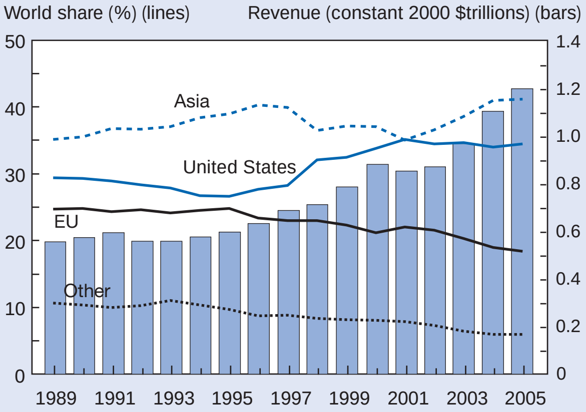
ogy industries and their factories are coveted by local, state, and national governments because these industries consistently show a larger share of value added to gross revenue in the final product than do other manufacturing industries. (Value-added revenue equals gross revenue excluding purchases of domestic and foreign supplies and inputs.)

In the United States, high-technology industries created about 20% more value-added per dollar of gross revenue than other manufacturing industries (figure 6-12).[14] High-technology industries also generally pay higher wages than other manufacturing industries.[15] Recognition of these contributions has led to intense competition among nations and localities to create, attract, nurture, and retain high-technology industries.[16]

During the 1990s, manufacturing output in the United States and other high-wage countries continued to shift into higher value-added, technology-intensive goods, often referred to as *high-technology manufactures* (figure 6-13). In 1990, high-technology manufacturing accounted for about 14% of all U.S. manufacturing value added. Growth in demand for communications and computer equipment increased the high-technology share of U.S. manufacturing to 19% in 2000 and 24% in 2005. The EU also saw high-technology manufactures account for a growing share of its total domestic production, although to a lesser degree. In 1990, high technology accounted for 10% of EU manufacturing value added, but by 2005 this had risen to 14%.

Asia's manufacturing production is also driven by high-technology industries (figure 6-13). The high-technology share of Asia's total manufacturing value added increased from 16% in 1990 to 22% in 2005. Japan's share, however, remained flat between 2000 and 2005. China's high-technology share of its total manufacturing more than doubled from 11% in 1990 to 28% in 2005, exceeding the comparable figure for the United States. India's share grew modestly from 6% to 9% during this period.

Figure 6-10
Value-added revenue and world share of high-technology manufacturing industries, by selected regions/countries: 1989–2005



EU = European Union

NOTES: High-technology manufacturing industries classified by Organisation for Economic Co-operation and Development and include aerospace, communications equipment, office machinery and computers, pharmaceuticals, and scientific instruments. Revenue on value-added basis, which excludes purchases of domestic and imported materials and inputs. Asia includes China, India, Indonesia, Japan, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. China includes Hong Kong. EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia.

SOURCES: Global Insight, Inc., World Industry Service database, special tabulations (15 April 2007). See appendix tables 6-8 and 6-9.

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Global Competitiveness of Individual High-Technology Industries

The global market for communications equipment is the largest of the high-technology markets, as measured by share of global value added, accounting for nearly half of the total output of high-technology industries in 2005 (table 6-9; appendix tables 6-10 and 11).[17] Pharmaceuticals are the next largest segment, comprising 19%, followed by scientific instruments (14%), office machinery and computers (14%), and aerospace (8%).

The United States has a leading position, as measured by its world share of value added, in scientific instruments, aerospace, and pharmaceuticals compared with Asia and the EU. The United States is ranked second of the three economies in communications equipment and office machinery and computers (table 6-9; appendix tables 6-10 and 6-11). The large size and openness of the U.S. market that benefits U.S. service industries similarly benefits high-technology manufacturing industries. Additionally, the U.S. government influences the size and growth of the nation's high-technology industries through 1) investments in industrial R&D purchases of new products, 2) laws regulating sales to foreign entities of certain products produced by each of the five high-technology industries, and 3) policies that create an enabling environment by promoting innovation, investment, and entrepreneurship.[18]

Communications equipment. In this industry, U.S. manufacturers reversed downward trends evident during the 1980s to grow and gain market share in the mid- to late 1990s, partly because of increased capital investment by U.S. businesses (see sidebar, "U.S. IT Investment"). The U.S. share of world communications equipment value added grew by more than 20 percentage points between 1995 and 2005 to reach 34% (figure 6-14; appendix tables 6-10 and 6-11). Asia's world share slipped by about 10 percentage points because of the rapid decline of Japan, which had been the world's leading supplier of communications equipment until 2000. Japan's share fell from 42% to 23% during this period. China's world share tripled, rising from 5% to 15%. The EU's world share decreased from 19% to 12%, led by losses by Italy and the UK.

Table 6-7
World share of value-added revenue of high-technology manufacturing industries for selected Asian countries: Selected years, 1989–2005
(Percent)

Region/country	1989	1993	1997	2000	2003	2005
Asia	35.1	37.0	39.9	37.0	38.6	41.2
China	1.9	3.3	3.9	5.3	11.1	16.1
India	0.2	0.3	0.4	0.3	0.4	0.4
Japan	29.3	27.3	27.3	22.0	17.9	16.2
Malaysia	0.2	0.6	1.0	1.0	0.9	1.0
Singapore	0.9	1.3	1.6	1.5	1.2	1.2
South Korea	1.2	1.8	2.7	3.7	3.8	3.6
Taiwan	1.3	2.0	2.1	2.5	2.4	1.7

NOTES: High-technology manufacturing industries classified by Organisation for Economic Co-operation and Development and include aerospace, communications equipment, office machinery and computers, pharmaceuticals, and scientific instruments. Value-added revenue excludes purchases of domestic and imported materials and inputs. Asia includes China, India, Indonesia, Japan, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. China includes Hong Kong.

SOURCE: Global Insight, Inc., World Industry Service database, special tabulations (15 April 2007). See appendix tables 6-8 and 6-9.

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Consumption of High-Technology Manufactured Goods

Production of high-technology goods feeds both domestic demand and foreign markets. A broad measure of domestic use is provided by adding domestic sales to imports and subtracting exports. Use so defined encompasses two different concepts: consumption of final goods and capital investment for further production (intermediate goods). Available data series do not permit examining these two concepts separately.

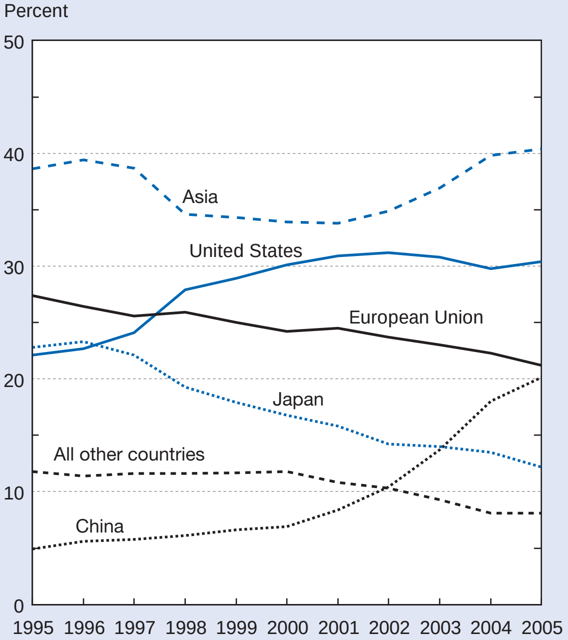
During the past decade, use of high-technology goods has more than doubled after accounting for inflation, from $1.6 trillion to $3.5 trillion (table 6-8). The strong U.S. economy registered higher growth, more than tripling from 1995 to 2005, compared with below-average growth for the EU and almost no change for Japan. In China, use of high-technology manufactures rose ninefold, approaching the level of the EU.

The Chinese trend underscores the difficulty of teasing out *final consumption* from use as intermediate goods. The strong rise in the Chinese trend is considered by many observers to reflect the rising inflow of intermediate goods, often previously produced in China, from other Asian manufacturing centers into China for further assembly and ultimate export.

Patterns of the world's use of high-technology manufactures have changed considerably over the past decade. Bearing in mind the difficulty of breaking these trends into final consumption versus investment, the U.S. share rose from 22% in 1995 to about 30% in 2000 and has largely stayed at that level (figure 6-11). The EU's share fell from 27% to 21% during the same decade (1995–2005), and Japan's declined by nearly half from 23% to 12%. China's share accelerated from 7% in 1999 to 20% in 2005.

Figure 6-11

World share of apparent consumption of high-technology manufacturing industries: 1995–2005



NOTES: Apparent consumption is domestic production and imports minus exports. European Union excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia. Asia includes China, India, Indonesia, Japan, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. China includes Hong Kong.

SOURCE: Global Insight, Inc., World Industry Service database, special tabulations (15 April 2007).

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Table 6-8

Domestic use of high-technology goods, by selected regions/countries/economies: Selected years, 1995–2005

(Billions of constant 2000 dollars)

Region/country/economy	1995	1997	1999	2001	2003	2005
All countries	1,565	1,904	2,245	2,524	2,819	3,533
United States	346	458	649	781	867	1,074
European Union	429	488	561	617	649	747
Asia	604	736	771	853	1,039	1,426
China	76	111	148	212	385	709
Japan	357	421	401	399	395	432
South Korea	45	55	71	97	103	127
Taiwan	42	49	68	57	66	74
All others	185	221	264	273	263	285

NOTES: Domestic use is sum of domestic production and imports minus exports. High-technology manufacturing industries classified by Organisation for Economic Co-operation and Development and include aerospace, communications equipment, office machinery and computers, pharmaceuticals, and scientific instruments. European Union excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia. Asia includes China, India, Indonesia, Japan, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. China includes Hong Kong.

SOURCE: Global Insight, Inc., World Industry Service database, special tabulations (15 April 2007).

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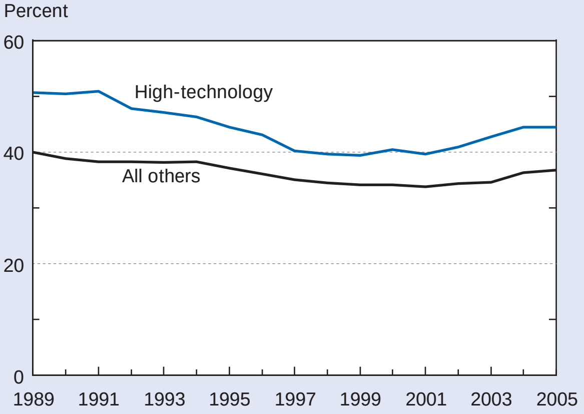
Figure 6-12
Value-added share of gross revenue of U.S. manufacturing industries: 1989–2005



NOTES: High-technology manufacturing industries classified by Organisation for Economic Co-operation and Development and include aerospace, communications equipment, office machinery and computers, pharmaceuticals, and scientific instruments. Value-added revenue excludes purchases of domestic and imported materials and inputs. Gross revenue includes purchases of domestic and imported materials and inputs.

SOURCE: Global Insight, Inc., World Industry Service database, special tabulations (15 April 2007).

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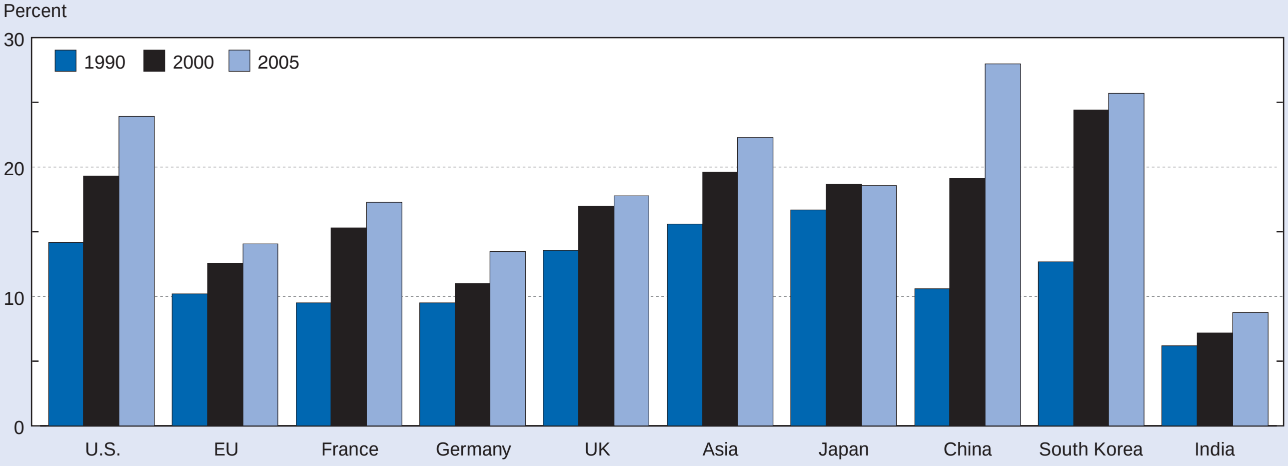
Computers and office machinery. The trends in the office and computer machinery manufacturing industry were similar to those in communications equipment. The United States, which was the second-ranked country by its world value added in 1995 (13%), doubled its share over a decade, surpassing Japan in 2000, to become the largest country until 2003, when it was overtaken by China (figure 6-15; appendix tables 6-10 and 6-11). Japan, which had been the largest country producing computer and office machinery equipment for most of the past two decades, had a sharply lower value added share, from 45% in 1995 to 9% in 2005. China's progress, however, was remarkable; its share of world value added expanded from 2% in 1995 to 46% in 2005. This rapid rise resulted in China surpassing both Japan in 2002 and the U.S. in 2003 to become the largest producing country in this industry.

Pharmaceuticals. As a result of varying degrees of public financing and regulation of pharmaceuticals throughout the world, as well as differing national laws governing the distribution of foreign pharmaceuticals, market comparisons in this industry may be less meaningful. The United States, the EU, and Asia accounted for 90% of global value-added revenue in 2005 (table 6-9; appendix tables 6-10 and 6-11). The United States is the leader by a small margin, and its world share has fluctuated between 30% and 35% over the past decade. The EU's world market share was roughly

Figure 6-13
High-technology share of all manufacturing industry value-added revenue for selected regions/countries: 1990, 2000, and 2005



EU = European Union; UK = United Kingdom

NOTES: High-technology manufacturing industries classified by Organisation for Economic Co-operation and Development and include aerospace, communications equipment, office machinery and computers, pharmaceuticals, and scientific instruments. Revenue on value-added basis, which excludes purchases of domestic and imported materials and inputs. EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia. Asia includes China, India, Indonesia, Japan, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. China includes Hong Kong.

SOURCE: Global Insight, Inc., World Industry Service database, special tabulations (15 April 2007).

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Table 6-9
Global value-added revenue of high-technology manufacturing industries and world share of selected regions/countries: 1995 and 2005
(Percent)

Industry and region/country	1995	2005
Aerospace		
Global value-added revenue (2000 constant $billions)	77.0	91.7
World share		
United States	56.9	49.4
EU	27.1	26.8
Asia	5.4	15.6
Pharmaceuticals		
Global value-added revenue (2000 constant $billions)	135.5	233.8
World share		
United States	29.8	32.2
EU	28.5	29.5
Asia	28.0	28.4
Office and computing machinery		
Global value-added revenue (2000 constant $billions)	65.7	163.5
World share		
United States	12.8	23.9
EU	20.6	8.4
Asia	60.6	64.2
Communications equipment		
Global value-added revenue (2000 constant $billions)	218.7	544.0
World share		
United States	13.6	34.4
EU	18.9	11.7
Asia	60.1	50.5
Medical, precision, and optical instruments		
Global value-added revenue (2000 constant $billions)	101.1	168.3
World share		
United States	36.4	40.1
EU	33.4	29.8
Asia	19.3	20.1

EU = European Union

NOTES: High-technology manufacturing industries classified by Organisation for Economic Co-operation and Development. Value-added revenue excludes purchases of domestic and imported materials and inputs. EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia. Asia includes China, India, Indonesia, Japan, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. China includes Hong Kong.

SOURCE: Global Insight, Inc., World Industry Service database, special tabulations (15 April 2007). See appendix tables 6-10 and 6-11.

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steady during the past decade. In Asia, Japan, China, and South Korea are the largest producers of pharmaceuticals (appendix tables 6-10 and 6-11). Although Japan still has the larger domestic industry, China's share has grown steadily while Japan's has generally declined. In 1995, domestic production by Japan's industry accounted for 21% of global value-added revenue, but by 2005 this proportion had fallen to 13%. In 2005, China's pharmaceutical industry accounted for an estimated 8% of global value-added revenue, quadruple its share in 1995. South Korea's share of global value added edged up from 2% to 3%, and India's share doubled from 1% to 2% during this period.

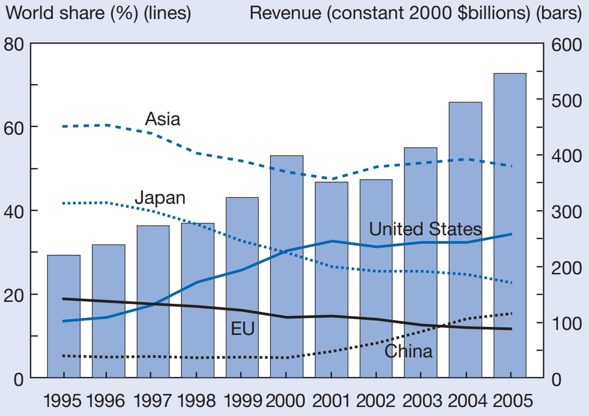
Scientific instruments. In 2001, the industry that produces scientific instruments (medical, precision, and optical instruments) was added to the group of high-technology industries, reflecting that industry's high level of R&D within advanced nations (table 6-6). The United States is the leading producer of scientific instruments, accounting for 40% of global revenue on a value-added basis in 2005 (table 6-9; appendix tables 6-10 and 6-11). The U.S. position has strengthened since 1995, as measured by world share, which rose 4 percentage points. Ranked second, the EU lost 3 percentage points in world share between 1995 and 2005, resulting from declines on the part of the UK, Italy, and Germany.

In Asia, Japan and China are the largest producers of scientific instruments. As in some other high-technology manufacturing industries, Japan's share of value-added global revenue in this industry is declining while China's share is increasing (appendix tables 6-10 and 6-11). In 1995, Japan's industry producing scientific instruments accounted for 15% of world value-added output; however, its share declined to about 11% in 2005. China's industry, which accounted for 2% of global value-added revenue in 1995, tripled to 6% in 2005.

Aerospace. The U.S. aerospace industry has long maintained a leading position in the global marketplace. The U.S. government is a major customer for the U.S. aerospace industry, contracting for military aircraft, missiles, and 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.

In recent years, however, the aerospace industry's manufacturing share has fallen more than any other U.S. high-technology industry. Since peaking at 73% of global value-added revenue in 1987, the U.S. share fell to 58% in 1999 and continued to decline to less than half of global value-added revenue in 2005 (table 6-9; appendix tables 6-10 and 6-11). European aerospace manufacturers, particularly within Germany and the UK, made gains during this time. By 2005, the EU accounted for 27% of world aerospace value-added revenue, up from 19% in 1985 (appendix tables 6-10 and 6-11).[19] Asia's share of the global aerospace market reached 5% by the mid-1990s and then, accelerating sharply, grew to 16% in 2005, driven by gains in Japan and China. Japan's share of value-added global revenue rose from 3% in 1996 to almost 7% in 2005. China's aerospace industry grew just as rapidly, and exceeded 6% in 2005.

Figure 6-14
Global value-added revenue of communications equipment and world share of selected regions/countries: 1995–2005



EU = European Union

NOTES: Communications equipment includes communications, radio, and television equipment. Revenue on value-added basis, which excludes purchases of domestic and imported materials and inputs. Asia includes China, India, Indonesia, Japan, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. China includes Hong Kong. EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia.

SOURCE: Global Insight, Inc., World Industry Service database, special tabulations (15 April 2007). See appendix tables 6-10 and 6-11.

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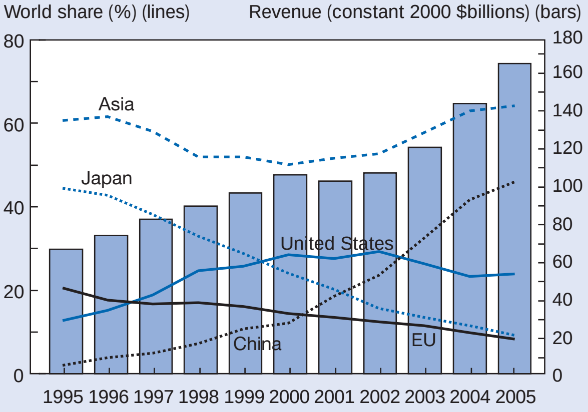
Figure 6-15
Global value-added revenue of computer manufacturing industry and world share of selected regions/countries: 1995–2005



EU = European Union

NOTES: Computer manufacturing includes computer, office, and accounting machinery. Revenue on value-added basis, which excludes purchases of domestic and imported materials and inputs. Asia includes China, India, Indonesia, Japan, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. China includes Hong Kong. EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia.

SOURCES: Global Insight, Inc., World Industry Service database, special tabulations (15 April 2007). See appendix tables 6-10 and 6-11.

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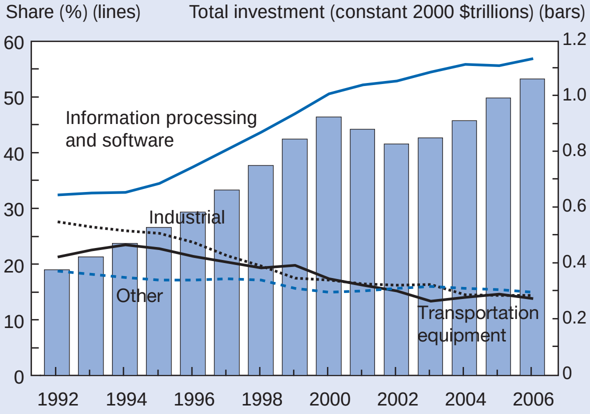
U.S. IT Investment

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 has led to productivity gains and production efficiencies.

From 1992 through 2006, U.S. industry purchases of IT equipment and software exceeded industry spending on all other types of capital equipment (figure 6-16). 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 41% of all industry investment (including structures and equipment) in 1997, 53% in 2002, and 57% in 2006.

Figure 6-16
U.S. industry investment in capital equipment and share of equipment type: 1992–2006



SOURCE: Bureau of Economic Analysis, National Income and Product Accounts, http://www.bea.gov/national/nipaweb/NIPA_Underlying/TableView.asp SelectedTable=39&FirstYear=2006&LastYear=2007&Fre = tr, accessed 15 March 2007.

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U.S. Global Position in Medium- and Low-Technology Manufacturing Industries

S&T is used in many industries, not just high-technology manufacturing and services. Manufacturing industries not classified as high technology are divided into three categories: medium-high technology, medium-low technology, and low technology. Relevant industries include motor vehicle manufacturing and chemicals production excluding pharmaceuticals (medium-high technology), rubber and plastic production and basic metals (medium-low technology), and paper and food product production (low technology).

These industries use advanced manufacturing techniques, incorporate technologically advanced inputs in manufacture, and/or perform or rely on R&D in applicable scientific fields. The U.S. value added world share in medium- and low-technology industries is lower than its share of high-technology industries, but the U.S. global position in these industries is fairly strong (table 6-10; appendix tables 6-12 and 6-13):

- **Medium-high-technology industries:** These industries produced $1.7 trillion in year 2000 constant dollars of value added in 2005. Although the United States is ranked third (23%) after Asia and the EU in share of world value added, it has the largest share of any individual country. U.S. and EU shares fell slightly between 1996 and 2005 while Asia's share increased from 32% to 37%, largely because of the doubling of China's world share from 4% to 8%.
- **Medium-low-technology industries:** The United States is also ranked third in these industries compared with Asia and the EU, although it has the largest share of any single country. Between 1996 and 2005, Asia's share grew 4 percentage points to 35%, largely because China's world share rose from 4% to 11%. Japan's share fell from 20% to 15%.
- **Low-technology industries:** The United States is ranked first in these industries, which produced $2 trillion in constant dollars in value added in 2005. The U.S. share of low-technology industry value added has remained steady during the past decade (30% in 2005). Asia's share rose slightly during this period, even though Japan's share fell from 18% to 14%, because China's world share doubled from 4% to 9%.

In addition, some industries are not classified as either manufacturing or services (see sidebar, "U.S. Global Market Position in Other Industries").

U.S. Exports of Manufacturing Industries

High-Technology Manufacturing Industries

Data on international trade attribute products to a single country of origin and in some cases to a single industry. For goods manufactured in more than one country, the United States and many other countries determine country of origin on the basis of where the product was "substantially transformed" into the final product. For example, a General Motors car destined for export to Canada that was assembled in the United States with components imported from Germany and Japan will be labeled "Made in the USA." The country where the product was "substantially transformed" may not necessarily be where the most value was added, although that often is the case.

In this chapter, trade in U.S. high-technology products is counted in two different ways. The contrasting methods may attribute products to different countries of origin (see sidebar, "Classifying Products in Trade").

During the 1990s, U.S. high-technology industries accounted for about one-fifth of world high-technology exports, approximately twice the level of all other U.S. manufacturing industries.[20] Starting in the late 1990s, however, the U.S.

Table 6-10
Value-added revenue and world share of manufacturing industries by select technology levels for selected regions/countries: Selected years, 1996–2005
(Percent)

Industry and region/country	1996	2001	2005
Medium-high technology			
All regions/countries (2000 constant $trillions)	1.391	1.422	1.682
United States	26.3	24.4	22.9
EU	29.8	31.2	28.2
Asia	31.5	31.0	36.7
Japan	21.4	20.1	20.7
China	3.5	4.5	7.8
Medium-low technology			
All regions/countries (2000 constant $trillions)	1.190	1.272	1.459
United States	23.7	22.8	22.0
EU	28.6	28.2	25.2
Asia	31.0	31.0	35.2
Japan	19.5	17.1	15.1
China	4.3	5.5	10.6
Low technology			
All regions/countries (2000 constant $trillions)	1.721	1.783	1.953
United States	29.7	29.4	30.3
EU	26.6	27.2	25.0
Asia	27.6	26.4	28.6
Japan	18.2	15.9	13.9
China	4.2	4.7	9.0

EU = European Union

NOTES: Technology level of manufacturing industries classified by Organisation for Economic Co-operation and Development on basis of R&D intensity of output. Value-added revenue excludes purchases of domestic and imported materials and inputs. EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia. Asia includes China, India, Indonesia, Japan, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. China includes Hong Kong.

SOURCE: Global Insight, Inc., World Industry Service database, special tabulations (15 April 2007). See appendix tables 6-12 and 6-13.

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U.S. Global Market Position in Other Industries

Agriculture, construction, mining, and utilities are not classified as either manufacturing or service industries and are not categorized by their level of technology or knowledge intensity. Like those in the manufacturing and service sectors, however, these industries incorporate and use S&T in their products and processes. For example, agriculture relies on breakthroughs in biotechnology, construction uses knowledge from materials science, mining is dependent on earth sciences, and utilities rely on advances in energy science.

In construction and utilities, the United States produces more than a fourth of the world's value added (table 6-11). The U.S. share of the global construction industry, valued at $1.7 trillion in constant dollars in 2005, rose from 23% to 27% during the past decade. At 17%, however, the U.S. world share of mining in 2005 was 5 percentage points less than a decade ago. The U.S. world share of agriculture edged up from 8% to nearly 11% during this period.

Table 6-11

U.S. world share and global value-added revenue of agriculture, construction, mining, and utilities: Selected years, 1996–2005

Sector/year	U.S. world share (%)	Value-added world revenue (2000 constant $billions)
Agriculture		
1996	8.4	913
1999	9.3	975
2002	9.6	1,003
2005	10.6	1,081
Construction		
1996	22.7	1,606
1999	26.1	1,626
2002	26.5	1,621
2005	26.5	1,730
Mining		
1996	23.2	580
1999	22.6	605
2002	20.1	643
2005	17.3	722
Utilities		
1996	27.7	686
1999	27.9	727
2002	28.1	745
2005	26.8	805

NOTES: Value-added revenue excludes purchase of domestic and foreign materials and supplies. Agriculture includes forestry, fishing, and hunting. Utilities include electricity, gas, and water.

SOURCE: Global Insight, Inc., World Industry Service database (2007).

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Classifying Products in Trade

The characteristics of goods in international trade can be determined from either an industry or a product perspective:

- **Industry perspective.** U.S. industry exports and imports are collected from government surveys of companies with physical operations in the United States, where respondents are asked to report the value of foreign shipments and purchases from abroad. These shipments, both exports and imports, are classified by the primary industry of the responding company. Under this scheme, whether Ford Motor Company exports automobiles or tires, both types of exports would be classified under Ford's primary industry code "manufacturer of motor vehicles and parts." The value of industry exports includes the value of components, inputs, or services purchased from domestic industries or imported from other countries. The value of industry imports includes the value of components, inputs, or services that may have originated from a different industry or country than the country of origin.
- **Product perspective.** Data on product trade, such as that reported below in the section about U.S. trade in advanced technology products, are first recorded at U.S. ports of entry. Each type of product is assigned a product trade code by the customs agent according to the harmonized system.* Exporters generally identify the product being shipped and include its proper code. Because many imported products are assessed an import duty and these duties vary by product category, the receiving country customs agent inspects or reviews the shipment to make the final determination of the proper product code and country of origin. The value of products entering or exiting U.S. ports may include the value of components, inputs, or services classified in different product categories or originating from other countries than the country of origin.

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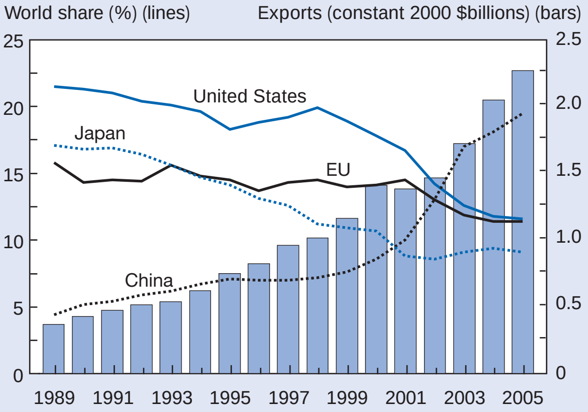
*The Harmonized Commodity Description and Coding System, or Harmonized System (HS), is a system for classifying goods traded internationally, developed under the auspices of the Customs Cooperation Council. Beginning on 1 January 1989, HS numbers replaced previously adhered-to schedules in more than 50 countries, including the United States.

Figure 6-17
Global exports of high-technology manufacturing industries and world share of selected regions/countries: 1989–2005



EU = European Union

NOTES: High-technology manufacturing industries classified by Organisation for Economic Co-operation and Development and include aerospace, communications equipment, office machinery and computers, pharmaceuticals, and scientific instruments. EU exports do not include intra-EU exports. EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia. China includes Hong Kong.

SOURCE: Global Insight, Inc., World Industry Service database, special tabulations (15 April 2007). See appendix tables 6-14 and 6-15.

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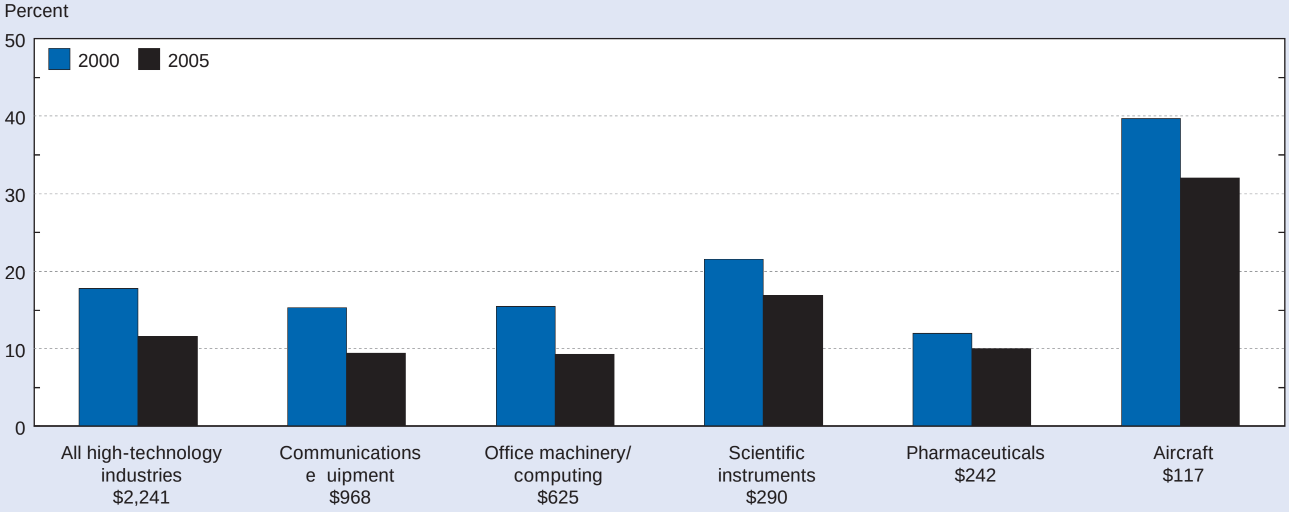
world export share declined continuously across all five high-technology manufacturing industries, dropping to an average of 12% in 2005 (figure 6-17; appendix tables 6-14 and 6-15). Losses in communications equipment and office machinery and computers, which collectively account for nearly 60% of U.S. high-technology exports, primarily drove the decline in U.S. export share (figure 6-18; appendix tables 6-16 through 6-19).

The drop in the U.S. export share coincided with the rapid rise of China's high-technology export industries that began in 1999 (figure 6-17; appendix tables 6-14 and 6-15). Between 1999 and 2005, China's export share more than doubled from 8% to 19%. China surpassed Japan in 2001, the EU in 2002, and overtook the United States in 2003, becoming the world's largest exporter as measured by world market share.[21] China's rise in market share has been driven by its exports from the office machinery and computers and communications equipment industries (appendix tables 6-16 through 6-19). Between 2000 and 2005, China's world export share in office machinery and computers tripled from 10% to 30% and its share in communications equipment more than doubled from 10% to 21%. Japan's share of world high-technology industry exports fell from 17% in the early 1990s to 9% in 2001 and has remained essentially flat.

Figure 6-18
U.S. world export share for individual high-technology manufacturing industries: 2000 and 2005



NOTES: High-technology manufacturing industries classified by Organisation for Economic Co-operation and Development. 2005 exports in billions of 2000 dollars shown below each industry.

SOURCE: Global Insight, Inc., World Industry Service database, special tabulations (15 April 2007). See appendix tables 6-14 to 6-19.

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Medium- and Low-Technology Manufacturing Industries

Compared with trends for high-technology industries, the United States has historically had lower world export shares in non-high-technology manufacturing industries, although these, too, have converged somewhat starting in the late 1990s. The U.S. share of world exports in medium-high-technology industries was 11% in 2005, nearly equal to its share in high-technology industries (table 6-12; appendix tables 6-12 and 6-13). This makes the United States the third-ranked exporter in these industries behind Japan (13%) and the EU (excluding intra-EU exports) (12%). The market position of these three economies has not changed over the past decade. China, however, has made rapid strides; its world export share in these industries has doubled from 4% in 1996 to 8% in 2005.

The United States ranks third in exports of medium-low-technology industries, with a world share in 2005 of 7% (table 6-12; appendix tables 6-12 and 6-13). The EU at 13% of world share and China at 11% of world share are the first- and second-ranked exporters in these industries. The U.S. share of exports of low-technology industries in 2005 was 8%, ranked third behind the EU (14%) and China (16%). China's world export share is nearly double that of the United States, having grown 5 percentage points since 1996.

Table 6-12
Global export revenue of manufacturing industries by technology level and world share of selected regions/countries: 1996, 2001, and 2005
(Percent)

Industry and region/country	1996	2001	2005
Medium-high technology			
All regions/countries (2000 constant $billions)..........	1,673	1,830	2,833
United States	13.1	13.5	11.1
EU................................	12.2	12.1	12.4
Japan	13.5	11.0	13.1
China...........................	3.6	4.7	8.4
Medium-low technology			
All regions/countries (2000 constant $billions)..........	662	747	1,020
United States	8.1	8.6	6.6
EU................................	14.7	13.1	12.8
Japan	8.3	6.4	6.3
China...........................	5.2	6.3	10.7
Low technology			
All regions/countries (2000 constant $billions)..........	1,142	1,288	1,716
United States	10.6	10.6	8.4
EU................................	17.0	15.1	14.2
Japan	2.8	3.3	3.3
China...........................	10.9	10.4	16.1

EU = European Union

NOTES: Technology level of manufacturing industries classified by Organisation for Economic Co-operation and Development on basis of R&D intensity of output. EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia. Asia includes China, India, Indonesia, Japan, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. China includes Hong Kong. EU exports do not include exports within each region.

SOURCE: Global Insight, Inc., World Industry Service database, special tabulations (15 April 2007). See appendix tables 6-12 and 6-13.

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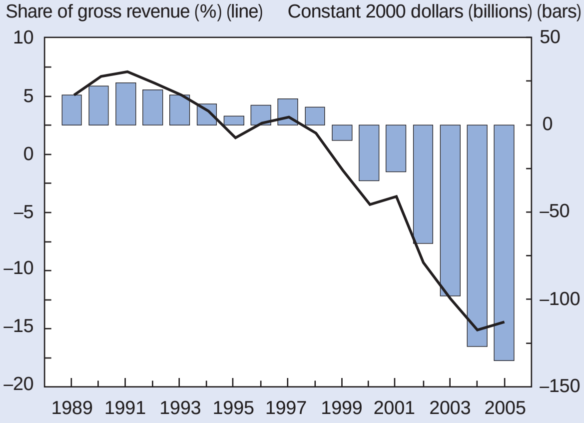
Trade Balance of High-Technology Industries

U.S. high-technology industries consistently exported more than they imported throughout the 1980s to early 1990s, in contrast to the consistent deficits recorded by other U.S. manufacturing industries.[22] The trade balance of high-technology industries shifted from surplus to deficit in the late 1990s, however, because imports of high-technology manufacturing industries grew almost twice as fast as exports during that decade (figure 6-19; appendix tables 6-14 and 6-15). In 2000, the deficit was $32 billion in constant dollars, equivalent to 4% of gross revenues of U.S. high-technology manufacturing industries; in 2005, the deficit widened to $135 billion, amounting to 14% of gross revenue.

Two industries are driving the U.S. high-technology industry trade deficit: communications equipment and office machinery and computing. In 2005, these two industries ran a collective deficit of more than $140 billion in constant dollars (figure 6-20). The emergence of large deficits in these industries coincided with rising domestic output, stimulating imports of components. The deficit in office machinery and computing was not only a major driver of the overall trade deficit but was also quite large when viewed as a share of

Figure 6-19
Trade balance and share of gross revenue for U.S. high-technology manufacturing industries: 1989–2005



NOTES: High-technology manufacturing industries classified by Organisation for Economic Co-operation and Development and include aerospace, communications equipment, office machinery and computers, pharmaceuticals, and scientific instruments. Revenue on gross basis, which includes purchase of domestic and foreign materials and inputs.

SOURCE: Global Insight, Inc., World Industry Service database, special tabulations (15 April 2007). See appendix tables 6-14 and 6-15.

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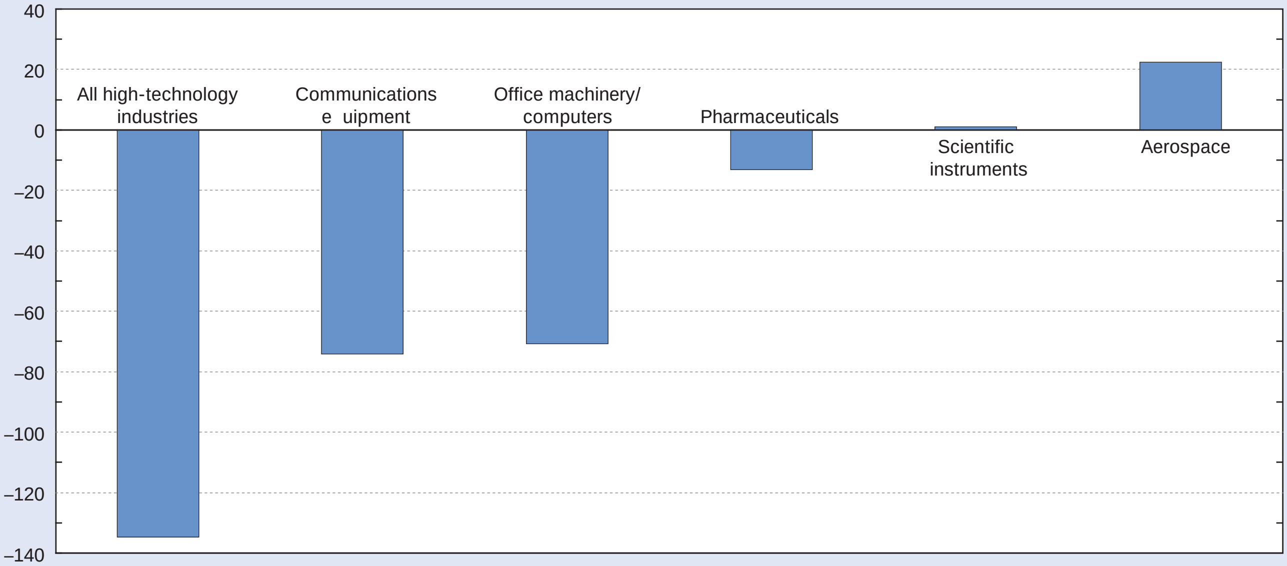
Figure 6-20

U.S. trade balance for individual high-technology manufacturing industries: 2005



NOTE: High-technology manufacturing industries classified by Organisation for Economic Co-operation and Development.

SOURCE: Global Insight, Inc., World Industry Service database, special tabulations (15 April 2007). See appendix tables 6-16 to 6-19.

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gross revenue of this industry. In 2005, this industry's trade deficit represented about a 60% share of gross revenues, the largest share of any U.S. high-technology industry (appendix tables 6-18 and 6-19). The pharmaceuticals industry ran a deficit of $13 billion in 2005.

Two other high-technology industries, scientific instruments and aerospace, are not contributors to the trade deficit. The U.S. aerospace industry registered a $22 billion trade surplus in 2005, continuing its trend of sizable trade surpluses since the late 1990s. The U.S. scientific instruments manufacturing industry had a modest $1 billion surplus in 2005.

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"). 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 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, 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 computers, video conferencing, routers, 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 in-

tegrated 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.

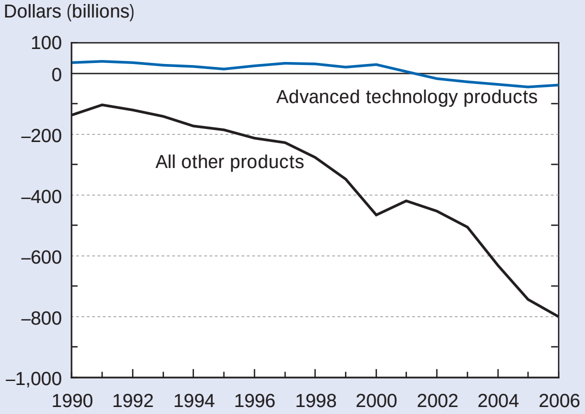
- **Flexible manufacturing.** The development of products for industrial automation, including robots, numerically controlled machine tools, and automated guided vehicles, that permit greater flexibility in the manufacturing process and reduce human intervention.
- **Advanced materials.** The development 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 (communications 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 these leading-edge technologies, accounting for a significant portion of the product's value. In this report, computer software is examined separately, creating an 11th technology area.[23] In official statistics, computer software is included in the information and communications technology area (see sidebar, "Comparison of Data Classification Systems Used").

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, producing consistent trade surpluses for the United States. Beginning in 2000 and coinciding with the dot.com collapse, the trade balance for U.S. technology products began to erode, about the same time the U.S. trade balance in high-technology industries shifted to a deficit (figures 6-20 and 6-21; appendix table 6-20).[24] In 2002, U.S. imports of advanced technology products exceeded exports, resulting in the very first U.S. trade deficit in this market segment. The U.S. trade deficit in advanced technology products grew larger each year thereafter until 2006, when it contracted somewhat. In 2002, the U.S. trade deficit in advanced technology products was $17.5 billion; in 2003, it increased to $27.4 billion, then again increased to $37.0 billion in 2004 and $44.4 billion in 2005. Contract manufacturing by U.S. companies in Asia and elsewhere may be a factor in this trend. The deficit was smaller in 2006, dropping to $38.3 billion, although still larger than any year except 2005.

Figure 6-21
U.S. merchandise trade balance, by product type: 1990–2006



NOTES: Technology products from special tabulations. All other products trade = total merchandise trade minus trade in advanced technology products.

SOURCE: Census Bureau, Foreign Trade Division, special tabulations (2006); and data on total product trade, http://www.fedstats.gov. See appendix tables 6-20 and 6-21.

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The U.S. trade deficit is largely driven by trade deficits with Asia, especially with China and Malaysia. U.S. trade with the rest of the world is either relatively balanced or in surplus (figure 6-22; appendix table 6-21).

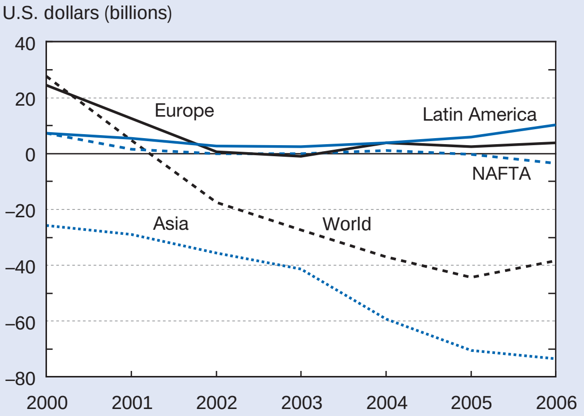
Technologies Generating a Trade Surplus

Throughout most of the 1990s, U.S. exports of advanced technology products generally exceeded imports in 8 of the 11 technology areas.[25] Since 2000, the number of technology areas showing a trade surplus has slipped to five or six (figure 6-23; appendix table 6-20).

Trade in aerospace products has consistently produced the largest surpluses for the United States since the 1990s. In 2005, U.S. trade in aerospace products generated a net inflow of $37.2 billion, which rose to $53.6 billion in 2006 (figure 6-23; appendix table 6-20). 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. In 2000, U.S. trade in electronics products generated a net inflow of $15.2 billion, which increased to $16.1 billion in 2002, then rose to more than $21 billion in both 2003 and 2004, and rose again to $25.4 billion in 2006. Trade activity in biotechnology, computer software, flexible manufacturing products (e.g., industrial automation products, robotics), and weapon technologies also has generated small surpluses during the past few years.

Figure 6-22

U.S. advanced technology product trade balance, by world and region: 2000–06



NAFTA = North American Free Trade Agreement

NOTES: Asia includes China, India, Indonesia, Japan, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. China includes Hong Kong. Europe includes Austria, Belgium, Czech Republic, Denmark, Germany, Finland, France, Greece, Hungary, Ireland, Italy, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland, and United Kingdom. Latin America includes Argentina, Brazil, Chile, Costa Rica, Peru, and Venezuela. NAFTA includes Canada and Mexico.

SOURCE: Census Bureau, Foreign Trade Division, special tabulations (2007). See appendix table 6-21.

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Technologies Generating a Trade Deficit

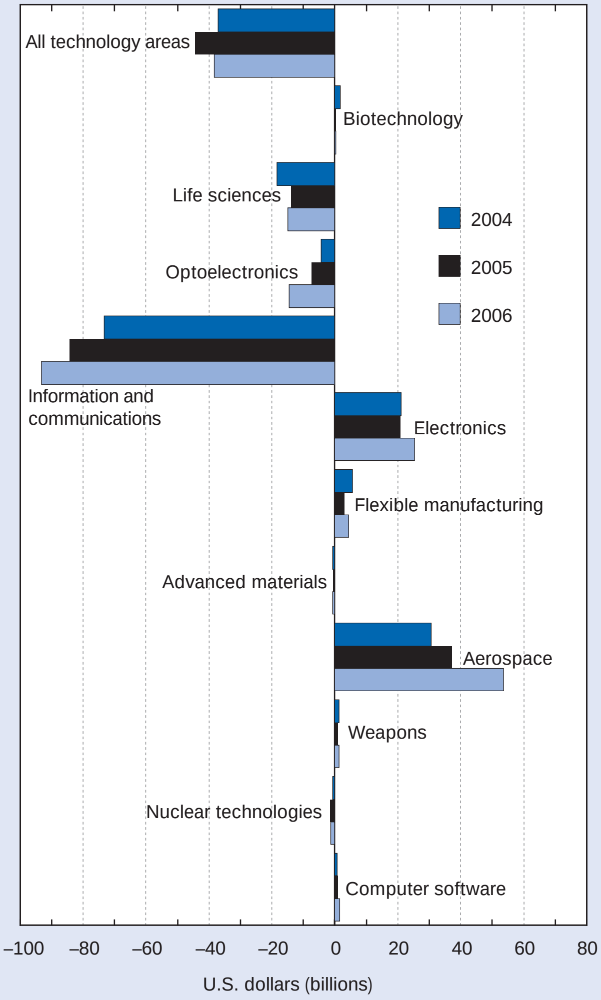
Throughout most of the 1990s, trade deficits were recorded in just 2 of the 11 technology areas: information and communications and optoelectronics. Rapidly rising imports of life science technologies during the late 1990s produced the first U.S. trade deficit in that third technology area in 1999. Since 2000, U.S. imports have exceeded exports in about half of the 11 technology areas; the largest trade deficits continue to be in the information and communications technology area (figure 6-23; appendix table 6-20). In 2006, imports exceeded exports in five technology areas. U.S. trade in information and communications resulted in a net outflow of $93.2 billion; net outflows in life science technologies and optoelectronics were $15 billion and $14.5 billion, respectively. Small deficits were also recorded in nuclear technologies ($1.4 billion) and advanced materials ($0.8 billion).

Top Customers by Technology Area

Asia, Europe, and North America together purchase nearly 85% of all U.S. exports of advanced technology products. Asia is the destination for about 40% of these exports, Europe about 26%, and Canada and Mexico together about 17% (appendix table 6-21). China, Canada, and Japan are the largest country customers across a broad range of U.S. technology products, with China accounting for about 10% of all U.S. exports of advanced technology products in 2006, Canada for about 9%, and Japan about 8% (table 6-13; appendix table 6-21). In 2006, China ranked among the top three customers in 5 of the 11 technology areas, Mexico in 4 areas, Canada in 3 areas, and Japan in 7 areas.

Figure 6-23

U.S. trade balance, by technology area: 2004, 2005, and 2006



SOURCES: Census Bureau, Foreign Trade Division, special tabulations (2007); and FedStats data on total product trade, http://www.fedstats.gov.

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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 that China is among the top three customers in aerospace, advanced materials, software, electronics, and information and communications technologies. Taiwan is among the top three customers in optoelectronics, flexible manufacturing, and nuclear technologies, South Korea in flexible manufacturing and weapons technologies, and Malaysia in electronics technologies.

European countries are also important consumers of U.S. technology products, particularly Germany, the UK, France, and the Netherlands. The European market is particularly important in two technology areas: biotechnology and aerospace. The Netherlands, Belgium, and the UK are the top customers for U.S. biotechnology products, together consuming more than half of all U.S. exports within this technology area. Germany is the leading European consumer of U.S. life science technologies and optoelectronics, whereas France and the UK are the leading European consumers of U.S. aerospace technology products.

Top Suppliers by Technology Area

The United States is not only an important exporter of technologies to the world but also 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 97% of all U.S. imports across all classes of advanced technology products (table 6-14; appendix table 6-21). In 2006, Asia supplied more than 60%, Europe about 21%, and North America about 16%.

China is by far the largest supplier of technology products to the United States, as the source for 25% of U.S. imports in 2006, followed by Mexico with 11% (table 6-14; appendix table 6-21). By comparison, Japan, the third largest supplier, was a distant second among all Asian sources, supplying 9% of U.S. technology imports in 2006. Malaysia, South Korea,

Table 6-13
Three largest export markets for U.S. technology products: 2006
(Percent)

	Largest market		Second largest market		Third largest market	
Export	Country	Percent	Country	Percent	Country	Percent
All technologies	China	9.6	Canada	9.3	Japan	7.7
Computer software	Canada	41.6	Mexico	8.6	China	6.5
Advanced materials	Mexico	14.1	China	11.5	Japan	11.1
Aerospace	Japan	8.7	France	8.5	China	8.1
Biotechnology	Netherlands	28.8	Belgium	13.1	UK	12.6
Electronics	China	16.9	Malaysia	11.1	Mexico	10.6
Flexible manufacturing	South Korea	15.4	Taiwan	13.7	Japan	13.0
Information/communications	Canada	16.2	Mexico	13.7	China	8.0
Life sciences	Japan	12.6	Germany	10.9	Canada	8.6
Nuclear technology	Japan	36.9	UK	15.0	Taiwan	9.8
Optoelectronics	Japan	15.4	Germany	10.6	Taiwan	9.7
Weapons	UK	16.4	Japan	14.4	South Korea	10.0

UK = United Kingdom

SOURCE: Census Bureau, Foreign Trade Division, special tabulations.

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Table 6-14
Three largest foreign suppliers of technology products to United States: 2006
(Percent)

	Largest supplier		Second largest supplier		Third largest supplier	
Import	Country	Percent	Country	Percent	Country	Percent
All technologies	China	25.3	Mexico	10.6	Japan	8.9
Advanced materials	Japan	44.2	Mexico	11.3	Germany	10.1
Aerospace	France	24.7	Canada	22.9	UK	13.0
Biotechnology	Germany	25.6	Ireland/UK	11.1	Belgium	9.3
Computer software	Mexico	23.7	China	17.0	Canada	16.6
Electronics	Taiwan	16.2	South Korea	11.1	Malaysia	10.8
Flexible manufacturing	Japan	43.4	Netherlands	10.2	Germany	9.5
Information/communications	China	40.5	Malaysia	13.4	Mexico	10.1
Life sciences	Ireland	35.3	Germany	10.6	Mexico	6.6
Nuclear technology	UK	29.9	Russia	27.8	Netherlands	14.9
Optoelectronics	Mexico	51.9	China	22.8	Japan	6.8
Weapons	Canada	15.8	UK	15.0	China	13.4

UK = United Kingdom

SOURCE: Census Bureau, Foreign Trade Division, special tabulations.

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and Taiwan are other major Asian suppliers. In the electronics technology area, the top three suppliers are all in Asia and supply about 38% of total U.S. imports.

Among European countries, Germany, the UK, and France are major suppliers of technology products to the United States. Many smaller European countries also have become important sources for technology products, although they tend to specialize. Ireland was among the top suppliers of life science and biotechnology products to the United States in 2006, as the source for 35% and 11%, respectively, of U.S. imports in these categories (table 6-14; appendix table 6-21). Belgium supplied 9% of U.S. biotechnology imports, and the Netherlands supplied 10% of U.S. flexible manufacturing technology imports in 2006.

U.S. Royalties and Fees Generated From Intellectual Property

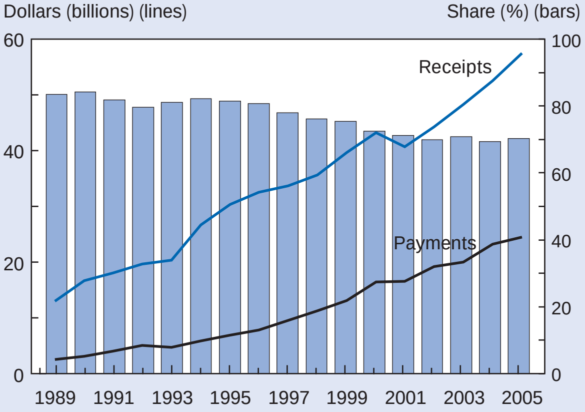
Companies trade intellectual property when they license or franchise proprietary technologies, trademarks, and entertainment products to entities in other countries. Trade in intellectual property can involve patented and unpatented techniques, processes, formulas, and other intangible assets and proprietary 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.[26] The exception is contract manufacturing, which may permit the use of intellectual property without a licensing fee.

U.S. Royalties and Fees From All Transactions

In contrast to the country's merchandise trade position, the United States runs a surplus from its trade of intellectual property (figure 6-24; appendix table 6-22). U.S. receipts from licensing of intellectual property have grown every year since 1986 (except for 2001) and in 2005 reached $57.4 billion, 9% higher than in 2004 (appendix table 6-22). U.S. payments for foreign intellectual property were $24.5 billion in 2005, 6% higher than 2004 and more than 20% higher than in 2003. The slowdown in 2005 primarily resulted from a falling off of U.S. company payments to unaffiliated foreigners. In 2004, U.S. payments to foreign companies spiked because of payments to broadcast the summer Olympic Games in Greece (BEA 2006).

In 2005, U.S. trade in intellectual property produced a surplus of $32.9 billion, up 12% from the $29.3 billion surplus recorded a year earlier (figure 6-24; appendix table 6-22). About three-quarters of transactions involved exchanges of intellectual property between U.S. companies and their foreign affiliates.[27] Companies with marketable intellectual property may prefer affiliated over unaffiliated transactions to exercise greater control over the distribution and use of this property, especially when the intellectual property is instrumental to the company's competitive position in the marketplace (Branstetter, Fisman, and Foley 2005). Despite the greater value of transactions among affiliated companies, both affiliated and unaffiliated transactions have grown at the same pace during the past two decades (appendix table 6-22). These trends suggest a greater internationalization of U.S. business activity and a growing reliance on intellectual property developed overseas.[28]

Figure 6-24
U.S. receipts and payments of trade for intellectual property and receipts share of trade volume: 1989–2005



SOURCE: Bureau of Economic Analysis, *Survey of Current Business* 86(10):50–54 (2006). See appendix table 6-22.

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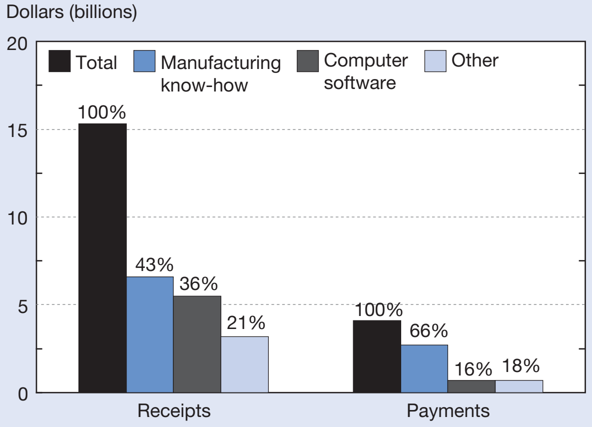
U.S. Royalties and Fees From U.S. Trade Between Unaffiliated Companies

Data on intellectual property transactions between unaffiliated companies, in which prices are set through market-based negotiation, may better reflect the value of U.S. intellectual property than data on exchanges between affiliated companies. About 80% of receipts and payments from trade of U.S. intellectual property with unaffiliated foreign companies are generated by licenses for manufacturing know-how and computer software (figure 6-25; appendix table 6-23).

Trade in manufacturing know-how as described above consists of U.S. trade in industrial processes (including patents and trade secrets) used in the production of goods. Trade in computer software consists of cross-border software licensing agreements, such as on-site licensing. When receipts (sales of manufacturing know-how and software license agreements) consistently exceed payments (purchases), these data may indicate a comparative advantage in the creation of industrial technology and licensing of computer software. These data also provide an indicator of trends in the production and diffusion of these technologies as intellectual property.

Figure 6-25

U.S. trade in intellectual property between unaffiliated companies: 2005



NOTE: Percentage of share shown above each component.

SOURCE: Bureau of Economic Analysis, *Survey of Current Business* 86(10):50–54 (2006). See appendix tables 6-23 to 6-25.

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U.S. Royalties and Fees From Trade in Manufacturing Know-How

The United States is a net exporter of manufacturing know-how sold as intellectual property (table 6-15; appendix tables 6-23 and 6-24). In 2005, the surplus from trade in manufacturing know-how was $3.9 billion, which was $1 billion greater than the 2004 surplus because of strong growth in receipts and a flat trend for payments.

The U.S. surplus from trade in manufacturing know-how is driven largely by trade with Asia (BEA 2007) (table 6-15; appendix table 6-24).[29] Asia has been the single largest consumer of U.S. manufacturing know-how for the past 20 years, led primarily by Japan.[30] With a 39% share of total receipts in 2005, Japan has historically spent more to purchase U.S. manufacturing technology than any other country. South Korea, a major consumer of U.S. manufacturing know-how since the early 1990s, had the second highest share of any country, accounting for 19% of total U.S. receipts in 2005.

China's and Taiwan's shares of total receipts are much smaller than those of Japan or South Korea, although they have increased over the past decade (table 6-15; appendix table 6-24). China's and Taiwan's shares were 3% and 6% of total receipts in 2005, respectively, at least double their levels in 1995. Asia was also an important supplier of manufacturing know-how to U.S. companies during this period, although U.S. purchases from Asia largely consisted of trade with Japan. In 2005, Asia supplied nearly 16% of U.S. manufacturing know-how licensed from foreign sources, of which close to 90% came from Japan.

Unlike trade with Asia, U.S. trade with the EU in manufacturing know-how is much more balanced (table 6-15; appendix table 6-24). Receipts from the EU were $1.3 billion in 2005, accounting for 20% of all U.S. receipts from U.S. intellectual property trade in manufacturing know-how. France, Germany, and the UK accounted for more than half

Table 6-15

U.S. royalties and fees generated from trade in manufacturing know-how between unaffiliated companies, by share of selected region/country/economy: 1995 and 2005

(Percent distribution)

	Receipts		Payments	
Region/country/economy	1995	2005	1995	2005
All royalties and fees ($billions)	3.5	6.6	0.9	2.7
All royalties and fees	100.0	100.0	100.0	100.0
Asia	69.0	69.8	34.7	15.6
China	1.5	3.0	D	0.8
Japan	44.1	38.9	32.4	14.0
South Korea	17.3	18.8	D	0.3
Taiwan	2.3	6.1	0.0	D
EU	21.5	20.2	48.6	60.9
France	2.4	2.3	12.8	19.1
Germany	4.9	5.8	11.6	7.9
United Kingdom	3.3	3.4	13.3	10.4
Other	9.5	10.0	16.6	23.5

D = suppressed to avoid disclosure of confidential information

EU = European Union

NOTES: Industrial processes (or manufacturing know-how) include patents and other proprietary inventions and technology. Affiliate refers to business enterprise located in one country directly or indirectly owned or controlled by entity in another country. Controlling interest must equal ≥10% of voting stock or equivalent. Asia includes China, India, Japan, Malaysia, Singapore, South Korea, Taiwan, Thailand, and other unspecified Asian countries. China includes Hong Kong. Percents may not add to total because of rounding.

SOURCES: Bureau of Economic Analysis, *Survey of Current Business* 86(10):50–54 (2006). See appendix tables 6-23 and 6-24.

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of the receipts from the EU in 2005, with Germany having the largest single share among EU countries. Payments to the EU were about $1.6 billion in 2005, accounting for 61% of total payments. France, Germany, and the UK received more than half of U.S. payments to the EU to license its manufacturing know-how.

U.S. Royalties and Fees From Licensing of Computer Software

The United States is also a net exporter when licensing computer software (table 6-16; appendix tables 6-23 and 6-25). The trade surplus from computer software licensing transactions reached a record high of $4.8 billion in 2005, driven by much faster growth in receipts relative to payments. Although 2005 receipts from transactions involving manufacturing know-how ($6.6 billion) were greater than those involving computer software ($5.5 billion), U.S. companies paid almost four times as much for foreign manufacturing know-how ($2.7 billion) than for foreign computer software ($0.7 billion).

Incomplete data suggest that Asia is a large licensor of U.S. computer software (table 6-16; appendix table 6-25). Asia was responsible for more than half of all licensing fees paid to U.S. companies for computer software in 2005. Since 1998, the first year that data were collected on computer software licensing, Asia's share has steadily increased, surpassing the EU's share in 2001. Japan is the largest purchaser of U.S. computer software of any country, accounting for 31% of total U.S. receipts in 2005, which is more than 8 percentage points higher than in 1998. South Korea, the only other Asian country from which data are consistently available, had a 5% share in 2005.

The EU accounted for 30% of U.S. receipts from licensing of computer software in 2005. About three-fourths of the EU's receipts originated from France, Germany, and the UK (table 6-16; appendix table 6-25). Even so, the EU licenses more computer software to U.S. companies than any other region. In 2005, U.S. companies purchased more than 85% of the $0.7 billion spent worldwide on computer software from the EU. The EU, however, spends considerably more on licensing computer software from U.S. companies; as a result, the EU's deficit in 2005 for this trade area was $1.1 billion.

New High-Technology Exporters

Several nations are rapidly becoming more competitive in international high-technology trade. Large ongoing investments in S&T, education, and R&D[31] have supported their progress, but other factors, such as political stability, access to capital, and an infrastructure that can support technological and economic advancement, are likely to affect their ability to advance in the future.

This section presents four indicators that may be relevant to the long-term potential of developing economies to maintain or improve their competitiveness in international high-technology markets. National scores on each indicator are computed using both statistical data and systematic expert assessments (Porter et al. 2005).[32] The indicators are:

Table 6-16

U.S. royalties and fees generated from trade in computer software between unaffiliated companies, by share of selected region/country/economy: 1998 and 2005

(Percent distribution)

Region/country/economy	Receipts 1998	Receipts 2005	Payments 1998	Payments 2005
All royalties and fees ($billions)	3.2	5.5	0.5	0.7
All royalties and fees	100.0	100.0	NA	NA
Asia	37.0	51.1	NA	NA
China	2.0	D	NA	D
Japan	22.7	31.1	5.2	0.4
South Korea	D	4.9	NA	0.0
Taiwan	6.7	D	0.2	0.0
EU	42.2	30.3	89.6	86.2
France	4.8	2.0	D	D
Germany	13.9	13.3	15.3	2.7
United Kingdom	10.0	7.2	7.6	10.0
Other	20.8	18.6	NA	NA

NA = not available; D = suppressed to avoid disclosure of confidential information

EU = European Union

NOTES: Computer software includes rights to distribute and use general-use software. Affiliate refers to business enterprise located in one country directly or indirectly owned or controlled by entity in another country. Controlling interest must equal ≥10% of its voting stock or equivalent. EU includes 25 member countries following May 2004 enlargement. Bulgaria and Romania, which joined in January 2007, not included. Asia includes China, India, Indonesia, Japan, Malaysia, Philippines, Singapore, South Korea, Taiwan, Thailand, and other unspecified Asian countries. China includes Hong Kong.

SOURCES: Bureau of Economic Analysis, *Survey of Current Business* 86(10):50–54 (2006). See appendix tables 6-23 and 6-25.

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- **Technological infrastructure.** This term refers to the social and economic institutions that help a nation develop, produce, and market new technology. This indicator combines statistical data on the number of scientists employed in R&D and electronic data processing purchases with expert assessments of technical training and education, industrial R&D, and technological mastery.
- **Socioeconomic infrastructure.** This term refers to the social and economic institutions necessary to sustain and advance technology-based development. This indicator combines statistical data on educational attainment with expert assessments of national policies toward multinational investment and capital mobility.
- **Productive capacity.** This term refers to the physical and human resources devoted to manufacturing products and the efficiency with which these resources are used. This indicator combines statistical data on electronics production with expert assessments of the management capability and indigenous supply of skilled labor and component parts for high-technology manufactured goods.
- **National orientation.** This term refers to national policies, institutions, and public opinion that help a nation become technologically competitive. This indicator combines a statistical measure of investment risk with expert assessments of national strategy, implementation, entrepreneurship, and attitudes toward technology.

In their present form, these four indicators have been tracked for a relatively stable set of developing and industrialized countries since the early 1990s. Because these indicators were designed to forecast long-term changes in national high-technology competitiveness, especially among developing nations, analyses of whether and how they predict future competitiveness and how they compare to other measures remain preliminary and inconclusive (Porter et al. 2001).[33] As a result, the primary value of these indicators at this stage is that they synthesize a large amount of potentially relevant data in a way that enables systematic comparisons and lays the groundwork for more probing analyses in the near future.

This section examines composite scores of the four indicators in 2007 for 14 developing countries, classified as middle or low income by the World Bank. The developing countries were divided into groups of larger and smaller economies according to their 2004 GDP in 1990 purchasing power parities: larger being economies that are greater or equal to $750 billion and smaller being less than $750 billion).

According to its 2007 composite score, China is the highest ranked of the six large developing economies examined (table 6-17; appendix table 6-26). Ranked fourth a decade ago, China moved to second in 1999, then to first in 2002, overtaking India, the previous leader. China's ascent was largely driven by a near doubling of its productive capacity indicator score over the last decade. The high rankings of both China and India in part result from advantages associated with size: a large and rapidly growing domestic market, a big population, and a growing number of scientifically and technically trained graduates.

Russia's ranking has fluctuated over the last decade (table 6-17; appendix table 6-26). In 2007, it was third, ahead of Mexico and Brazil. Mexico's 2007 ranking was higher than in past cycles as a result of rising scores for all four indicators. Brazil continued a decade-long decline resulting from low or negative growth for all four indicators. Indonesia has been ranked last among the six large developing economies for much of the decade.

Among the eight smaller developing economies examined, Malaysia ranks first in future high-technology export potential, followed by Poland and Hungary (table 6-18; appendix table 6-26). Thailand, ranked fourth, improved from its seventh rank in 1999 and 2002 as a result of growth for all four indicators. South Africa, Argentina, the Philippines, and Venezuela occupy the bottom half of this group. Among these countries, the Philippines has exhibited the most change in its position during the last decade, dropping from first in 1996 to seventh in 2007. Venezuela has been the lowest-ranked of the eight countries for the last decade. Although higher-ranked than Venezuela, the remaining two countries,

Table 6-17

Ranking of future high-technology export potential for larger developing countries: Selected years, 1996–2007

Country	1996	1999	2002	2005	2007
China	4	2	1	1	1
India	2	1	3	2	2
Russia	1	4	2	4	3
Mexico	5	6	5	5	4
Brazil	3	3	4	3	5
Indonesia	6	5	6	6	6

NOTES: Countries grouped by 2007 ranking. Developing countries classified as low or middle income by World Bank. Larger economies have 2004 gross domestic product ≥$750 billion expressed in 1990 purchasing power parities. Overall indicator is simple average of raw scores of four component indicators scaled to U.S. overall score. National orientation composed of an investment risk index, and questions addressing national strategy, implementation, entrepreneurship, and attitudes toward technology. Socioeconomic infrastructure composed of educational attainment and questions on national policies toward multinational investment and capital mobility. Technological infrastructure composed of number of scientists employed in R&D, electronic data processing purchases, and questions on technical training and education, industrial R&D, and technological mastery. Productive capacity composed of electronics production, and questions on supply of skilled labor and indigenous component supply and management capability.

SOURCES: Georgia Institute of Technology, Technology Policy and Assessment Center, High Tech Indicators: Technology-Based Competitiveness of 33 Nations. 2007 Final Report to National Science Foundation, Division of Science Resources Statistics (2007); Conference Board and Groningen Growth and Development Centre, Total Economy Database (January 2007), http://www.ggdc.net/dseries/totecon.shtml; and World Bank, http://web.worldbank.org/WBSITE/EXTERNAL/DATASTATISTICS/0,,contentMDK:20420458~menuPK:64133156~pagePK:64133150~piPK:64133175~theSitePK:239419,00.html.

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Table 6-18
Ranking of future high-technology export potential for smaller developing countries: Selected years, 1996–2007

Country	1996	1999	2002	2005	2007
Malaysia	2	2	3	1	1
Poland	3	3	2	3	2
Hungary	4	1	1	2	3
Thailand	5	7	7	6	4
South Africa	6	5	5	5	5
Argentina	7	6	6	7	6
Philippines	1	4	4	4	7
Venezuela	8	8	8	8	8

NOTES: Countries grouped by 2007 ranking. Developing countries classified as low or middle income by World Bank. Larger economies have 2004 gross domestic product ≥$750 billion expressed in 1990 purchasing power parities. Overall indicator is simple average of raw scores of four component indicators scaled to U.S. overall score. National orientation composed of an investment risk index, and questions addressing national strategy, implementation, entrepreneurship, and attitudes toward technology. Socioeconomic infrastructure composed of educational attainment and questions on national policies toward multinational investment and capital mobility. Technological infrastructure composed of number of scientists employed in R&D, electronic data processing purchases, and questions on technical training and education, industrial R&D, and technological mastery. Productive capacity composed of electronics production, and questions on supply of skilled labor and indigenous component supply and management capability.

SOURCES: Georgia Institute of Technology, Technology Policy and Assessment Center, High Tech Indicators: Technology-Based Competitiveness of 33 Nations. 2007 Final Report to National Science Foundation, Division of Science Resources Statistics (2007); Conference Board and Groningen Growth and Development Centre, Total Economy Database (January 2007), http://www.ggdc.net/dseries/totecon.shtml; and World Bank, http://web.worldbank.org/WBSITE/EXTERNAL/DATASTATISTICS/0,,contentMDK:20420458~menuPK:64133156~pagePK:64133150~piPK:64133175~theSitePK:239419,00.html.

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South Africa and Argentina, have consistently ranked in the bottom half of this group.

S&E Publications in Peer-Reviewed Journals

Output indicators in the form of articles appearing in the research literature are discussed in Chapter 5 because academic researchers account for most of those articles. This section focuses on trends first in the number and share of S&E articles produced by authors affiliated with industry, then in their collaboration patterns with other U.S. sectors and internationally.[34]

Number of Articles

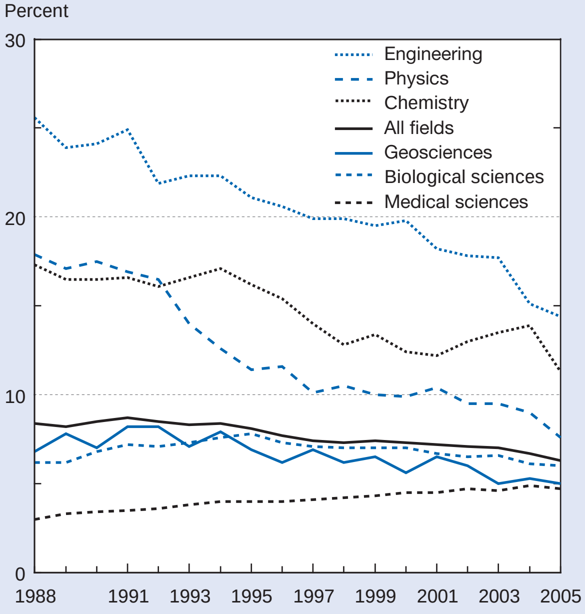
Trends in the number of S&E articles written by industrial researchers that appear in peer-reviewed journals, while not a direct indicator of innovation, are a rough indicator of outputs from research being carried out in industrial settings. This section examines the total number of articles authored by industry researchers as an indicator of overall industrial research activity, and the number of articles by these researchers published in basic research journals as an indicator of the volume of basic research carried out in industrial laboratories.[35]

Articles With an Industrial Author

The number of scientific articles with at least one author in U.S. private industry fluctuated between about 13,000 and 16,000 per year between 1988 and 2005, peaking at slightly more than 16,000 in 1991, then falling to its lowest level just below 13,000 in 2004. During this same period, however, the total number of U.S. S&E articles increased from 169,000 to 215,000 (appendix table 6-27). Consequently, industry's overall share of U.S. article output declined from just below 9% to about 6% (figure 6-26).

Six broad fields accounted for about 90% of the S&E literature by U.S. industry authors from 1988 to 2005: biological sciences, medical sciences, engineering, chemistry, physics, and the geosciences. With one exception, the number of industry articles peaked in 1995 or earlier for all of

Figure 6-26
U.S. S&E articles by authors in private industry as share of all U.S. S&E articles, by selected field: 1988–2005



NOTES: Fields are those in which authors from private industry made significant contribution (500 articles/year). Percentages based on fractional counts and an expanding journal set.

SOURCES: Thomson Scientific, Science Citation Index and Social Sciences Citation Index, http://www.scientific.thomson.com/products/categories/citation/; ipI , Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix table 6-27.

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these fields. The exception is medical sciences, for which articles increased throughout the period, peaking in 2005. In four of these broad fields, industry's share of all U.S. articles in the field declined between 1988 and 2005, from 26% to 14% in engineering, 18% to 8% in physics, 17% to 11% in chemistry, and 7% to 5% in the geosciences. Industry's share of articles in the biological sciences remained stable throughout the period (between 6% and 8%), whereas its share of articles in the medical sciences increased (from 3% to 5%) (figure 6-26).

Articles in Basic Research Journals

Between 1988 and 1995, the total number of basic research articles having authors in U.S. private industry fluctuated between 3,400 and 4,200 per year (appendix table 6-28). However, after peaking in 1995, the number declined by 30% through 2005. In contrast, the total number of basic research articles by authors from all sectors grew between 1995 and 2005. As a result, industry's share of this output declined, from slightly more than 6% to 4% (figure 6-27).

Five broad fields accounted for about 95% of the basic research literature by U.S. industry authors during the entire 18-year period: biological sciences, chemistry, physics, the geosciences, and the medical sciences. The trend in the number of basic research articles by U.S. industry researchers in the biological, medical, and geosciences, as a percentage of basic research articles in those fields, generally mirrored the trend for all fields, with gradual declines in share of about 1 percentage point.

Article output by U.S.-industry authors in physics and chemistry showed notably different patterns. In physics, the total number of these articles decreased sharply from nearly 1,000 in 1988 to about 300 in 2005. As a result, industry's share of basic research articles in physics dropped by more than 7 percentage points (figure 6-27). Most of this decline is accounted for by widespread restructuring of a few large corporations during this period, including closure, downsizing, or reorientation of large central research laboratories. Increased globalization, intensified competition, and commercial priorities may have contributed to the decline in publishing by companies and their researchers.

The pattern in chemistry has been different. U.S.-industry authors' share of basic research articles in chemistry fluctuated between 9% and 13% over the period. Researchers at large pharmaceutical companies continued or increased their already strong publishing traditions in chemistry basic research journals despite consolidation within the industry. The pharmaceutical industry's far greater reliance on patents and exclusivity for intellectual property protection relative to other industries may have played a role in its continued strong publishing record. Beyond pharmaceuticals, some of the same companies that saw declines in physics basic research articles also declined in chemistry.

Changing Emphasis on Basic Research

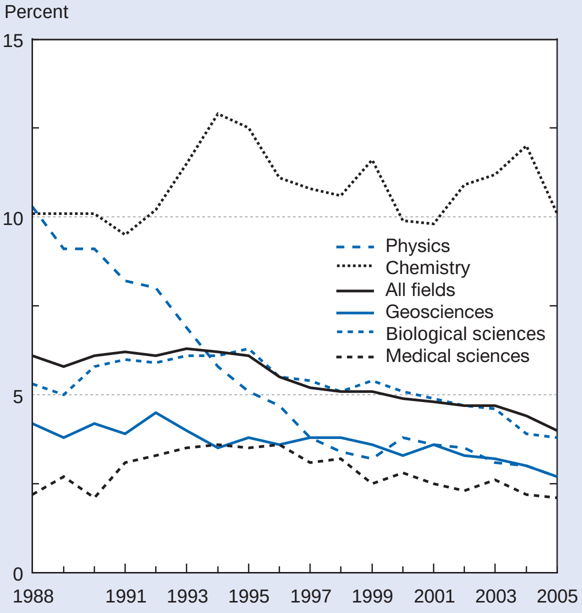
Industrial publications tended to shift away from basic research between 1988 and 2005. After peaking at 26% in 1995, the percentage of articles with an industrial author published in basic research journals declined to 22% by 2005 (figure 6-28).[36] This declining emphasis on basic research in industry publications has been especially strong in the biological sciences (from around 50% in the early 1990s to 39% in 2005), in physics (from 31% in 1988 to 20% in 2005), and in the medical sciences (from 10% in the early- to mid-1990s to 5% in 2005). Again, however, the pattern in chemistry has been quite different. The basic research share of industrially authored articles in chemistry increased from around 30% during the late 1980s to 46% in 2005.

Industry Collaboration in Publications

Both in the United States and worldwide, a major increase in collaboration across sectors and countries on S&E publications has been evident during the past decade. (For a more complete discussion of collaboration patterns, see "Coauthorship and Collaboration" and "Trends in Output and Collaboration Among U.S. Sectors" in chapter 5.)

Figure 6-27

U.S. S&E basic research articles by authors in private industry as share of all U.S. S&E basic research articles, by selected field: 1988–2005



NOTES: Fields have basic research journals to which authors from private industry make significant contribution (100   articles/year). Percentages based on fractional counts and an expanding journal set.

SOURCES: Thomson Scientific, Science Citation Index and Social Sciences Citation Index, http://www.scientific.thomson.com/products/categories/citation/; ipl   , Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix table 6-28.

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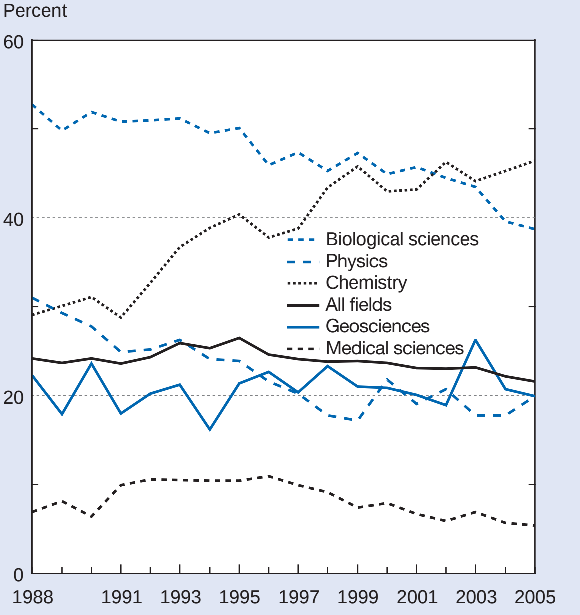
Figure 6-28
Industry S&E basic research articles as share of all industry S&E articles, by selected field: 1988–2005



NOTES: Fields have basic research journals to which authors from private industry make significant contribution (100 articles/year). Percentages based on fractional counts and an expanding journal set.

SOURCES: Thomson Scientific, Science Citation Index and Social Sciences Citation Index, http://www.scientific.thomson.com/products/categories/citation/; ipI , Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix table 6-28.

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Articles by Institutional Author Type

Articles with one or more authors in private industry can be broken down into five unique types:

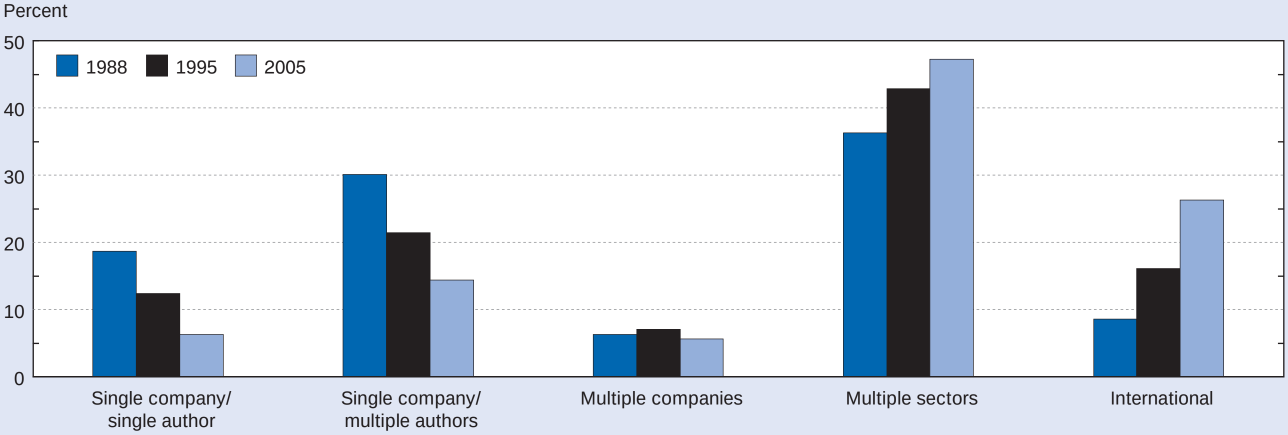
- Single company-single author[37]
- Single company-multiple authors
- Multiple companies, with authors from more than one U.S. company
- Multiple sectors, with U.S. authors from more than one sector[38]
- International, with at least one foreign author.

Between 1988 and 2005, single company-single author articles declined by almost 60% (to about 2,000) and single company-multiple author articles declined by almost 40% (also to about 2,000) (appendix table 6-29). Multiple-company articles increased by 20% during this period. In contrast, multiple-sector articles and international articles increased by about 70% and 300%, respectively (about 5,000 in both cases). The net result of these trends were drops from 19% to 6% in the proportion of single company-single author articles and from 30% to 14% for single company-multiple author articles. During the period, international articles increased from 9% to 26% and multiple-sector articles increased from 36% to 47% (figure 6-29).

Industry Collaboration Across U.S. Sectors

Coauthorship data indicate that U.S. industry collaborates more frequently with the academic sector than with other U.S. sectors.[39] Since 1988, more than 60% of the articles that industry authors have coauthored with someone outside their company have had an academic coauthor (appendix table 6-30). This is

Figure 6-29
S&E articles with industry authors, by institutional author type: 1988, 1995, and 2005



NOTE: Percentages based on whole counts and an expanding journal set.

SOURCES: Thomson Scientific, Science Citation Index and Social Sciences Citation Index, http://www.scientific.thomson.com/products/categories/citation/; ipI , Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix table 6-29.

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not unexpected, because the vast majority of S&E articles with a U.S. author include an author from academia.

Although the number of industry articles not limited to a single company increased substantially between 1988 and 2005, collaboration patterns between industry and other sectors changed very little during that period (figure 6-30). The only sector in which a large change in collaboration has occurred is the private nonprofit sector. The proportion of industry articles coauthored with the private nonprofit sector steadily increased from 9% to 15% from 1988 to 2005.

Global Trends in Patenting

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 in exchange for publicly disclosing details and licensing the use of the invention.[40] Inventors obtain patents from government-authorized agencies for inventions judged to be "new…useful…and…nonobvious."[41]

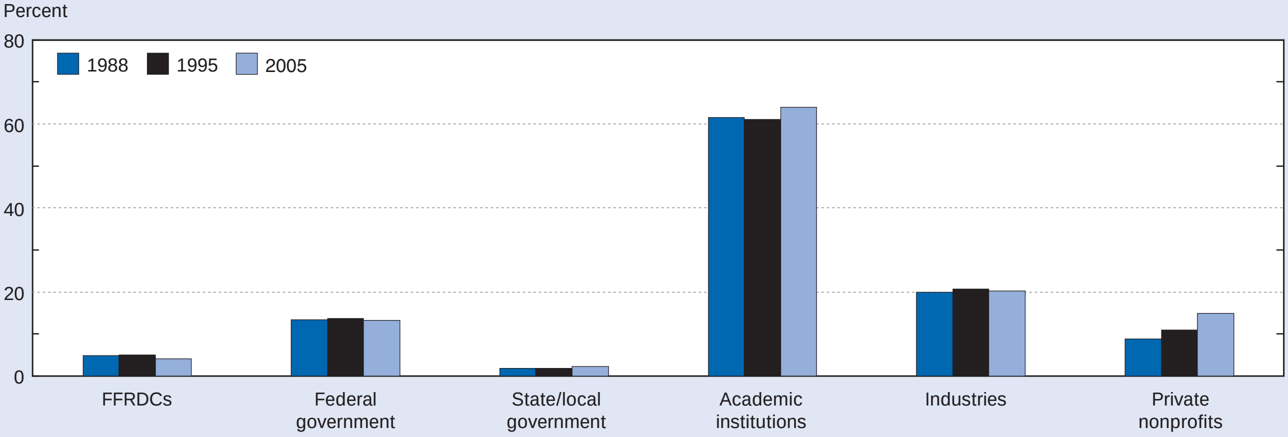
Patented inventions are of great economic importance when they result in new or improved products or processes or even entirely new industries, and, as is increasingly the case, when their licensing provides an important source of revenue. Worldwide revenues from patent licensing increased from $15 billion in 1990 to $110 billion in 2000 (Idris 2003).

This discussion focuses on patent activity at the U.S. Patent and Trademark Office (USPTO) and the European Patent Office (EPO).[42] These two patent offices are among the largest in the world in terms of volume of patents and have a significant share of applications and grants from foreign inventors.[43] The size and openness of the U.S. and EU markets offer potentially higher returns than smaller markets. Therefore, many domestic and foreign companies sell new products and services there and have a strong incentive to patent their inventions in both the United States and the EU.

These market attributes make data on patenting in the United States and Europe informative for the purpose of identifying trends in global inventiveness. Patenting indicators have several well-known drawbacks, however, 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 and the type and intensity of R&D differ by industry and technology area. For example, pharmaceutical companies patent more heavily and engage in years of costly R&D before achieving a fundamental breakthrough, whereas computer software companies patent less heavily and achieve more rapid but generally more incremental breakthroughs.
- **Inconsistency in importance.** The importance of patented inventions can vary considerably. Inventors may use other methods to protect their inventions, such as secrecy and product lead time. In addition, entities with large patent portfolios manage these carefully to control the cost of filing, maintaining, and defending their patents, including assessing the marginal benefits of potential new patents.
- **Varying motivations for patenting.** Inventors may patent for reasons other than commercialization or licensing,

Figure 6-30
Industry-coauthored S&E articles, by sector of coauthorship: 1988, 1995, and 2005



FFRDC = federally funded research and development center

NOTES: Percentages based on whole counts and an expanding journal set. Percents do not add to 100 because an article can have coauthors from multiple sectors.

SOURCES: Thomson Scientific, Science Citation Index and Social Sciences Citation Index, http://www.scientific.thomson.com/products/categories/citation/; ipI , Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix table 6-30.

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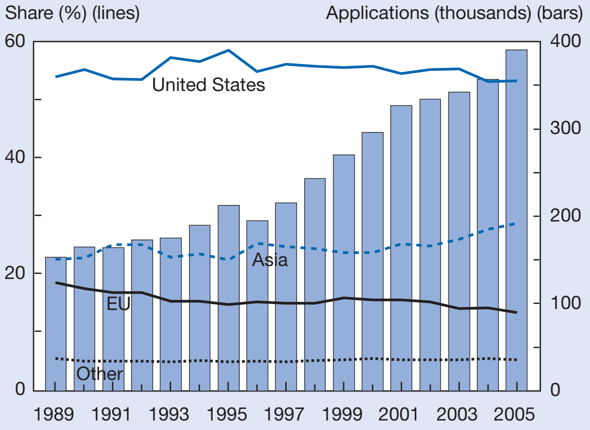
Figure 6-31
USPTO patent applications and share of total, by inventors from selected regions/countries/economies: 1989–2005



EU = European Union; USPTO = U.S. Patent and Trademark Office

NOTES: Patent applications assigned to region/country/economy based on residence of first-named inventor. Asia includes China, India, Indonesia, Japan, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. China includes Hong Kong.

SOURCES: USPTO, Number of Utility Patent Applications Filed in the United States, By Country of Origin, Calendar Years 1965 to Present (1), http://www.uspto.gov/web/offices/ac/ido/oeip/taf/appl_yr.htm, accessed 15 December 2006; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix tables 6-29 to 6-31 and 6-35.

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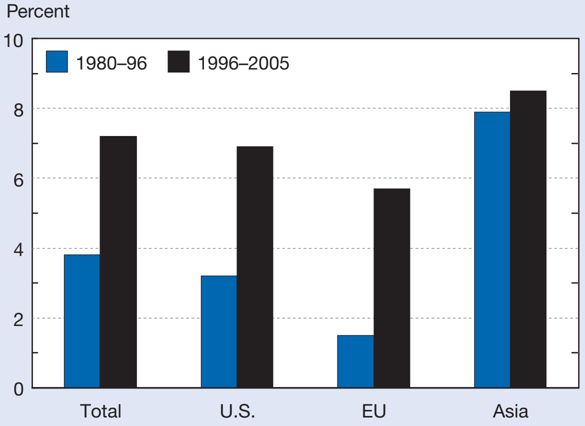
Figure 6-32
Average annual growth rate of USPTO patent applications for inventors from selected regions/countries/economies: 1980–2005



EU = European Union; USPTO = U.S. Patent and Trademark Office

NOTES: Patent applications assigned to region/country/economy based on residence of first-named inventor. Asia includes China, India, Indonesia, Japan, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. China includes Hong Kong.

SOURCES: USPTO, Number of Utility Patent Applications Filed in the United States, By Country of Origin, Calendar Years 1965 to Present (1), http://www.uspto.gov/web/offices/ac/ido/oeip/taf/appl_yr.htm, accessed 15 December 2006; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix tables 6-29 and 6-30.

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including blocking rivals from patenting related inventions, using patents as a tactic to negotiate with competitors, and helping to prevent infringement lawsuits (Cohen, Nelson, and Walsh 2000).

This discussion of patenting trends somewhat mitigates the above limitations by: (1) presenting data from two major markets, the United States and Europe; (2) looking at trends in key technology and industry areas, information and communications technology (ICT), and biotechnology; and (3) looking at trends in triadic patents, which are inventions valuable enough to patent in the three largest world markets, i.e., the United States, Europe, and Japan. With these adjustments, patent data may serve as an approximate indicator of inventiveness over time. In addition, information about foreign inventors seeking patents in the United States and Europe may offer some insights into inventiveness in and new technological competition from foreign countries (see sidebar, "Comparison of Data Classification Systems Used"). The discussion also examines data on U.S. patents granted to U.S. inventors by type of ownership and by state.

Applications for Patents in the United States and Europe

Trends in the number and sources of patent applications provide indicators of new sources of high-technology competition. Because the time from patent application to grant has grown rapidly in the United States and now averages 2–4 years in both the United States and Europe, data on patent filings provide a more instantaneous look at inventive trends than data on patents granted.[44] However, patent applications provide a less-definitive indicator of inventiveness compared with patent grants because some applications are rejected by the patent office or withdrawn by the inventor.

Applications for U.S. Patents

Applications filed for U.S. patents numbered more than 390,000 in 2005, a 9% increase from 2004, continuing the trend of strong growth over the past decade (figure 6-31; appendix tables 6-31 and 6-32). Starting in the mid-1990s, the growth rate of USPTO applications doubled compared with the 1980s and the early 1990s (figure 6-32). The acceleration of U.S. patent applications coincided with a strengthening of the patent system and extension of patent protection into new technology areas through policy changes and judicial decisions during the 1980s and 1990s (NRC 2004).

Inventors residing in the United States filed 208,000 applications in 2005, a little more than half of all U.S. patent applications filed that year.[45] Again starting in the mid-1990s, the growth rate for patent filings by U.S. inventors accelerated, but not as fast as the growth rate for filings by foreign inventors; the U.S. share dropped from 55% in 1996 to 53% in 2005 (appendix table 6-33). This may be indica-

U.S. Patents Granted by State and Type of Ownership

Examination of USPTO-issued patents provides information on patenting activity by U.S. states and type of ownership. More than half of USPTO patents issued to the United States come from seven states: California, Texas, New York, Michigan, Massachusetts, New Jersey, and Illinois (table 6-19; appendix tables 6-34 and 6-35). These seven top patenting states are among the top 10 states that accounted for almost two-thirds of U.S. R&D expenditures (see Chapter 4). California, which has the largest single share of any state, has showed a steady increase in its share from 15% in 1993 to 24% in 2005.

When patent output by U.S. states is adjusted for their population, however, the rankings change considerably. Two states with small populations, Idaho and Vermont, are ranked first and second, respectively, in their per capita output of U.S. patents in 2005 (figure 6-33; appendix table 6-36). Two of the six top patenting states, California and Massachusetts, however, remain highly ranked on a per capita basis.

Patents granted to U.S. inventors can be further analyzed by patent ownership at the time of the grant. Ownership is assigned on the basis of the first-named organization listed on the patent. Corporations own the majority of patents granted to U.S. entities, and their share has been steadily increasing since the early 1990s (figure 6-34). The PTO defines the corporate sector to include U.S. corporations, small businesses, and educational institutions. U.S. universities and colleges owned about 4% of U.S. utility patents granted to corporations in 2003. (For further discussion of academic patenting, see chapter 5.)

Almost all patents are issued to either corporations or individuals. In 2005, U.S. corporations owned 86% of patents issued to U.S. inventors, with individuals owning 14%; in 1992, the respective shares were 74% and 24%. Corporations also own the majority of U.S. patents issued to the rest of the world, and that share also has been increasing over the past decade. The share of individual ownership in patents issued to the rest of the world, which is about half of the level in the United States, has also fallen since the early 1990s.

Table 6-19
USPTO patents granted to inventors of selected states: Selected years, 1993–2005
(Percent)

State	1993	1995	1997	1999	2001	2003	2005
U.S. patents issued to all states (number)	53,231	55,739	61,708	83,905	87,600	87,893	74,637
Total of seven states	50.9	51.0	51.6	52.3	52.9	52.9	53.2
California	15.3	16.6	18.3	20.0	21.2	22.4	24.1
Texas	6.4	7.0	6.7	7.2	7.3	6.9	7.1
New York	8.8	8.4	7.8	7.3	7.2	7.1	6.3
Michigan	5.4	5.0	4.6	4.4	4.4	4.4	4.5
Massachusetts	4.1	3.9	4.2	4.2	4.2	4.4	4.2
New Jersey	5.5	4.9	5.2	4.8	4.4	4.0	3.4
Illinois	5.3	5.2	4.9	4.5	4.2	3.8	3.7

USPTO = U.S. Patent and Trademark Office

NOTE: Patents assigned to state based on residence of first-named inventor.

SOURCES: Patents By Country, State, and Year-Utility Patents (December 2006), http://www.uspto.gov/web/offices/ac/ido/oeip/taf/cst_utl.htm, accessed 15 February 2007. See appendix tables 6-34 and 6-35.

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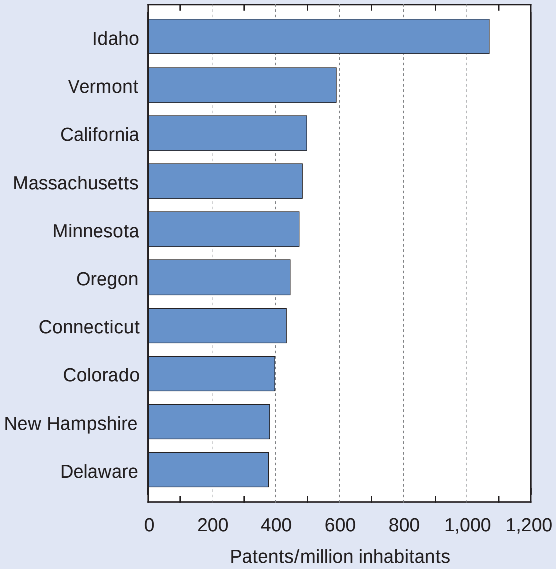
tive of increased globalization and increased recognition by developing countries of the potential value of intellectual property. Most USPTO patents credited to the United States are owned by corporations and granted to inventors in six states (see sidebar, "U.S. Patents Granted by State and Type of Ownership").[46]

Asia and the EU are the main sources of inventors outside of the United States filing for U.S. patent applications. Inventors residing in these two regions filed nearly 90% of applications filed by foreign inventors. Asia was the first-ranked foreign source in 2005, filing 112,000 U.S. patent applications (figure 6-31; appendix tables 6-31 and 6-32). Applications from Asia increased at a faster rate than those from the United States and the EU between 1985 and 2005 (figure 6-32), and Asia's share of U.S. patent filings increased from 19% to 29% during this period (appendix table 6-33). Japan, which produced much of the increase in Asia's share prior to the early 1990s, showed slower growth than the rest of Asia between 1996 and 2005 (table 6-20; appendix table 6-33). The three Asian economies of China, South Korea, and Taiwan drove the increase in Asia's share of U.S. patent filings between 1996 and 2005:

- China's applications grew eightfold, and its share of U.S. patent filings quadrupled from 0.2% to 0.8%. China's share ranking moved from 20th place in 1995 to 12th place in 2005 (appendix tables 6-37 and 6-38).

Figure 6-33
USPTO patents granted per capita for inventors from selected U.S. states: 2005



USPTO = U.S. Patent and Trademark Office

NOTES: Patents assigned to state based on residence of first-named inventor. States ranked by number of 2005 patents per million inhabitants in 2005.

SOURCES: USPTO, Patents By Country, State, and Year - Utility Patents, http://www.uspto.gov/web/offices/ac/ido/oeip/taf/cst_utl.htm (December 2006); and Census Bureau, Annual Estimates of the Population for the United States, Regions, and States and for Puerto Rico: April 1, 2000 to July 1, 2006 (NST-EST2006-01), http://www.census.gov/popest/states/NST-ann-est.html, accessed 15 December 2006. See appendix table 6-34.

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- South Korea's applications quadrupled, doubling its share of U.S. patent filings from 2.2% to 4.4%. South Korea's rapid growth caused its share ranking to move from eighth in 1995 to fourth in 2005, moving past France, the UK, and Canada (appendix tables 6-37 and 6-38).
- Taiwan's applications more than tripled, and its share of U.S. patent filings advanced from 2.4% to 4.3%. Taiwan's share ranking moved from seventh to fifth place, moving past the same countries overtaken by South Korea (appendix tables 6-37 and 6-38).
- India's applications grew more than 12-fold, but from an extremely low base, and its share of U.S. patent filings rose from 0.1% to 0.4%. India's share ranking moved from 29th to 17th during this period (appendix tables 6-37 and 6-38).

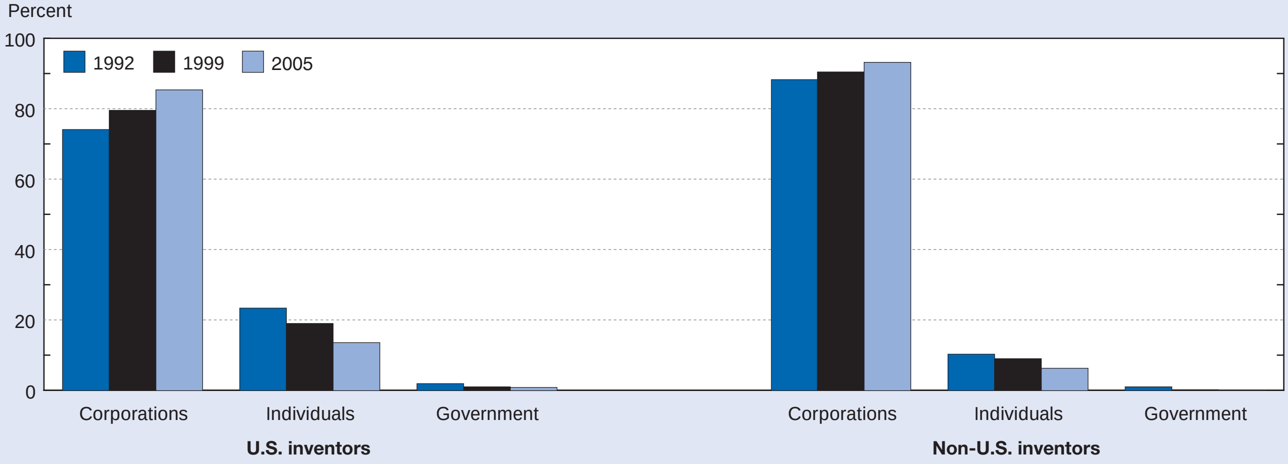
From 1996 to 2005, USPTO applications from the EU rose at the slowest rate of the three major world economies, and the EU's share of U.S. patent filings fell from 15% to 13% (figure 6-31; appendix tables 6-31 and 6-32).[47] The share of U.S. patent applications from inventors in France, Germany, and the UK, as a group, declined from 11% to 9% during this period.

A comparison of shares of USPTO patents granted among the three major world economies, the United States, Asia, and the EU, reveals trends similar to those observed concerning their applications (appendix tables 6-39 and 6-40).

Applications for European Patents

Applications for EPO patents reached nearly 114,000 in 2004, a 1% increase from 2003 (figure 6-35; appendix tables 6-41 and 6-42). The growth rate of EPO applications

Figure 6-34
USPTO patents granted, by type of ownership: 1992, 1999, and 2005



= 0.5

USPTO = U.S. Patent and Trademark Office

NOTES: Corporations refer to private, nonprofit, and educational institutions. Bulk of corporate patents originate from private companies.

SOURCE: USPTO, All Technologies (Utility Patents) Report, http://www.uspto.gov/web/offices/ac/ido/oeip/taf/all_tech.htm, accessed 15 December 2006.

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Table 6-20
USPTO patent applications for inventors from selected Asian regions/countries/economies: 1996, 2001, and 2005

Region/country/economy	1996 Number	1996 World share (%)	2001 Number	2001 World share (%)	2005 Number	2005 World share (%)
Asia	49,249	25.2	81,966	25.1	111,620	28.6
China	364	0.2	1,252	0.4	2,943	0.8
India	115	0.1	643	0.2	1,463	0.4
Japan	39,510	20.2	61,238	18.8	71,994	18.4
South Korea	4,248	2.2	6,719	2.1	17,217	4.4
Taiwan	4,766	2.4	11,086	3.4	16,617	4.3

USPTO = U.S. Patent and Trademark Office

NOTES: Patent applications assigned to region/country based on residence of first-named inventor. Asia includes China, India, Indonesia, Japan, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. China includes Hong Kong.

SOURCES: USPTO, Utility Patent Applications by Country of Origin, Calendar Years 1965–2005, http://www.uspto.gov/web/offices/ac/ido/oeip/taf/appl_yr.htm, accessed 15 December 2006. See appendix tables 6-32, 6-33, and 6-37.

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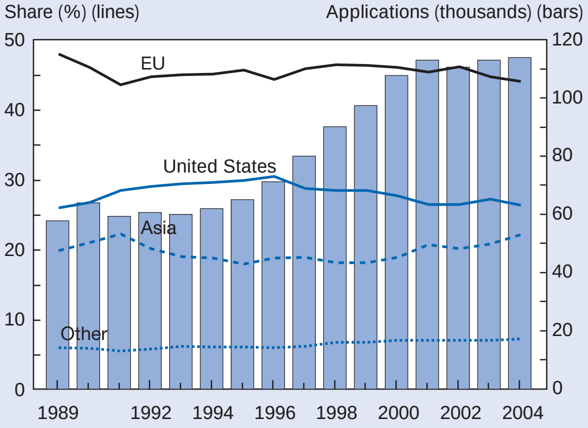
Figure 6-35
EPO patent applications and share of total, by inventors from selected regions/countries/economies: 1989–2004



EPO = European Patent Office; EU = European Union

NOTES: Patent applications assigned to year based on application date to EPO. Patent applications on fractional-count basis. For patent applications with multiple inventors from different countries, each country receives fractional credit based on proportion of its participating inventors. Asia includes China, India, Indonesia, Japan, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. China includes Hong Kong.

SOURCE: Organisation for Economic Co-operation and Development, Patent database, http://stats.oecd.org/wbos/default.aspx DatasetCode=PATS_IPC, accessed 15 February 2007. See appendix tables 6-31, 6-39, and 6-40.

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picked up in the mid-1990s, which is similar to the trend for USPTO applications except that EPO applications began to flatten starting in 2001.

The EPO received 30,000 patent applications from U.S. inventors in 2004, making the United States the first-ranked foreign source of EPO filings (appendix table 6-42). The growth rate of U.S. applications to the EPO picked up in the mid-1990s but leveled off starting in 2001, paralleling the growth trend of EPO applications by all countries (appendix tables 6-41 and 6-42).[48] Comparing U.S. applications to the EPO with those filed by inventors from the EU and Asia, the U.S. number grew at the slowest rate between 1996 and 2004, resulting in a decline of the U.S. share of filings at the EPO from 31% to 26% during this period (figure 6-35).

As expected, EU inventors have the largest share at the EPO with 44% of total applications in 2004 (figure 6-35; appendix table 6-33). The EU's EPO share remained flat between the mid-1990s and 2004, although the shares of some EU countries changed. The combined EPO share of France and the UK fell from 13% to 11% between 1996 and 2004, offset by small gains by Germany, the Netherlands, Spain, and several other countries.

Asia's EPO applications grew faster than those from the EU or the United States, and Asia's share of total patent filings at the EPO rose from 19% in 1996 to 22% in 2004 (figure 6-35; appendix table 6-33). During this same period, the share gap between the United States and Asia narrowed from 12 percentage points to 4. The same Asian economies that led Asia's patent filings at the USPTO, which were China, South Korea, and Taiwan, drove the rise in Asia's share of EPO patent applications.

A comparison of shares of EPO patents granted among the three major world economies, the United States, Asia, and the EU, reveals trends similar to those observed in their applications (appendix tables 6-43 and 6-44). Gains in EPO patents granted to China, India, South Korea, and Taiwan, however, have been lower than gains in EPO applications.

Patents Granted for Information and Communications Technology and Biotechnology

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. Inventions that lead to the creation of entire new industries, however, have a more profound impact on national and global economies. Two examples of the latter are ICT and biotechnology patents.

ICT patents have helped to create new industries and products such as home computers, cellular phones, and wireless devices. ICT technology has revolutionized and improved productivity in non-ICT industries and services, such as the health, finance, and retail sectors.

Biotechnology research and patents have led to entirely new industries that closely collaborate with and rely on basic research from the academic, government, and nonprofit sectors. Biotechnology patents have led to fundamental breakthroughs such as mapping the human genome and creating new diagnostic and therapeutic products. This section examines recent trends in ICT and biotechnology patenting in the United States and Europe and identifies countries that are the source for most of the ICT and biotechnology patenting in these two major markets.[49]

ICT Patenting

The numbers of ICT patents granted by the USPTO and EPO have increased rapidly over the past decade and a half (table 6-21; appendix tables 6-45 and 6-46). Between 1993 and 2006, the number of ICT patents granted by USPTO tripled, and the ICT share of all USPTO patents almost doubled from 26% to 49% (table 6-22; figure 6-36). ICT patents granted by the EPO grew less dramatically. Even so, they almost doubled, and the ICT share of EPO patents rose from 24% in 1993 to 28% in 1996, then flattened out before increasing to 29% in 2006.

Table 6-22
ICT and biotechnology patents share of total USPTO and EPO patents granted: Selected years, 1993–2006

Industry/agency	1993	1996	2000	2003	2005	2006
ICT						
EPO	23.6	28.1	27.3	25.3	27.2	29.2
USPTO	26.3	31.6	34.9	39.9	45.6	49.3
Biotechnology						
EPO	3.2	2.9	3.1	2.9	3.9	4.6
USPTO	2.0	2.8	3.6	3.1	2.9	3.3

EPO = European Patent Office; ICT = information and communications technology; USPTO = U.S. Patent and Trademark Office

NOTES: ICT includes telecommunications, consumer electronics, computers and office machinery, and other ICT as defined by Organisation for Economic Co-operation and Development (OECD). Biotechnology defined by OECD. Patent counts on fractional-count basis. For patent grants with multiple inventors from different countries, each country receives fractional credit based on proportion of its participating inventors.

SOURCES: OECD, Patent database, http://stats.oecd.org/wbos/default.aspx?DatasetCode=PATS_IPC, accessed 15 February 2007. See appendix tables 6-39, 6-40, and 6-43 to 6-45.

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Table 6-21
Share and activity index of ICT patents granted by USPTO and EPO, by inventors from selected regions/countries: 1993, 1999, and 2006

	1993		1999		2006	
Agency and region/country	Share (%)	Activity index	Share (%)	Activity index	Share (%)	Activity index
USPTO						
All regions (number)	25,830	na	51,258	na	77,982	na
United States	48.0	0.89	51.5	0.95	50.4	0.98
Asia	37.9	1.52	35.4	1.39	34.6	1.17
EU	11.4	0.68	10.0	0.64	10.8	0.76
EPO						
All regions (number)	8,643	na	9,803	na	17,256	na
United States	27.1	1.20	28.4	1.14	25.5	1.13
Asia	31.1	1.49	33.5	1.60	29.2	1.38
EU	38.5	0.76	34.2	0.71	40.1	0.80

na = not applicable

EPO = European Patent Office; EU = European Union; ICT = information and communications technologies; USPTO = U.S. Patent and Trademark Office

NOTE: ICT includes telecommunications, consumer electronics, computers and office machinery, and other ICT as defined by Organisation for Economic Co-operation and Development (OECD). Patent counts on fractional-count basis. For patent grants with multiple inventors from different countries, each country receives fractional credit based on proportion of its participating inventors. ICT activity index is region/country's share of ICT patents adjusted for its share of all patents. Asia includes China, India, Indonesia, Japan, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. China includes Hong Kong.

SOURCES: OECD, Patent database, http://stats.oecd.org/wbos/default.aspx?DatasetCode=PATS_IPC, accessed 15 February 2007. See appendix tables 6-45 to 6-47.

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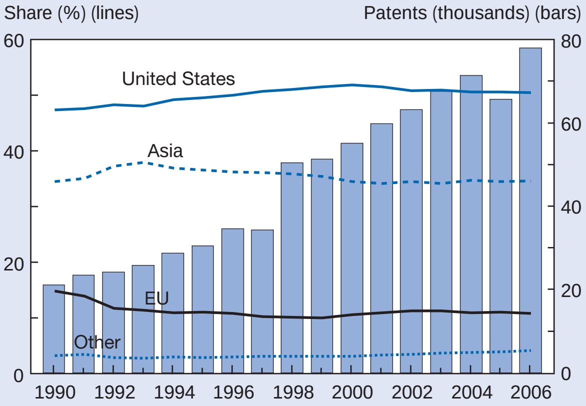
Figure 6-36
USPTO ICT patents granted and share of total, by inventors from selected regions/countries/ economies: 1990–2006



EU = European Union; ICT = information and communications technologies; USPTO = U.S. Patent and Trademark Office

NOTES: ICT consists of telecommunications, consumer electronics, computers and office machinery, and other ICT as defined by Organisation for Economic Co-operation and Development (OECD). Patent counts on fractional-count basis. For patent grants with multiple inventors from different countries, each country receives fractional credit on basis of proportion of its participating inventors. Asia includes China, India, Indonesia, Japan, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. China includes Hong Kong.

SOURCES: OECD, Patent database, http://stats.oecd.org/wbos/default.aspx DatasetCode=PATS_IPC, accessed 15 February 2007; and Compendium of Patent Statistics 2006,www.OECD.org/sti/ipr-statistics. See appendix tables 6-43 and 6-44.

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The United States has the largest share of ICT patents granted by the USPTO (figure 6-36; appendix tables 6-45 and 6-46). The U.S. activity index in USPTO ICT patents (the U.S. share of USPTO ICT patents compared with its share of all USPTO patents) is an indicator of U.S. patenting intensity in ICT compared with other technology areas. The U.S. activity index is around 1.0, which indicates that U.S.-resident inventors show about the same propensity to patent in ICT as in other technology areas (table 6-21; appendix table 6-47). In Europe, the United States is ranked third in share of EPO ICT patents granted. The U.S. inventor activity index at the EPO (1.13 in 2006), however, unlike its activity index at the USPTO, indicates that U.S. inventors have a higher propensity to patent ICT compared with other technologies.

Asia is ranked second in ICT at both patent offices among the three major economic areas (table 6-21; appendix tables 6-45 and 6-46). Asia's inventors also patent more intensively in ICT compared with other technology areas, according to its activity indexes (table 6-21; appendix table 6-47). A decline in its index for ICT over the past decade, however, indicates that Asia may be expanding its patenting activity to other technology areas. Japan has the largest share of world ICT patents of any Asian economy, although its share has fallen as South Korea and Taiwan have increased their patenting of ICT. ICT patents issued by the United States and the EPO to China and by the United States to India have sharply increased recently, although from very low levels.

The EU has a significantly lower presence in ICT patents compared with the United States and Asia (figure 6-36; appendix tables 6-45 and 6-46). The EU's activity index (0.76 in the USPTO and 0.80 in the EPO) indicates that the EU patents less intensively in ICT compared with other technology areas in both patent offices (appendix table 6-47). Five EU countries, however, do patent more intensively in ICT compared with the rest of the EU. In the USPTO and EPO, Finland and Ireland emphasize ICT compared with other technology areas, and the UK patents at about the same level of intensity in ICT as for other technology areas. Sweden and the Netherlands patent with the EPO more intensively in ICT than for other technology areas.

Biotechnology Patents

The number of biotechnology patents granted by the USPTO accelerated rapidly in the mid-1990s, almost doubling its share of all patents granted between 1993 and 2000 (figure 6-37; table 6-22; appendix tables 6-48 and 6-49).[50] The growth trend stopped and turned negative starting in 2001, however, and the biotechnology share of USPTO patents declined from 4% to 3% from 1998 to 2006. Biotechnology patents issued by the EPO, on the other hand, grew in volume between 2001 and 2006.[51] In 2004, the biotechnology share of all patents granted by the EPO surpassed that granted by the USPTO.

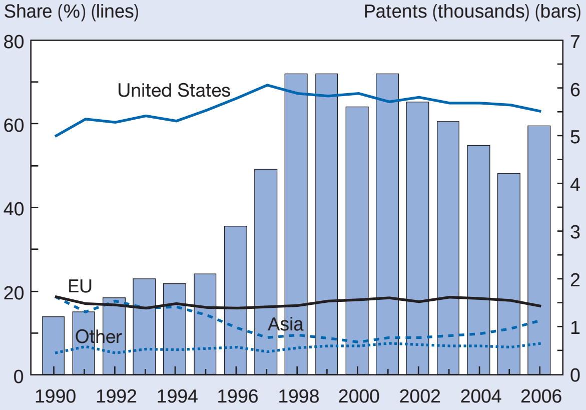
U.S. resident inventors have the largest share of biotechnology patents granted by the USPTO and EPO (table 6-23; appendix tables 6-48 and 6-49). The U.S. activity index in biotechnology patenting indicates that inventors residing in the United States patent more intensively in biotechnology compared with other technology areas within both patent offices. Asia has the smallest share of biotechnology patents from both patent offices compared with those of the United States and the EU. Asia's activity index in biotechnology patents also shows less emphasis on biotechnology than is evident within the United States and the EU.

The EU, on the other hand, ranks second to the United States in its share of biotechnology patents from both patent offices, although its activity index in EPO biotechnology patents indicates less-intensive patenting in biotechnology compared with other technology areas. The EU's activity index in USPTO, however, indicates a higher level of intensity in biotechnology compared with other technology areas (table 6-23).

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 has been developed that helps to address this problem by counting only those inventions for which patent protection is sought in the world's three largest

Figure 6-37
USPTO biotechnology patents granted and share of total, by inventors from selected regions/countries: 1990–2006



EU = European Union; USPTO = U.S. Patent and Trademark Office

NOTES: Biotechnology patents defined by Organisation for Economic Co-operation and Development (OECD). Patent counts on fractional-count basis. For patent grants with multiple inventors from different countries, each country receives fractional credit on basis of proportion of its participating inventors. Asia includes China, India, Indonesia, Japan, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. China includes Hong Kong.

SOURCE: OECD, Patent database, http://stats.oecd.org/wbos/default.aspx DatasetCode=PATS_IPC, accessed 15 February 2007. See appendix tables 6-46 and 6-47.

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markets: the United States, the EU, and Japan. These inventions are called *triadic patent families*.[52] The high cost of filing for patents from three separate patent offices and the need to manage patent costs in competitive industries make triadic patent families a more accurate measure of inventions deemed economically valuable than simple patent counts.

The number of triadic family patents was estimated to be almost 54,000 in 2003 (the last year for which data are available), a 3% increase compared with 2002 (figure 6-38; appendix tables 6-50 and 6-51). Since 2001, growth in triadic patent families has flattened compared with most of the previous decade. The same three sources that file the majority of U.S. and European patents (the United States, the EU, and Asia) account for the majority (more than 90%) of triadic patent families.[53] The United States has been the leading source of filings (37% of estimated world share) since 1989, when it surpassed the EU. Between 1996 and 2003, the gap between the U.S. share and the EU's share widened from less than 1 to 7 percentage points as the U.S. world share edged up and the EU's world share declined.

Asia's share (estimated at 28% in 2003) has stayed relatively constant since the early 1990s (figure 6-38; appendix tables 6-50 and 6-51). China, India, South Korea, and Taiwan, which are the same Asian countries that have increased their share in USPTO patents, also gained world share in triadic patent families, although on a more limited basis. Japan continues to have by far the dominant share of Asian countries, accounting for more than 90% of triadic patent families credited to Asia.

Table 6-23
Share and activity index for biotechnology patents granted by USPTO and EPO, by inventors from selected regions/countries: 1993, 1999, and 2006

	1993		1999		2006	
Agency and region/country	Share (%)	Activity index	Share (%)	Activity index	Share (%)	Activity index
USPTO						
All regions (number)	1,969	na	6,290	na	5,194	na
United States	61.9	1.15	66.6	1.22	62.9	1.22
Asia	15.9	0.64	8.8	0.35	13.0	0.44
EU	16.0	0.97	17.7	1.14	16.5	1.17
EPO						
All regions (number)	1,176	na	934	na	2,695	na
United States	33.2	1.47	42.7	1.71	38.7	1.71
Asia	23.2	1.00	13.0	0.62	15.0	0.71
EU	38.8	1.11	35.7	0.74	37.9	0.76

na = not applicable

EPO = European Patent Office; EU = European Union; USPTO = U.S. Patent and Trademark Office

NOTES: Biotechnology defined by Organisation for Economic Co-operation and Development (OECD). Patent counts on fractional-count basis. For patent grants with multiple inventors from different countries, each country receives fractional credit based on proportion of its participating inventors. Biotechnology activity index is region/country's share of biotechnology patents adjusted for its share of all patents. Asia includes China, India, Indonesia, Japan, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. China includes Hong Kong.

SOURCES: OECD, Patent database, http://stats.oecd.org/wbos/default.aspx?DatasetCode=PATS_IPC, accessed 15 February 2007; and Compendium of Patent Statistics 2006, www.OECD.org/sti/ipr-statistics. See appendix tables 6-48 and 6-49.

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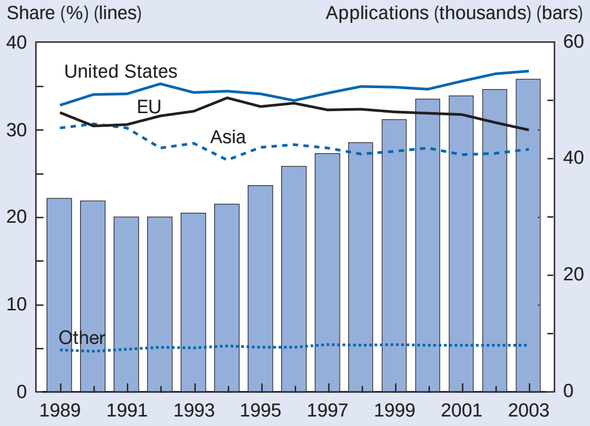
Figure 6-38

Triadic patent applications and share of total, by inventors from selected regions/countries: 1989–2003



EU = European Union

NOTES: Triadic patent families on fractional-count basis. For patent families with multiple inventors from different countries, each country receives fractional credit based on proportion of its participating inventors. Year on patent is first priority filing. Asia includes China, India, Indonesia, Japan, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. China includes Hong Kong.

SOURCE: Organisation for Economic Co-operation and Development, Patent database, http://stats.oecd.org/wbos/default.aspx DatasetCode=PATS_IPC, accessed 15 February 2007. See appendix tables 6-48 and 6-49.

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If triadic patents are normalized for either the size of the economy or for population, the rankings of the three regions (the United States, the EU, and Asia) do not change (table 6-24). The differences are considerably larger, however, when normalized by population. Four European countries (Finland, Switzerland, Germany, and Sweden) and Japan have a higher per capita and size-of-economy triadic patent family output than the United States.

U.S. High-Technology Small Businesses

Many of the new technologies and industries seen as critical to U.S. economic growth are also closely identified with small businesses, i.e., those employing fewer than 500 people. Biotechnology, the Internet, and computer software are examples of industries built around new technologies that were initially commercialized by small businesses. Operating within commercial environments characterized by fast-moving technology and rapidly changing consumer needs, small businesses learn from their customers, suppliers, and government labs and universities, and innovate based on what they have learned. This agility makes high-technology small businesses a key sector for developing, adopting, and diffusing new technologies within the U.S. economy.

Table 6-24

Triadic patents, by size of economy (GDP) and population for inventors from selected regions/countries/economies: 2003

Region/country/economy	GDP (1990 PPP $billions)	Population (millions)
Finland	5.94	121.83
Switzerland	5.43	120.82
Japan	5.02	106.57
Germany	4.51	86.02
Sweden	4.20	90.19
Israel	3.53	58.03
Netherlands	2.85	62.81
United States	**2.28**	**66.20**
EU	**1.91**	**36.93**
France	1.81	39.15
Denmark	1.60	37.08
United Kingdom	1.57	33.68
South Korea	1.09	17.40
Asia	**1.08**	**5.01**
Canada	0.95	22.04
Norway	0.95	24.81
Australia	0.93	21.84
Singapore	0.89	19.53
Italy	0.76	14.55
Ireland	0.61	15.04
Hungary	0.28	2.29
Taiwan	0.27	4.77
South Africa	0.20	0.85
Spain	0.17	2.86
Czech Republic	0.15	1.46
Russian Federation	0.06	0.39
India	0.04	0.09
Brazil	0.04	0.19
China	0.04	0.17
Mexico	0.02	0.16

EU = European Union; GDP = gross domestic product; PPP = purchasing power parity

NOTES: Triadic patent families on fractional-count basis. For patent families with multiple inventors from different countries, each country receives fractional credit based on proportion of its participating inventors. Year on patent is first priority filing. Asia includes China, India, Indonesia, Japan, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. China includes Hong Kong.

SOURCE: Organisation for Economic Co-operation and Development, Patent database, http://stats.oecd.org/wbos/default.aspx?DatasetCode=PATS_IPC, accessed 15 February 2007.

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This section covers patterns and trends that characterize small businesses operating in high-technology industries, based on data from the Census Bureau and Corporate Technology Information Services, Inc. (Corptech). The section reports on the number of companies, their formation, and employment figures. Two sources of financing for high-technology small businesses are examined, using data from the National Venture Capital Association and the University of New Hampshire's Center for Venture Research.

Employment in High-Technology Small Businesses

According to Census Bureau data, U.S. small businesses employed slightly more than half of the total labor force and accounted for one-third of employment in high-technology industries[54] in 2004 (table 6-25). Small businesses operating in high-technology industries numbered nearly one-half million firms and employed 5 million workers in 2004.[55]

In 2004, most workers in high-technology small businesses (67%) were in the service sector (table 6-26; appendix table 6-52). Service-sector employment is concentrated within six industries: architecture, computer systems design, consulting, management, commercial equipment and services, and R&D. These service industries collectively employed more than four-fifths of workers employed by all small businesses in high-technology service industries in 2004. The manufacturing sector employs most of the remainder of workers in high-technology small businesses (31% in 2004).

Employment in manufacturing is similarly concentrated within a relatively small number of industries: motor vehicle parts, metal working, semiconductors, other machinery, fabricated metals, and navigational and measurement tools. These six industries collectively employed more than half of all workers employed by all manufacturing high-technology small businesses and 16% of the entire high-technology small business labor force in 2004.

Table 6-26
Leading types of employers of high-technology small businesses, by industry: 2004

Industry	Employment (thousands)	Share (%)
All industries	5,045	100.0
Services	3,374	66.9
Top six combined	2,844	56.4
All others	530	10.5
Manufacturing	1,553	30.8
Top six combined	801	15.9
All others	752	14.9
Other	118	2.3

NOTES: Small businesses are firms with <500 employees. Firms include those reporting no employees on their payroll. Firm is an entity that is either in a single location with no subsidiaries or branches or is topmost parent of a group of subsidiaries or branches. High-technology industries defined by Bureau of Labor Statistics on basis of employment intensity of technology-oriented occupations. Other consists of agriculture, mining, and utilities.

SOURCES: Census Bureau, Statistics of U.S. Businesses, http://www.census.gov/csd/susb/susb.htm; and Hecker DE. 2006. High-technology employment: A NAICS-based update. *Monthly Labor Review* 128(7):57–72, http://www.bls.gov/opub/mlr/2005/07/art6full.pdf, accessed 19 September 2007.

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Formation of High-Technology Small Businesses

Corptech has created a database on the formation of high-technology businesses by technology area. Corptech identifies 17 industry areas as high technology (using a classification that is not comparable to the Bureau of Labor Statistics definition of high-technology businesses used in the previous section).[56] Formations of U.S. high-technology small businesses sharply increased in the mid-1990s, rising from around 1,000 annually to an annual average of about 1,400 from 1995 to 1999 (figure 6-39). Coinciding with the end of the dot.com boom in 2000, formations declined steeply and have remained at half or less of 1990s levels.

Changes in the share of high-technology small business formations by technology area may indicate emerging areas of technologies. Factory automation accounted for the largest share of formations (15%) between 2003 and 2004, which was 9 percentage points higher than during the 2000–02 period (figure 6-40; appendix table 6-53). Computer software had the second highest share during the period 2003–04 (10%), sharply down compared with its 25% share from 1997 to 2002. The shares of three industries that

Table 6-25
Firms and employment in U.S. small businesses versus all businesses: 2004

Technology	All businesses	Small businesses	Small business share (%)
High-technology			
Firms (thousands)	497	482	97.0
Employment (millions)	15.1	5.0	33.5
All technologies			
Firms (thousands)	5,886	5,869	99.7
Employment (millions)	115.1	58.6	50.9

NOTES: Small businesses are firms with <500 employees. Firms include those reporting no employees on their payroll. Firm is an entity that is either a single location with no subsidiary or branches or topmost parent of a group of subsidiaries or branches. High-technology industries defined by Bureau of Labor Statistics on basis of employment intensity of technology-oriented occupations.

SOURCES: Census Bureau, Statistics of U.S. Businesses, http://www.census.gov/csd/susb/susb.htm; and Hecker DE. 2006. High-technology employment: A NAICS-based update. *Monthly Labor Review* 128(7):57–72, http://www.bls.gov/opub/mlr/2005/07/art6full.pdf, accessed 19 September 2007.

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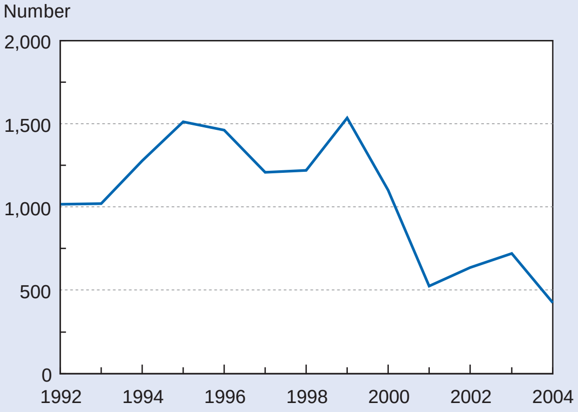
Figure 6-39
U.S. high-technology small business formation: 1992–2004



NOTE: High-technology areas defined by Corporate Technology Information Services, Inc. (Corptech).

SOURCE: Corptech, http://www.corptech.com/index.php, special tabulations (15 June 2007). See appendix table 6-53.

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rank just below computer software, i.e., computer hardware, manufacturing equipment, and subassemblies, have at least doubled compared with their shares from 1997 to 1999. The most dramatic change was the decline in new telecommunications and Internet-related small businesses. This industry's share from 2003 to 2004 was 6%, which is 20 percentage points lower compared with the period from 2000 to 2002, and down 35 percentage points compared with the period from 1997 to 1999.

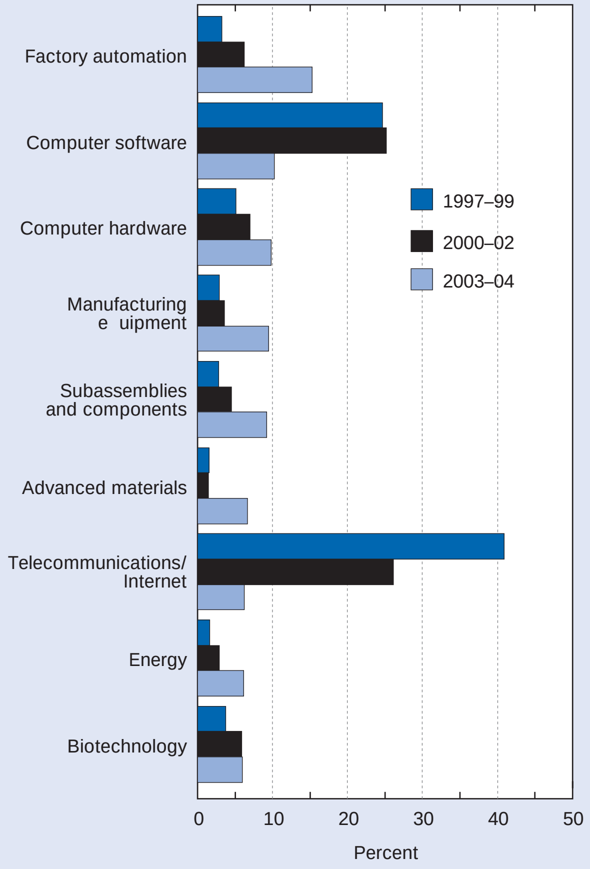
Financing of High-Technology Small Businesses

Entrepreneurs seeking to start up or expand a small firm with new or unproven technology may not have access to public or credit-oriented institutional funding. Two types of financing, *angel* and *venture*, are often critical to financing nascent and growing high-technology and entrepreneurial businesses. (In this section, *business* denotes anything from an entrepreneur with an idea to a legally established operating company.)

Angel investors tend to be wealthy individuals who invest their own funds in entrepreneurial businesses, either individually or through informal networks, usually in exchange for ownership equity. Venture capitalists manage the pooled investments of others, typically wealthy investors, investment banks, and other financial institutions in a professionally managed fund. In return, venture capitalists receive ownership equity and almost always a say in managerial decisions.

Venture capital firms have categorized their investments into four broad financing stages, which are also relevant for discussion of angel investment:

Figure 6-40
U.S. high-technology small business formation, by share of selected technology areas: 1997–2004



NOTE: High-technology areas defined by Corporate Technology Information Services, Inc. (Corptech).

SOURCE: Corptech, http://www.corptech.com/index.php, special tabulations (15 June 2007). See appendix table 6-53.

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- **Seed and startup funding,** referred to as *seed-startup* throughout this section, provides financing at the earliest stage of business development. Seed funding develops proof of a concept, and startup funding supports product development and initial marketing.
- **Early funds** provide financing 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.
- **Later-stage funds** include acquisition financing and management and leveraged buyouts. Acquisition financing provides resources for the purchase of another company, and a management and leveraged buyout provides funds to enable operating management to acquire a product line or business from either a public or private company.

Angel investor funds are concentrated in the seed-startup and early stages. During the period 2005–06, they provided 92% of investment for these stages compared with 8% in later stages. Venture capital, however, is provided primarily in the expansion and later stages (figure 6-41).

This section examines angel and venture capital investment patterns in the United States, focusing on the period from 2001 to the present and examining: (1) changes in the overall level of investment, (2) investment by stage of financing, and (3) the technology areas that U.S. angel and venture capitalists find attractive.

U.S. Angel Capital Investment

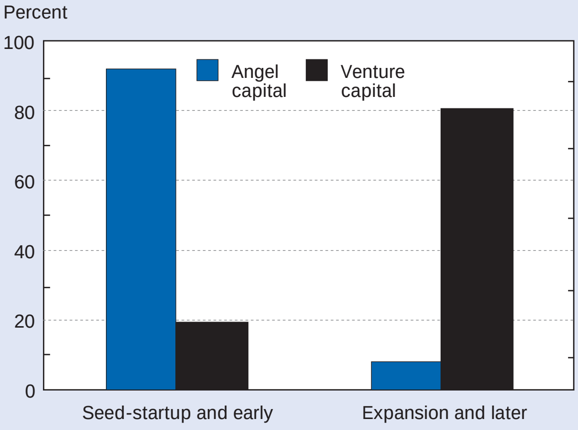
According to data from the Center for Venture Research, angel investors provided $25.6 billion in financing in 2006, an 11% increase compared with 2005 and the fourth consecutive annual increase since 2002 (figure 6-42; appendix table 6-54).[57] An estimated 51,000 businesses received financing from angel investors in 2006, 1,500 more compared with 2005, and 3,000 more compared with 2004. The average investment per business from 2004 to 2005 increased from about $470,000 to $500,000 in 2006 (table 6-27).

Although angel investors continue to concentrate on the riskier stages of business development, they have become more conservative in their investment patterns. Slightly more than half of all angel investment financing was seed-startup financing in 2006, down from nearly 60% in 2002 (figure 6-43). Conversely, angel investment financing in the early stage grew from 41% to 47% during this period.

Changes in the technology areas that attract angel investment may indicate changes in the parts of the economy that offer future growth opportunities. Healthcare and medical devices received the largest share of angel investment in 2006 (21%), 5 percentage points higher than its 2004 share (figure 6-44). Biotechnology received 18% of total angel investment in 2006, 8 percentage points higher than its 2004 share. Software also received 18% share of total angel investment during the same period, 4 percentage points lower than its share in 2004.

Businesses receiving angel investment in 2006 employed about 200,000 workers. This figure is about the same as employment in 2005, but 60,000 jobs greater compared with the 2004 level (appendix table 6-54). Each business employed an average number of four workers from 2005–06, up from three workers in 2003.

Figure 6-41
Share of angel and venture capital investment, by financing stage: 2005–06



NOTES: Seed-startup includes proof of concept (seed), research, and product development. Early includes financing for activities such as initial expansion, commercial manufacturing, and marketing. Expansion includes major expansion of activities, or to prepare a company expecting to go public within 6–12 months. Later includes acquisition financing and management and leveraged buyout.

SOURCES: Center for Venture Research, University of New Hampshire, http://wsbe2.unh.edu/center-venture-research; and Thomson Financial, National Venture Capital Association Yearbook 2007 (2007). See appendix table 6-56.

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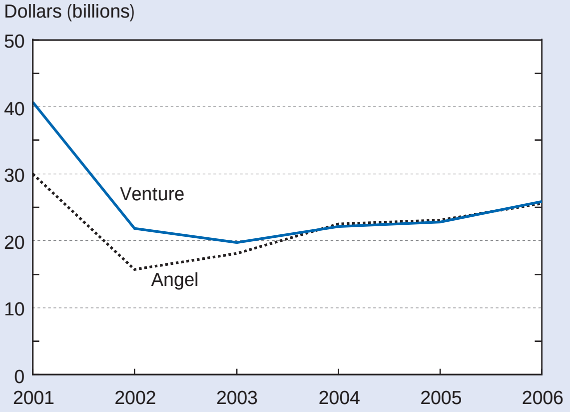
U.S. Venture Capital Investment

U.S. venture capitalists invested $26 billion in 2006, a 14% gain compared with the level in 2005 (figure 6-42; appendix table 6-55). The amounts of angel and venture capital investment have been very similar for the last 5 years. Since declining sharply in 2002 following the end of the dot.com boom, angel and venture capital investment have been strengthening.

Venture capitalists financed 2,910 firms in 2006, far fewer than the number of businesses financed by angel investors (51,000). The average venture capital investment was $8.9 million per firm, much larger than the corresponding figure for angel investors (table 6-27; appendix table 6-56).

The number of businesses funded by venture capital and the average amount of investment have been increasing during the

Figure 6-42
Angel and venture capital investment: 2001–06



SOURCES: Center for Venture Research, University of New Hampshire, http://wsbe2.unh.edu/center-venture-research; and Thomson Financial, National Venture Capital Association Yearbook 2007 (2007). See appendix tables 6-54, 6-55, and 6-56.

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Table 6-27
Average investment of angel and venture capital per business: 2002–06

	Angel			Venture		
Year	Businesses (number)	Total investment ($billions)	Average investment/business ($thousands)	Businesses (number)	Total investment ($billions)	Average investment/business ($thousands)
2002.........	36,000	15.7	436	2,619	21.8	8,324
2003.........	42,000	18.1	431	2,416	19.7	8,154
2004.........	48,000	22.5	469	2,574	22.1	8,586
2005.........	49,500	23.1	467	2,646	22.8	8,617
2006.........	51,000	25.6	502	2,910	25.9	8,900

NOTE: Business includes anything from an entrepreneur with an idea to a legally established operating company.

SOURCES: Center for Venture Research, University of New Hampshire, http://wsbe2.unh.edu/center-venture-research; and Thomson Financial, National Venture Capital Association Yearbook 2007 (2007).

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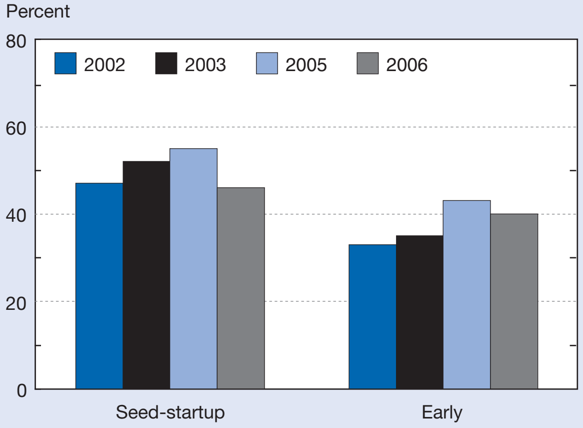
last several years. The number of businesses in 2006 was 10% higher than in 2005 and 13% higher than the 2004 level. Average investment per business in 2006 was about $300,000 higher compared with 2005 and 2004, and approximately $750,000 higher compared with 2003.

Like angel investment, venture capital investment has become generally more conservative and moved toward later stages of business development. As noted previously, the bulk of venture capital is provided for expansion and later-stage financing; from 2002 to 2006 these stages accounted for a combined share of 80% (figure 6-45; appendix table 6-56). Expansion financing has typically been the single largest stage financed by venture capital funds, accounting for approximately half or more of all venture investment from 1996 through 2004. Expansion financing's share, however, declined to 41% between 2005 and 2006. Later-stage investment, on the other hand, more than doubled from 15% during the mid-1990s to 31% from 2002 to 2004, before rising to 39% between 2005 and 2006, a level nearly equal to the share of expansion financing.

As the venture capital industry has consolidated, venture capitalists have largely abandoned the seed-startup stage and invested almost exclusively in early, expansion, and later stages. The share of venture capital devoted to seed-startup financing peaked at 19% in 1994 and then declined precipitously, bottoming out just above 1% in 2002 (figure 6-45; appendix table 6-56). Three factors help explain this shift:

Figure 6-43
Angel investment, by share of seed-startup and early activities: 2002–06



NOTES: 2004 data not available. Seed-startup includes proof of concept (seed), research, product development, or initial marketing. Early provides funding for initiating commercial manufacturing and sales.

SOURCE: Center for Venture Research, University of New Hampshire http://wsbe2.unh.edu/center-venture-research.

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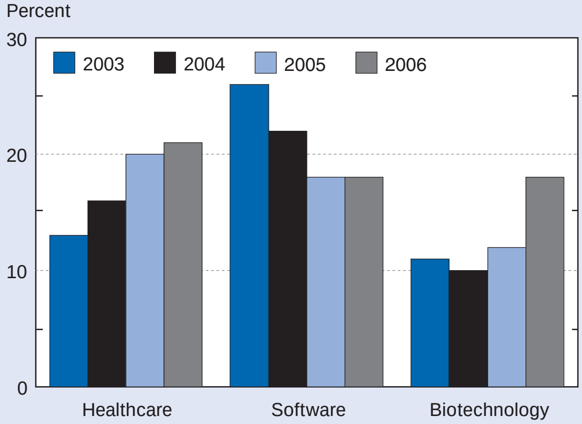
Figure 6-44
Share of top three technology areas receiving angel capital investment: 2003–06



NOTES: Technology areas ranked by 2006 share. Healthcare includes medical devices and equipment. Healthcare definition for 2003 slightly different from definition for 2004–06.

SOURCE: Center for Venture Research, University of New Hampshire, http://wsbe2.unh.edu/center-venture-research.

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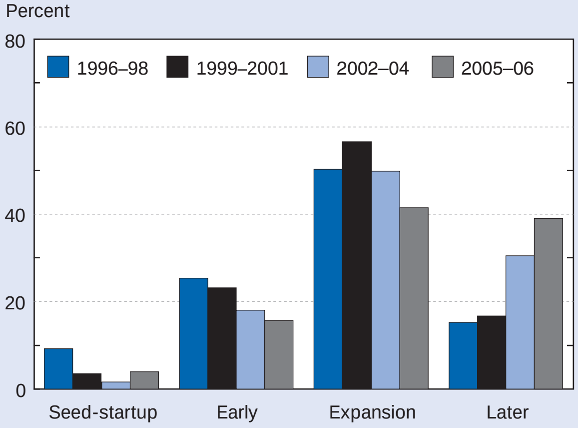
Figure 6-45
U.S. venture capital investment, by stage of investment: 1996–2006



NOTES: Seed-startup includes proof of concept (seed), research, product development, or initial marketing. Early includes financing for activities such as initial expansion, commercial manufacturing, and marketing. Expansion includes major expansion of activities, or to prepare a company expecting to go public within 6–12 months. Later includes acquisition financing and management and leveraged buyout.

SOURCE: Thomson Financial, National Venture Capital Association Yearbook 2007 (2007). See appendix table 6-56.

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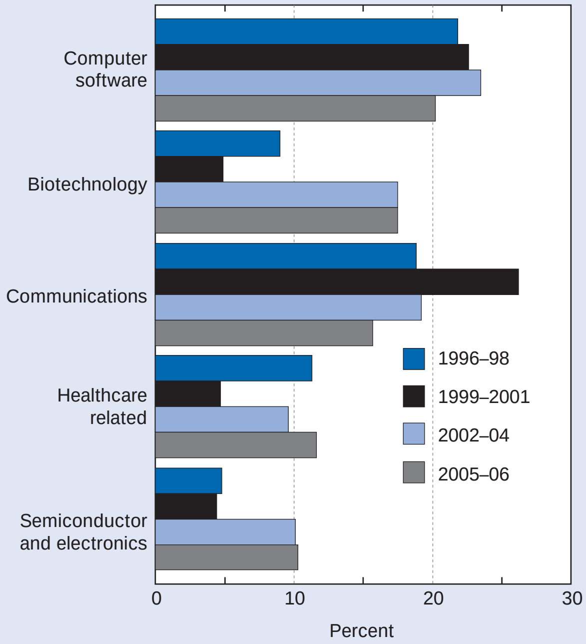
- Investment in early, expansion, and later stages is usually less risky compared with the seed-startup stage.
- Venture capital funds in the 21st century generally have a shorter time horizon for closing out their investments compared with the longer time required by seed-startup investments.
- The amount of investment required for seed-startup is typically below the minimum threshold of venture capital funds.

In 2003, however, the percentage of venture capital invested in the seed-startup stage began to inch up, reaching 4% by 2006. This recent increase has been attributed to two factors: the need for venture capitalists to find new investments after closing out their holdings in mature companies and the emergence of promising new opportunities that spurred investment in new businesses (NVCA 2007a).

Venture Capital Financing by Industry

Computer software had the largest share of venture capital funding of any industry from 2005 to 2006 (20%), a slight decline compared with 2002–04 levels (figure 6-46; appendix table 6-55). Biotechnology had the second highest share from 2005 to 2006 (18%), more than triple its share during the period 1999–2001. The growth in venture capitalist financing of biotechnology parallels rising interest by angel investors (figure 6-44). Communications, which had the largest share between 1999 and 2001, slipped to second place from 2002 to 2004 and fell slightly below biotechnology from 2005 to 2006. The healthcare and semiconductor industries each received 10%–12% of venture capital investment, about double their levels from 1999 to 2001.

Figure 6-46
U.S. venture capital investment, by share of selected industry: 1996–2006



SOURCE: Thomson Financial, National Venture Capital Association Yearbook 2007 (2007). See appendix table 6-55.

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During the late 1990s, the Internet emerged as a business tool, and companies developing Internet-related technologies drew venture capital investments in record amounts. The share of Internet-related companies more than doubled from 35% in 1996 to peak at more than 70% from 1999 to 2000 before falling sharply to a level of about 40% or less in 2004 (appendix table 6-55). Internet-related companies continue to command a substantial share of venture capital, however, especially in several high-technology industries. For example, in 2006, the share of Internet-related companies in the computer software and communications industries exceeded 65% (table 6-28). In retailing and media, Internet-related companies amounted to three-quarters of all companies financed by venture capital. Other sectors have far smaller shares of Internet-related companies, including semiconductors (9%), healthcare (3%), and industrial/energy (1%).

Venture Capital Investment by U.S. States

Venture capital is invested disproportionately in a few states that also perform most of the R&D conducted in the United States and that receive most U.S. patents (table 6-29; appendix table 6-57). California alone received nearly one-half of total venture capital investment in 2006; its 48% share that year was 8 percentage points higher than its share a decade earlier. Massachusetts has the second highest share of investment (11% in 2006); this share has remained steady during the last decade. The remaining top-10 states receiving venture capital have shares between 2% and 5%. These 10 states collectively account for 86% of total U.S. venture capital investment (see Chapter 8).

Venture Capital Financing and Employment

According to the National Venture Capital Association, firms that received venture financing employed an estimated 10 million workers in 2005, more than half of whom worked in R&D and technology-intensive industries including computer hardware (19%), industrial/energy (12%), financial services (9%), and software (9%) (table 6-30). Two other R&D-intensive industries, which have close ties to scientific research and academia, employed a combined 4% of the workers in venture capital-financed firms. In 2005, employment in firms with venture capital support was 9% higher than in 2003 and 16% higher than 2000 levels (NVCA 2007b).

Table 6-28

Share of Internet-related venture capital investments, by industry: 2006

Industry	Share (%)
All industries	38.1
Communications	83.2
Retailing and media	75.2
Computer software	65.6
Computer hardware	62.7
Business/financial	43.3
Semiconductor and electronics	8.9
Healthcare related	2.9
Industrial/energy	1.3
Biotechnology	0.0

NOTE: Industries ranked by their Internet-related share of venture capital investment.

SOURCE: Thomson Financial, National Venture Capital Association Yearbook 2007 (2007).

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Table 6-29

Top 10 U.S. states receiving venture capital investment: 1996, 2001, and 2006

(Percent share)

State	1996	2001	2006
All states ($billions)	11.3	40.7	26.0
All states (% share)	100.0	100.0	100.0
California	40.4	41.0	48.0
Massachusetts	9.6	11.8	10.9
Texas	4.7	7.2	5.3
New York	3.6	5.2	4.9
Washington	3.6	2.8	3.9
New Jersey	3.6	3.7	3.1
Pennsylvania	2.7	2.4	2.9
Maryland	1.2	2.4	2.6
Colorado	2.7	3.1	2.5
North Carolina	1.6	1.4	1.8
All others	26.3	18.9	14.0

NOTES: Data includes Puerto Rico and Washington, DC. States ranked by share in 2006.

SOURCE: Thomson Financial, National Venture Capital Association Yearbook 2007 (2007).

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Table 6-30

Employment in venture capital-backed firms, by industry: 2005

Industry	Number (thousands)	Share distribution (%)
All industries	10,000	100.0
Media, entertainment, and retail	2,006	20.1
Computers and peripherals	1,886	18.9
Industrial/energy	1,180	11.8
Financial services	897	9.0
Software	858	8.6
Biotechnology and medical devices/equipment	425	4.3
Other	2,748	27.5

SOURCE: Global Insight, Venture Impact: The Economic Importance of Venture Capital Backed Companies to the U.S. Economy. 4th ed. National Venture Capital Association (2007). http://www.nvca.org/pdf/NVCA_VentureCapital07-2nd.pdf, accessed 11 August 2007.

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Conclusion

The U.S. economy continues to be a leading competitor and innovator in the global economy as measured by its overall performance, market position in S&T industries, and trends in patenting of new technologies at home and abroad. The U.S. economy has grown relatively rapidly and become more productive while sustaining a high and rising per capita income. The U.S. gap with Asia on many of these measures is narrowing, however, because of rapid progress by China and several other countries. Although the EU's economic position is relatively strong, its market position in S&T industries has either flattened out or slipped.

The strong competitive position of the U.S. economy is tied to continued U.S. global leadership in many industries that have extensive ties to S&T. With the service sector increasingly dominating global economic activity, the United States continues to hold the dominant market position in service industries that rely on S&T. The U.S. trading position in technology-oriented services remains strong, as evidenced by the continued U.S. surplus in trade of computer software and manufacturing know-how.

The U.S. position in high-technology manufacturing industries, however, is not quite as strong as in services. The United States continues to be a leading innovator and producer in many high-technology manufacturing industries, but the historically strong U.S. trade position has decreased. Although in surplus for the prior two decades, the U.S. trade balance moved to a deficit during the late 1990s because of faster growth of imports, primarily in computer and communications equipment. The U.S. trade balance in advanced-technology goods has similarly moved from surplus to deficit during this period.

Led by China, South Korea, and Taiwan, Asia is challenging the U.S. market position in S&T industries and reducing the gap on technological innovation. China has rapidly risen to become a leading producer and exporter of high-technology manufacturing goods, as measured by world market share. This rapid ascent shows signs of continuing. South Korea, Taiwan, and other Asian economies have also become leading producers and exporters in S&T-intensive industries.

Various patenting indicators suggest that the United States will remain a leader in technological development within its domestic and foreign markets. The leading source of economically valuable patents known as triadic patents, the United States also leads in U.S. patent applications and is the leading foreign source of European patent applications. Asia shows a strengthening of technological development, however; its share of U.S. and European patents has risen markedly, led by Japan, South Korea, and Taiwan.

In sum, the United States continues to be a world-class competitive and technologically innovative country with a leading position in most high-technology industries. Several Asian economies, however, including China, South Korea, Taiwan, and India, have become global players in some high-technology industries, and their technological capabilities are strengthening. The EU, on the other hand, has lost market share in high-technology industries.

Notes

1. Educating a workforce that 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 Science and Engineering (chapter 2), and Science and Engineering Labor Force (chapter 3).

2. This chapter presents data from various public and private sources. Consequently, the countries included vary by data source.

3. The Bureau of Economic Analysis (BEA) estimates that treating R&D as an investment increased the level of current-dollar GDP by an average of 2.5% per year during the period 1959 to 2002 (Okubo et al. 2006). The BEA estimate measures the direct impact of R&D and does not include the indirect (spillover) impact of R&D.

4. GDP per capita does not reveal anything about comparative distribution of income across countries, for which data are not readily available.

5. Extensive literature exists on the impact of IT on U.S. economic growth in the mid-1990s. For example, see Stiroh K 2001. What drives productivity growth? *Economic Policy Review* 7(1):39–59; http://www.newyorkfed.org/research/epr/01v07n1/0103stir.html. Accessed 26 June 2007.

6. See OECD (2001) for discussion of classifying economic activities according to degree of "knowledge intensity."

7. 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 UK, 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 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. For additional perspectives on OECD's methodology, see Godin B. 2004. The new economy: What the concept owes to the OECD. *Research Policy* 33:679–90.

8. Data are extracted from the Global Insight World Industry Service database, which provides information for 70 countries that account for more than 97% of global economic activity. The Global Insight data on international country activity within the service and manufacturing industries are expressed in 2000 constant dollars. Constant dollar data for foreign countries are calculated by deflating industry data valued in each country's nominal currency.

9. Compared with 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 aggregation and types of data collected. For example, export and import data are currently not available for many services.

10. Gross revenue includes inputs or supplies purchased from other industries or services. Knowledge-intensive service and high-technology manufacturing industry data are expressed in 2000 constant dollars. Constant-dollar data for foreign countries is calculated by deflating nominal domestic currency with a sector-specific price index constructed for that country, then converting the result to U.S. dollars based on average annual market exchange rates.

11. Asia is defined in this section as consisting of China, India, Indonesia, Japan, Malaysia, the Philippines, Singapore, South Korea, Taiwan, and Thailand. China includes Hong Kong.

12. One of the earliest quantitative analyses of R&D was done in 1955 by R.H. Ewell, supported by the National Science Foundation. This study showed a definite correlation between research and productivity. Also see Godin B. 2004. The obsession for competitiveness and its impact on statistics: The construction of high-technology indicators. *Research Policy* 33:1217–29.

13. This conclusion is derived from an examination of weighted U.S. data from the Bureau of Labor Statistics Occupational Employment Survey concerning average annual pay during the period 1997–2001.

14. Global Insight's data show that U.S. high-technology industry manufacturers' share of value added to total output was 20% higher than the share of all other U.S. manufacturing industries.

15. This conclusion is derived from an examination of weighted U.S. data from the Bureau of Labor Statistics Occupational Employment Survey on average annual pay from 1997–2001.

16. Europe's success in growing its aerospace industry and China's efforts to develop a semiconductor industry are two examples.

17. 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.

18. In 1999, the State Department's responsibilities under the International Traffic in Arms Regulation were expanded to include research activity formerly covered under the 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.

19. Like the United States, other national governments usually have strong ties to their aerospace industries, often supporting and funding R&D and serving as major customers.

20. 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 the value resulting from domestic production. Exported shipments will, therefore, often include the value of purchased foreign inputs.

21. EU exports exclude intra-EU exports.

22. The U.S. trade balance is affected by many other factors including currency fluctuations, differing fiscal and monetary policies, and export subsidies between the United States and its trading partners.

23. U.S. trade in software products is not a separate National Institute of Standards and Technology 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, in effect creating an 11th category (see figure 6-23).

24. 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 dollar was a contributing factor in the broad-based decline in exports by U.S. manufacturers from 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.

25. Data on U.S. trade balance in advanced technology products during the 1990s is available at appendix table 6-3 in volume 2 of NSB (2002), accessible at http://www.nsf.gov/statistics/seind02/append/c6/at06-03.pdf.

26. 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.

27. 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.

28. 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' decisions to locate production abroad. See Borga and Mann (2004).

29. The Bureau of Economic Analysis (BEA), the source of U.S. royalty and fees data, collects data on the following Asian countries/economies: China, Hong Kong, India, Indonesia, Japan, Malaysia, the Philippines, Singapore, South

Korea, Taiwan, Thailand, and other unspecified Asian countries. See BEA (2007).

30. Asia has purchased more manufacturing know-how than the EU since 1987, the first year data were collected on manufacturing know-how. See BEA (2007).

31. See chapter 2 for a discussion of international higher education trends and chapter 4 for a discussion of trends in U.S. R&D.

32. For details on survey and indicator construction, see Porter et al. (2005).

33. For information on the validity and reliability testing the indicators have undergone, see Porter et al. (2001, 2005) and Roessner, Porter, and Xu (1992).

34. These articles are identified by at least one author having a private, for-profit institutional address.

35. In this section, article counts were reported on a fractional-count basis. In the following section's discussion of collaboration trends, articles are reported on a whole-count basis. See the sidebar "Bibliometric Data and Terminology" in chapter 5 for a description of these methods of counting articles and how they are generally used.

36. In contrast to the decline in emphasis on basic research in industry publications, about one-third of U.S. publications overall were published in basic research journals from 1988 to 2005.

37. All addresses for a company and its subsidiaries are unified into a single code for the parent company.

38. Other U.S. sectors in which researchers produced articles are academia, the federal government, state and local governments, federally funded R&D centers, and the private nonprofit sector.

39. The base for the percentages discussed in this section is the number of industry articles with one or more industry authors minus the number of single company articles.

40. 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.

41. U.S. patent law states that any person who "invents or discovers any new and useful process, machine, manufacture, or composition of matter, or any new and useful improvement thereof, may obtain a patent." The law defines "nonobvious" as "sufficiently different from what has been used or described before [so] that it may be said to be nonobvious to a person having ordinary skill in the area of technology related to the invention." These terms are part of the criteria in U.S. patent law. For more information, see USPTO, "What is a patent?" at http://www.uspto.gov/web/offices/pac/doc/general/index.html#patent, accessed 28 June 2007.

42. Although the USPTO 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.

43. The Japan Patent Office (JPO) is also a major patent office but has much smaller share of foreign patents compared with the USPTO and EPO.

44. USPTO reports that average time to process an application (pendancy) was 31.1 months for utility, plant, and reissue patent applications in FY 2006, compared with 18.3 months in FY 2003. Applications for utility patents account for the overwhelming majority of these requests. The EPO reports that the average pendancy was 45.3 months in 2005.

45. Unless otherwise noted, USPTO patents are assigned to countries on the basis of the residence of the first-named inventor.

46. U.S. patenting data on type of ownership and by state is available only for U.S. patents granted.

47. Some of the decline in U.S. patenting by inventors from the EU and other leading industrialized nations may be because of movement toward European unification, which has encouraged wider patenting within Europe.

48. EPO patents are assigned to countries on a fractional-count basis. For patents with inventors from different countries, each country receives credit on basis of proportion of its participating inventors.

49. The data source for EPO and USPTO patents is the OECD. USPTO data drawn from the OECD database are not directly comparable with data reported by the USPTO because of methodological differences and consequent OECD adjustments.

50. A 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 can be patented.

51. The EU issued a directive that harmonized the laws of member states on biotechnology patenting, which may explain the lag and subsequent growth of EU biotechnology patents compared with the United States.

52. The database is housed at the OECD and produced as a collaborative project among the OECD, the National Science Foundation, the EU, the World Intellectual Property Organization, the USPTO, the JPO, and the EPO. Until March 2001, only patents granted in the United States were published in the database. Technically, the dataset counts those inventions for which patent protection is sought in Europe and Japan and obtained in the United States.

53. Triadic patent families with coinventors residing in different countries are assigned to their respective countries on a fractional count basis. Patents are listed by priority year, which is the year of the first patent filing. Data for 1998–2003 are estimated by the OECD.

54. The high-technology definition used here is from the Bureau of Labor Statistics and differs from that used in earlier sections.

55. See Hecker (2005) for their definition and methodology for determining high-technology industries. Several industries identified by the Bureau of Labor Statistics as high technology are not available in the Census Bureau's data prior to 2003.

56. Corptech classifies 17 fields as high technology: factory automation, biotechnology, chemicals, computer hardware, defense, energy, environmental, manufacturing equipment, advanced materials, medical, pharmaceuticals, photonics, computer software, subassemblies and components, testing and measurement, telecommunications and the Internet, and transportation. For more information, see www.corptech.com.

57. Comparable data on angel capital investment is not available prior to 2001.

Glossary

Activity index: A country's (based on residence of the inventor) world share of patents within a particular technology area, divided by a country's world share of all patents. The activity index is used to determine the propensity to patent within a particular technology area compared with other technology areas.

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.

Angel investment: Financing from affluent individuals for business startups, usually in exchange for ownership equity. Angel investors typically invest their own funds or organize themselves into networks or groups to share research and pool investment capital.

Asia-10: China (including Hong Kong), India, Indonesia, Japan, Malaysia, the Philippines, Singapore, South Korea, Taiwan, and Thailand.

Basic research journals: Scientific journals covered by the Institute of Scientific Information that are classified as "basic scientific research," one of the four categories of a research level classification system for scientific journals developed by ipIQ, Inc. (formerly CHI). Journals assigned to the other three categories publish science at a research level that is applied, developmental, or more targeted, as defined by ipIQ.

Company or firm: A business entity that is either a single location with no subsidiary or branches or the topmost parent of a group of subsidiaries or branches.

EU-15: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden, and the UK.

EU-20: Austria, Belgium, Bulgaria, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, the Netherlands, Poland, Portugal, Romania, Slovakia, Spain, Sweden, and the UK.

EU-25: Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, and the UK.

Gross domestic product (GDP): The market value of all final goods and services produced within a country within a given period of time.

Gross revenues (sales): The value of the industry's shipments or services, equivalent to the industry's sales, including domestic and imported supplies and inputs from other industries.

Harmonized code, harmonized system (HS): Developed by the Customs Cooperation Council, the Harmonized System, or Harmonized Commodity Description and Coding System, is used to classify goods in international trade.

High-technology manufacturing industries: Those that spend a relatively high proportion of their revenue on R&D, consisting of aerospace, pharmaceuticals, computers and office machinery, communications equipment, and scientific (medical, precision, and optical) instruments.

Intellectual property: Intangible property resulting from creativity that is protected in the form of patents, copyrights, trademarks, and trade secrets.

Intra-EU exports: Exports from EU countries to other EU countries.

Knowledge-intensive industries: Those that incorporate science, engineering, and technology into their services or the delivery of their services, consisting of business, communications, education, financial, and health services.

Market-oriented knowledge-intensive [services]: Knowledge-intensive services that are generally privately owned and compete in the marketplace without public support. These services are business, communications, and financial services.

Normalizing: To adjust to a norm or standard.

Not obvious: One criterion (along with "new" and "useful") by which an invention is judged to determine its patentability.

Productivity: The efficiency with which resources are employed within an economy or industry, measured as labor or multifactor productivity. Labor productivity is measured by GDP or output per unit of labor. Multifactor productivity is measured by GDP or output per combined unit of labor and capital.

Purchasing power parity (PPP): The exchange rate required to purchase an equivalent market basket of goods.

R&D intensity: The proportion of R&D expenditures to the number of technical people employed (e.g., scientists, engineers, and technicians) or the value of revenues.

Small business: A company or firm with less than 500 employees.

Triadic patent: A patent for which patent protection has been applied within the three major world markets: the United States, Europe, and Japan.

Utility patent: A type of patent issued by the U.S. Patent and Trademark office for inventions, including new and useful processes, machines, manufactured goods, or composition of matter.

Value added (value-added revenue): Gross revenue (sales) excluding purchases of domestic and imported inputs and materials.

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Chapter 7

Science and Technology: Public Attitudes and Understanding

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Highlights

Information Sources, Interest, and Involvement

Television and the Internet are Americans' primary sources of science and technology (S&T) information.

- More Americans select television as their primary source of S&T information than any other medium.
- The Internet ranks second among sources of S&T information, and its margin over other sources is large and growing.
- To learn about specific scientific issues, more than half of Americans choose the Internet as their main information source.
- Internet users do not always assume that online S&T information is accurate. About four of five surveyed said they had checked on the reliability of information at least once.

Surveys have long shown that most Americans express substantial interest in S&T. However, other indicators suggest a lower level of interest.

- In surveys conducted annually from 2001 to 2006, between 83% and 87% of Americans said they had "a lot" or "some" interest in new scientific discoveries.
- Survey data indicate that, relative to other topics, interest in S&T is not particularly high. However, some topics that rank higher than S&T, such as new medical discoveries, include extensive S&T content.
- As with many news topics, the percentage of Americans who say they follow S&T news closely has declined over the past 10 years, but S&T's decline has been more pronounced.
- Recent surveys indicate that elsewhere in the world, including Japan and Europe, public interest in S&T is lower than in the United States. China is a notable exception.
- In 2006, about three of five Americans said they had visited an informal science institution, such as a zoo or museum, in the past year. This proportion is generally consistent with results from surveys conducted since 1979.

Public Knowledge About S&T

Many Americans do not give correct answers to basic factual questions about science and questions about the scientific inquiry process.

- Americans' factual knowledge about science has not changed much over time. Factual knowledge is positively related to level of formal schooling, income level, and number of science and math courses taken.
- People who score well on long-standing survey questions that test for information typically learned in school also appear to know more about nanotechnology and the Earth's polar regions, topics that historically have not been central to the standardized content of American science education.
- Levels of factual knowledge of science in the United States are comparable with those in Europe and appear to be better than those in Japan, China, or Russia.
- Americans' understanding of the scientific process appears to have improved slightly in recent years. Their level of understanding is strongly associated with factual knowledge of science and with level of education.

U.S. scores on questions about the theory of evolution and the "big bang" are lower than those in other countries, and many Americans are receptive to including nonscientific views in science classrooms.

- Many Americans appear skeptical of established scientific ideas in these areas, even when they have some basic familiarity with them.
- Americans' responses to questions about evolution have remained virtually unchanged over the past 25 years.
- More Americans approved than disapproved of instruction about three explanations of the origins of life (evolution, intelligent design, and creationism) in public school science classes. However, many were unsure.

Public Attitudes About S&T in General

Americans consistently and by large margins endorse the past achievements and future promise of S&T. This support has been evident in surveys conducted since 1979.

- In 2006, more than half of Americans said that the benefits of scientific research have strongly outweighed the harmful results, and only 6% said the harms slightly or strongly outweighed the benefits. Other indicators yield similar results.
- Americans' positive attitudes about S&T cross demographic boundaries: men and women, college graduates and high school dropouts, and blacks and whites all express support.
- Americans also express some reservations about S&T. A majority agree that "scientific research these days doesn't pay enough attention to the moral values of society," although the proportion agreeing dropped substantially in annual surveys between 2001 and 2006. Nearly half believe that science makes life change too fast.
- Attitudes about the benefits of S&T are somewhat more favorable in the United States than in Europe, Russia, and Japan. Attitudes in China and South Korea, however, are comparable with and perhaps even more favorable than those in the United States.

Support for government funding of scientific research is strong and growing.

- In 2006, 87% of Americans expressed support for government funding of basic research, up from levels around 80% in past surveys dating back to 1979.
- The percentage of Americans who said that the government spends too little on scientific research grew from 34% to 41% between 2002 and 2006.
- Other kinds of federal spending, however, generate even stronger public support.

The public consistently expresses confidence in science leaders.

- In 2006, more Americans expressed a great deal of confidence in leaders of the scientific community than in the leaders of any other institution except the military. Despite a general decline in confidence in institutional leaders since the early 1970s, confidence in science leaders has remained relatively consistent.
- On science-related public policy issues (including global climate change, stem cell research, and genetically modified foods), Americans believe that science leaders, compared with leaders in other sectors, are relatively knowledgeable and impartial and should be relatively influential. However, they also perceive a significant lack of consensus among scientists on these issues.

In deciding whether a study is scientific, most Americans rely on criteria related to the research process: whether results are evidence based, carefully interpreted, and replicated.

- Research process characteristics are especially important among more highly educated Americans, who are less likely than others to rely on other criteria such as researchers' credentials, institutional settings, and consistency with common sense or with religious beliefs.
- Americans and Europeans both see medicine as more scientific than other fields, with physics and biology following close behind it.

Public Attitudes About Specific S&T Issues

Americans have recently become more concerned about environmental quality.

- In 2007, 43% of Americans expressed strong concern about the environment, up from 35% in 2005. However, concern about the environment ranks somewhere in the middle among 12 issues.
- Global warming has recently become more prominent among environmental issues of concern to the public, although it still ranks 8th among 10 issues.

Many Americans are unfamiliar with emerging technologies and research topics, and many have significant misconceptions about them.

- Few Americans (about 1 in 10) consider themselves "very familiar" with biotechnology.
- Most Americans (60%) believe they have not eaten genetically modified foods, although in fact processed foods commonly contain genetically modified ingredients.
- More than half of Americans (54%) have heard "nothing at all" about nanotechnology.
- Most Americans say they are "not very clear" (35%) or "not clear at all" (35%) about the distinction between reproductive and therapeutic cloning.

A majority of Americans support medical research that uses stem cells from human embryos. However, Americans are wary of innovations using cloning technology, and they overwhelmingly oppose reproductive cloning.

- In three surveys conducted between 2004 and 2006, a majority agreed with the statement that it was more important to continue with stem cell research than to avoid destroying human embryos used in the research.
- About half of Americans oppose using human cloning technology even if it is limited to helping medical research develop new treatments for disease.
- Four of five Americans oppose using "cloning technology to produce a child."

Americans, Europeans, and Canadians share similarly favorable attitudes about biotechnology and nanotechnology.

- In 2005, 71% of Americans and 67% of Canadians expressed support for products and processes involving biotechnology. Almost two-thirds of Europeans said they expected biotechnology to positively affect their way of life in the next 20 years.
- When told about nanotechnology, about half of Americans surveyed in 2005 foresaw substantial or some benefit from it, and 14% expected substantial or some risk. Canadian response to the same question was similar. Among Europeans, 48% expected positive effects from nanotechnology, whereas only 8% expected negative effects.

Introduction

Chapter Overview

In today's America, science and technology (S&T) are everywhere. Americans encounter S&T in their roles as citizens, workers, and consumers. As citizens, they vote for candidates with different views about global warming, stem cell research, and deficit spending, issues about which atmospheric scientists, microbiologists, and macroeconomists claim expertise. As workers, they compete for jobs in technology-driven sectors of the economy that did not exist a generation ago, where familiarity with recently invented devices and emerging scientific disciplines makes them more competitive. As consumers, in their leisure time, they rely on new technologies to entertain themselves, build relationships with others, and keep informed about the world around them.

It is increasingly difficult for Americans to be competent as citizens, workers, and consumers without some degree of competence in dealing with S&T. Because competence begins with understanding, this chapter presents indicators of how Americans get S&T news and information and how much they know about S&T. How the American citizenry collectively deals with public issues that centrally involve S&T in turn affects whether America will continue to be a fertile environment for developing scientific knowledge and applying it in practical contexts. It also affects the kinds of S&T development America will support. The chapter therefore includes indicators of attitudes about S&T-related issues. Because citizens often rely on trusted leaders to shape their attitudes on contested issues, the chapter includes indicators of public perceptions concerning the influence scientific experts ought to have on S&T-related policies.

Indicators of what Americans know and think concerning S&T may be considered in two essentially different ways. They may be compared to a benchmark that suggests what people ought to know or how they ought to apply their knowledge. These indicators may also be compared with similar indicators for past years or other countries. In an increasingly globalized world, international comparisons become increasingly relevant: a culture in which S&T flourish can give a country a competitive advantage, and public understanding of and support for S&T are components of such a culture.

Chapter Organization

The chapter is divided into four major sections. The first includes indicators of the public's sources of information about, level of interest in, and active involvement with S&T. This section contains data on public use of the mass media for science news and information and on involvement with informal science in museums, science centers, zoos, and aquariums. The second section of the chapter reports on indicators of public knowledge, including measures of factual knowledge and understanding of the scientific process. The third and fourth sections of the chapter are about attitudes toward S&T. The third section contains data on attitudes about S&T in general, including support for government funding of basic research, confidence in the leadership of the scientific community, perceptions of the prestige of S&E as occupations, and opinions about how much influence science and scientists ought to have in public affairs. The fourth section addresses attitudes on specific S&T-related issues. It includes indicators of public opinion about several emerging lines of research and new technologies, including biotechnology, genetically modified food, nanotechnology, stem cell research, and cloning.

A Note About the Data

Throughout, the chapter emphasizes trends over time, patterns of variation within the U.S. population, and international patterns. It gives less weight to the specific percentages of survey respondents who gave particular answers to the questions posed to them. Although, inevitably, the chapter reports these percentages, they are subject to numerous sources of error and should be treated with caution. Caution is especially warranted for data from surveys that omit significant portions of the target population, have low response rates, for which significant methodological information is unavailable, and have topics that are particularly sensitive to subtle differences in question wording (see sidebar, "Survey Data Sources"). In contrast to specific percentages, consistent and substantial trends and patterns warrant greater confidence. However, international comparisons, where language and cultural differences affect how respondents interpret questions and can introduce numerous complexities, also require special care.

Information Sources, Interest, and Involvement

Because S&T are relevant to so many aspects of daily life, information about S&T can help Americans make better decisions and develop more confidence in their ability to make sense of the world around them. In addition to opening up avenues to the intrinsic satisfactions that S&T offer, interest in and involvement with S&T can be paths to acquiring more information and achieving greater understanding.

S&T Information Sources

U.S. Patterns and Trends

More Americans get most of their information about current news events from television than any other source. About half report television as their main information source, with substantial percentages reporting newspapers (23%) and the Internet (14%) as their main source (appendix table 7-1). These figures have not changed substantially since 2004 (NSB 2006). Marked changes in media use for current news occurred throughout the 1990s, including rapid growth in Internet use and sharp declines in regular local and network news viewership and in newspaper readership. However, these trends appear to have slowed or stopped in recent years (Pew Research Center for the People and the Press 2006a).

Survey Data Sources

Primary topic	Sponsoring organization	Title	Years used	Information used	Data collection method	Number of respondents/ margin of error of general population estimates
U.S. (general)	National Science Foundation	NSF surveys on public attitudes toward and understanding of science and technology	1979–2004	Information sources, interest, knowledge, general attitudes	Random digit dialing (RDD) computer-assisted telephone survey	*n* = ~1,600–2,000 ±2.47% – ±3.03%
	University of Chicago, National Opinion Research Center	General Social Survey S&T module	2006	Information sources, knowledge, general attitudes, nanotechnology attitudes	Face-to-face interviews	*n* = 1,864 ±2.68%
	The Gallup Organization	Various ongoing surveys	1984, 1990–92, 1995, 1997–2007	Evolution, environment, stem cell	RDD	*n* = ~1,000 each for U.S., Canada, Great Britain
	Virginia Commonwealth University Center for Public Policy	VCU Life Sciences Survey	2001–06	Stem cell research, interest in S&T, general attitudes	RDD	*n* = ~1,000 ±3.0%
International	European Commission	Eurobarometer 224/Wave 63.1: *Europeans, Science and Technology*; Eurobarometer 225/Wave 63.1: *Social Values, Science and Technology* (2005)	1992, 2005	Various knowledge and attitude items, including public support for basic research and trust in scientists	Face-to-face interviews	*n* = 32,897 total (~1,000 each for 27 countries; ~500 each for 4 countries) ±1.9% – ±3.1%
	Canadian Biotechnology Secretariat	Canada-U.S. Survey on Biotechnology	2005	Attitudes toward technology, including biotechnology and nanotechnology (includes U.S. data on specific issues)	RDD	Canada: *n* = 2,000 ±2.19% U.S.: *n* = 1,200 ±2.81%
	British Council, Russia	*Russian Public Opinion of the Knowledge Economy* (2004)	1996, 2003	Various knowledge and attitude items	Paper questionnaires	*n* = 2,107 (2003)
	Chinese Ministry of Science and Technology	*China Science and Technology Indicators 2002* (2002)	2001	Various knowledge and attitude items	Information not available	*n* = 8,350
	Japan National Institute of Science and Technology Policy	The 2001 Survey of Public Attitudes Toward and Understanding of Science & Technology in Japan	2001	Various knowledge and attitude items	Face-to-face interviews	*n* = 2,146
	Korea Science Foundation	Survey of Public Attitudes Toward, and Understanding of Science and Technology 2006	2006	Various knowledge and attitude items	Face-to-face interviews	*n* = 1,000 ±3.1%
	Malaysian Science and Technology Information Centre	*Public Awareness of Science and Technology Malaysia 2004* (2005)	2004	Various knowledge and attitude items	Face-to-face interviews	*n* = 6,896 ±2.0%
	Indian National Science Academy	India Science Survey 2004	2004	Various knowledge and attitude items	Face-to-face interviews	*n* = 30,255

Americans report a somewhat different pattern of primary sources for S&T information than for information about current news events (Horrigan 2006) (figure 7-1; appendix table 7-2). For both kinds of information, more Americans select television as their primary source than any other medium. Unlike for current news, though, the Internet is the second most common primary source of S&T information, and its margin over other sources is large and growing. The Internet, magazines, and books or other printed material loom larger as primary information sources for S&T than for current news; the opposite is true for television, newspapers, and radio (figure 7-2).

To learn about specific scientific issues, over half of Americans choose the Internet as their main information source (figure 7-1; appendix table 7-3). Television (19%) is the only other medium that more than 10% of Americans choose as their primary source. Considering that about one-fourth of Americans lack access to the Internet at home or work (Harris Interactive 2006c), the overall proportion who rely on it for specific S&T information is especially noteworthy. However, presumably because of limited access, the percentage of Americans who say they ever get science information from the Internet is lower than the comparable figures for television, newspapers, or magazines (Horrigan 2006).

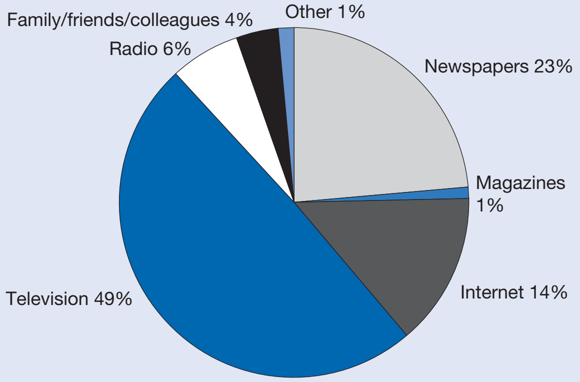
Survey Data Sources—continued

Primary topic	Sponsoring organization	Title	Years used	Information used	Data collection method	Number of respondents/ margin of error of general population estimates
Information sources, interest, and involvement	Pew Research Center for the People and the Press	Biennial News Consumption Survey	1996–2006	Information, interest	RDD	Biennial News Consumption Survey n = 3,204 (2006) ±2.0%
	Pew Research Center for the People and the Press	News Interest Index	2002–06	Information, interest	RDD	n = ~1,000 ±3.5%
	Pew Internet and American Life Project	Pew Internet and American Life Project Survey	2006	Information, interest, involvement	RDD	n = 2,000 ±3.0%
	USC Annenberg School Center for the Digital Future	Surveying the Digital Future	2000–06	Internet use	RDD	n = ~2,000
	Institute of Museum and Library Services	InterConnections: The IMLS national study on the use of libraries, museums, and the Internet	2006	Involvement	RDD	n = 1,057–5,082 ±1.47% – ±3.01%
Public attitudes in general	University of Chicago, National Opinion Research Center	General Social Survey	1973–2006	Government spending, confidence in institutional leaders	Face-to-face interviews	Government spending: n = 1,574–2,992 ±2.12% – ±2.84% Confidence in institutional leaders: n = 876–1,989 ±2.60% – ±3.80%
	Harris Interactive	The Harris Poll	1977–2006	Occupational prestige, Internet use	RDD	n = ~1,000 ±3.0%
Public attitudes about specific issues	Pew Initiative on Food and Biotechnology	Various ongoing surveys	2006	Biotechnology, genetically modified foods	RDD	n = 1,000 ±3.1%
	Research!America	Various ongoing surveys	2005	Stem cell research	RDD	n = 800–1,000 ±3.5%
	Public Agenda	Reality check 2006: Are parents and students ready for more math and science? (2006)	2005	S&E education	RDD	n = 1,379 ±3.8%

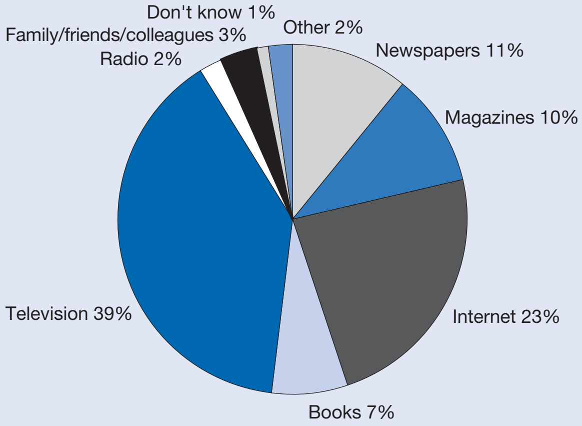
Recent trends in how Americans say they learn about specific scientific issues suggest the possibility of a declining reliance on longer printed sources, such as books and magazines (but not newspapers), and an increased use of television.[1] Reliance on the Internet, which had grown substantially over the past decade, is still growing but has shown signs of leveling off (figure 7-3).[2]

These trends are open to various interpretations. One possibility, consonant with the idea that the lengthy narrative in printed materials facilitates in-depth analysis of complex issues, is that Americans are increasingly seeking relatively brief and convenient overviews of such issues. This interpretation is consistent with data on recent trends in news consumption, which indicate that availability of Internet news has not increased overall news consumption and that Internet news users more often look for quick updates on the Web than for detailed information (Pew Research Center for the People and the Press 2006a). There are other possibilities, however. For example, because America's media environment is increasingly segmented, the assumption that a particular information source provides a particular kind or quality of information is becoming increasingly problematic. Thus television includes a range of science-related material, presented in specialized programs (e.g., *Nova*) and channels (e.g., the Science Channel) that cater to people with a sustained interest in science; outlets (e.g., news magazines) that offer occasional, ordinarily reliable scientific information; and even entertainment programs that indiscriminately

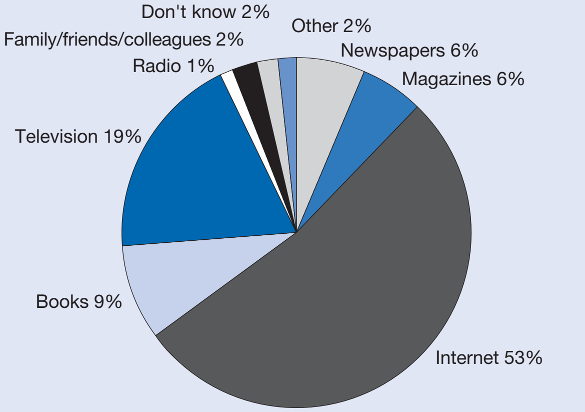
Figure 7-1
Primary source of information, by use: 2006



Current news events



Science and technology information



Specific scientific issues

NOTES: Government agencies included in “other” category. For current news events, books included in “other” category, and “don't know” not shown because <1.0% response. Detail may not add to total because of rounding.

SOURCE: University of Chicago, National Opinion Research Center, General Social Survey (2006). See appendix tables 7-1, 7-2, and 7-3.

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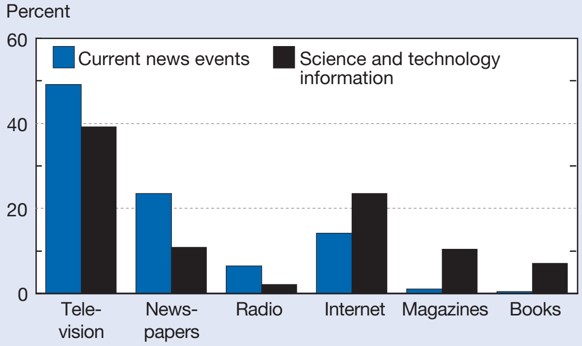
Figure 7-2
Primary source of current news events and science and technology information: 2006



SOURCE: University of Chicago, National Opinion Research Center, General Social Survey (2006). See appendix tables 7-1 and 7-2.

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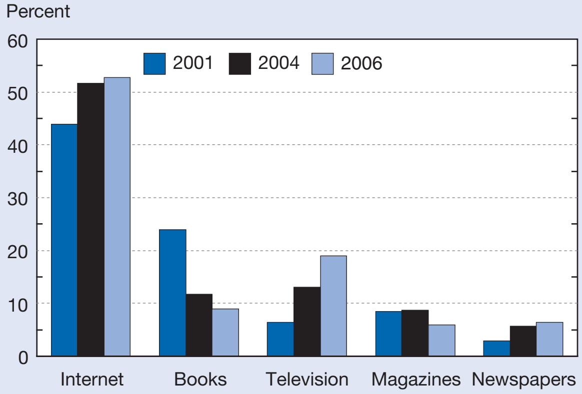
Figure 7-3
Primary source of information about specific scientific issues: 2001, 2004, and 2006



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); and University of Chicago, National Opinion Research Center, General Social Survey (2006). See appendix table 7-3.

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mix scientific information with fantasy speculations about the physical and biological worlds. Other media also present heterogeneous content. By this interpretation, then, a user who moves from magazines to television may be doing it for a variety of reasons and is not necessarily choosing information of lesser quality.

In general, people who rely more on television for news and information, including S&T information, tend to be older and have fewer years of education than those who rely on the Internet and other sources (appendix tables 7-1 and 7-2). Access to high-speed Internet connections is also associated with more extensive reliance on the Internet for news and information (Cole 2005; Horrigan 2006).

Perhaps because S&T information is not easily separable from the general flow of information in the mass media, national data that address the processes through which Americans acquire and sort through such information are scarce. A Pew Internet and American Life Project survey (Horrigan 2006) probed how Americans use the Internet to acquire information about science. It found that a clear majority of Internet users had engaged in some information search activities, including "look up the meaning of a particular scientific term or concept" (70%), "look for an answer to a question you have about a scientific concept or theory" (68%), and "learn more about a science story or scientific discovery you first heard or read about offline" (65%). In addition, just over half had used the Internet to "complete a science assignment for school, either for yourself or for a child" (55%) or "check the accuracy of a scientific fact or statistic" (52%). Fewer had used the Internet to "download scientific data, graphs or charts" (43%) or "compare different or opposing scientific theories" (37%). How skillfully or how often Americans engage in the search for scientific information, whether on the Internet or elsewhere, remains unknown.

Using information well involves more than finding it. In an information-saturated society, Americans need to make critical assessments of the information they encounter and somehow determine whether it is credible.

Survey data provide some indications of how Americans assess the credibility of public information. For the past two decades, Americans have been becoming more skeptical of the information they encounter in the major broadcast and print media generally, although this trend has leveled off somewhat recently (Pew Research Center for the People and the Press 2006a). Americans' judgments of media credibility appear to be shaped by more than their critical thinking skills and the quality of the information provided. For example, judgments of the credibility of particular mass media information sources are associated with political party affiliations (Pew Research Center 2005; Pew Research Center for the People and the Press 2006a). (For data on perceived credibility of biotechnology information sources, see section on "Biotechnology and Its Medical Applications.")

Compared with survey results on the credibility of the major broadcast and print media, data on the credibility of Internet information suggest greater public confidence, most likely because the survey questions are asked in a context that makes respondents think of information that is neither value laden nor controversial.[3] For example, a majority of Internet users considered most or all online information to be accurate and reliable. In a survey on Internet use, approximately three-quarters of Internet users rate government websites and websites associated with established print and broadcast media as reliable (Cole 2006). These same established media fare less well in survey contexts that are more likely to invite respondents to ponder the reliability of politically sensitive information in the media (Pew Research Center for the People and the Press 2006a).

Evidence about how Americans judge the credibility of S&T information in the media is scant. Pew's study of how Americans acquire science information indicates that Internet users who seek science information online do not always assume that the information they find there is accurate (Horrigan 2006). Eighty percent report that they have "ever" done at least one of the following kinds of checks:

- Compare it to other information you find online to make sure it's correct (62%)
- Compare it to an offline source like a science journal or encyclopedia (54%)
- Look up the original source of the information or the original study it's based on (54%)

It is natural to assume that people's choice of media sources affects how they think about S&T. However, it is difficult to design research that clearly isolates the effects of the media and establishes causal linkages. One reason is that people's preexisting opinions and orientations are likely to affect their media choices; another is that media content often affects people indirectly, filtered through the views of trusted friends and relatives (see sidebar, "Media Effects").

International Comparisons

Data collected between 2001 and 2004 on sources of S&T information used by people in other countries, including the European Union (EU) states, Japan, Russia, South Korea, and China, uniformly identify television as the leading source of S&T news and information. Newspapers generally ranked second. Relatively few survey respondents cited the Internet as an important source of S&T information, perhaps in part because many lacked access to the Internet. However, national differences in how questions were asked make precise comparisons among different countries impossible. In a 2006 South Korean survey, more respondents named the Internet (23%) as their primary source of S&T information than named newspapers (16%) (Korea Gallup 2007). More recent data on the other countries do not exist; further details on these older data are presented in the 2006 edition of *Science and Engineering Indicators* (NSB 2006).

Television is also the dominant source of S&T information in India, where about two-thirds of survey respondents in 2004 said it was their main information source (Shukla 2005). Radio (13%) and friends/relatives (12%) ranked ahead of written sources such as newspapers, books, and magazines, which together accounted for 9% of responses. India's relatively low literacy rate (144th of 176 countries in a 2005 ranking) is useful context for these findings.

Media Effects

Citizens of economically advanced societies live in a world that is permeated by mass media of communication. A large social science literature probes how these media operate, what kinds of messages they send, how they tailor their messages to reach different audience segments, and how those messages relate to public opinion. Mass media messages interact with the opinions of the American public in complex ways, and teasing out the reciprocal effects is complicated (Perse 2001).

Providers of media content are not free to supply whatever content they prefer. In making content decisions, the people who own and manage media organizations take into account the views of the segments of the public that purchase their products and are well aware that their audiences can select other content providers. Likewise, the journalists who gather information and report stories for mass media transmission, whatever their personal views, are guided by the standards of the organizations for which they work and the professions in which they are trained. In addition, they are typically motivated by the desire to make an impact on a large audience by presenting stories in compelling and dramatic ways.

At the same time, the mass media do not simply reflect the public they serve. Members of the public are dependent on mass media for much of their information about public issues, either through direct exposure or second hand from friends and relatives. Because Americans tend to rely on sources of information that typically adopt a perspective akin to their own, the ways trusted mass media pose new or less familiar issues can assume great importance. Moreover, even for members of the public who search out multiple points of view on an issue, the shared terms and assumptions in the media shape how they think about issues. Interested parties, including newsmakers, are increasingly sophisticated in crafting messages to capture media attention and appeal to the public.

Studies that seek to isolate the effects of mass media face numerous challenges:

- ♦ Laboratory research, which can control for factors other than media exposure that influence people's opinions, has an uncertain relationship to real world situations, in which people choose media programs, interpret media messages through conversations with others, and pay varying degrees of attention to what is said in the mass media. It is difficult to recreate these conditions in laboratories.
- ♦ Even when research can demonstrate short-term effects of media exposure, it is hard to know how much these persist over time or affect behavior in natural settings.
- ♦ People interpret a media message differently depending on the beliefs they bring to it and the attention they give it. Thus, media messages may affect individuals, but, because the effects are not uniform and can run in opposite directions, aggregate opinion may be left almost unchanged.
- ♦ Media messages may have more to do with motivating people who already hold an opinion to become more active in civic and political contexts than with persuading people to adopt new opinions. Surveys may have difficulty capturing this kind of effect.
- ♦ In a society with multiple sources of media content, even highly influential media sources, such as programs on major television networks, reach only a fraction of the population and, at any given time, change the perspectives of only a fraction of the people they reach.
- ♦ Mass media messages are significantly shaped by events—what is actually taking place in the situations about which they are reporting. Although facts are open to various interpretations and presentations, they set limits beyond which media organizations cannot go without losing credibility.
- ♦ It is easy to demonstrate correlations between media content and shifts in public opinion, but hard to demonstrate causation. Sometimes, changes in media content reflect changes in elite opinion or actual circumstances, rather than changes initiated or caused by the mass media themselves.
- ♦ Media exposure may have threshold effects, in which a certain amount of repetition is necessary for a message to get through, but beyond that amount further repetition has little or no impact. Compared with effects that work incrementally, threshold effects are harder to isolate.

Recent research in communications has stressed the role of the mass media in shaping the agenda for public debate and political action (*agenda-setting*) and the terms in which the public sees an issue (*framing*) (Scheufele and Tewksbury 2007). Agenda-setting works largely through making a topic more salient and accessible to memory by frequent or more prominent mention of it, thereby increasing the public's sense that the topic is important. Framing refers to ways that mass media construct stories to make a topic comprehensible and relevant to the public. Frames stress some aspects of a topic and minimize others. Some kind of framing is necessary to reduce complexity and provide a focus to make sense of what would otherwise be undigested facts. Interested parties vie to get the mass media to present topics in their preferred frames. Research on how S&T are discussed in the mass media has identified competing frames that have been used to present contested issues (Gamson and Modigliani 1989; Nisbet and Lewenstein 2002). Recognizing that most members of the public pay limited attention to S&T information, some researchers have argued that representatives of the scientific community need to do more to influence how the mass media frame issues (Nisbet and Mooney 2007; Scheufele 2006). In their view, when it comes to influencing public opinion, influencing the frames through which the public processes and understands science-related issues may be more important than increasing the scientific and technical content of news coverage.

Public Interest in S&T

U.S. Patterns and Trends

In surveys, Americans consistently express high levels of interest in S&T. Asked in 2006 whether "I enjoy learning about science and new science discoveries" describes them, about three-fourths of Americans said it describes them either very (43%) or somewhat (31%) well (Horrigan 2006). Likewise, in six annual surveys conducted between 2001 and 2006, between 83% and 87% of Americans reported that they had either "a lot" or "some" interest in new scientific discoveries, with the remaining small minority expressing less interest (table 7-1). In 2006, 47% claimed they had "a lot" of interest. More highly educated people tend to express greater interest in S&T (Pew Research Center for the People and the Press 2004).

High levels of expressed interest in S&T are part of a long-standing pattern, evidenced in the results of 11 National Science Foundation (NSF) surveys conducted between 1979 and 2001 (NSB 2002). In each survey, more than 80% of Americans reported that they were either "very" or "moderately" interested in "new scientific discoveries" and "new inventions and technologies."

However, the NSF surveys also give reason to doubt the strength and depth of Americans' interest in S&T. Relative to interest in other topics, interest in S&T in these surveys was not particularly high. S&T interest ranked in the middle among the 10 areas frequently listed in the surveys: above space exploration, international and foreign policy, and agriculture and farming; below new medical discoveries, local schools, and environmental pollution; and similar to economic and business conditions and military and defense policy. Of course, a more inclusive concept of S&T might treat several of the topics in this list, such as space exploration and new medical discoveries, as part of the S&T category; furthermore, other topics often include substantial S&T content (see sidebar, "What Are Science and Technology?").

Survey responses about S&T news also raise questions about how interested Americans are in S&T in general. For 10 years, Pew (Pew Research Center for the People and the Press 2006a) has collected data on categories of news that Americans follow "very closely." In 2006, S&T news was followed closely by 15% of the public and ranked 10th among 14 topics, ahead of only business and finance, entertainment, consumer news, and culture and the arts (table 7-2). As is the case for many other news topics, the percentage of Americans who say they follow S&T closely has declined over this period. But S&T's decline has been more pronounced, with the result that its relative standing in the list of topics has also slipped over the decade: whereas S&T ranked ahead of seven topics in 1996, three of these had surpassed it by 2002 and have remained ahead since then.

Among regular newspaper readers, articles on "health and medicine" and "technology" rank relatively high as portions of the newspaper that Americans spend "some time" or "a lot of" time reading (table 7-3). Data on these topics might

Table 7-1
Public interest in new scientific discoveries: 2001–06
(Percent)

Level of interest	2001	2002	2003	2004	2005	2006
A lot	43	39	44	42	45	47
Some	44	44	43	42	42	40
Not much	8	12	10	10	8	9
Not at all	4	4	3	5	4	4
Don't know	1	0	0	0	1	0

NOTE: Responses to: *How much are you personally interested in new **scientific** discoveries?*

SOURCE: Virginia Commonwealth University (VCU), Center for Public Policy, Survey and Evaluation Research Laboratory, VCU Life Sciences Survey 2006, http://www.vcu.edu/lifesci/centers/cen_ lse_surveys.html.

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What Are Science and Technology?

When Americans refer to science and technology (S&T), they rarely define their terms. Ordinary language rests on the assumption that terms such as these, even if their precise meanings are not quite the same for everyone, invoke a bundle of associations that are similar enough to enable people to communicate. Survey research gathers attitude data about how people respond to the ill-defined linguistic bundles, such as S&T, that people use in ordinary conversation.

For purposes of analysis and comparison, research studies usually classify topics in the news in a way that makes space, environment, and health and medicine separate from S&T. The meaning respondents ascribe to a topic category, such as S&T, is affected by the context in which it appears and the other categories listed with it.

In interpreting survey data that use these terms, it is important to take into account the uncertainties surrounding the meaning of S&T. For example, it is not clear how often survey respondents who are asked about "science and technology" think they are being asked about two separate entities about which they might have different interests or attitudes, rather than about a single complex whole. Likewise, although engineers often think of technology as a broad category of devices and systems that humans construct to solve problems and interact with their environments, there is some evidence that for many people the term technology refers more narrowly to electronic information technology, especially computers (Cunningham, Lachapelle, and Lindgren-Streicher 2005; Rose and Dugger 2002).

Table 7-2
News followed very closely by American public: 1996–2006
(Percent)

Type of news	1996	1998	2000	2002	2004	2006
Weather	NA	NA	NA	NA	53	50
Crime	41	36	30	30	32	29
Community	35	34	26	31	28	26
Health	34	34	29	26	26	24
Sports	26	27	27	25	25	23
Local government	24	23	20	22	22	20
Washington news	16	19	17	21	24	17
International affairs	16	16	14	21	24	17
Religion	17	18	21	19	20	16
Science and technology	20	22	18	17	16	15
Business and finance	13	17	14	15	14	14
Entertainment	15	16	15	14	15	12
Consumer news	14	15	12	12	13	12
Culture and arts	9	12	10	9	10	9

NA = not available, question not asked

NOTES: Data reflect respondents who said they followed type of news "very closely." Table includes all years for which data collected.

SOURCE: Pew Research Center for the People and the Press, Online papers modestly boost newspaper readership: Maturing Internet news audience broader than deep (30 July 2006), Biennial News Consumption Survey (27 April–22 May 2006), http://people-press.org/reports/display.php3?ReportID=282, accessed 26 April 2007.

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Table 7-3
What people read in the newspaper: 2006
(Percent)

Type of news	2006
News stories about one's city, town, or region	91
National news stories	88
International news stories	84
Articles on health and medicine	77
Articles about technology	63
Editorial and opinion pages	60
Business and financial news	60
Articles about food, diet, cooking	55
News stories and columns about religion	51
Consumer tips on products and services	50
Sports section	48
Entertainment news	46
Obituaries	42
Comics, puzzles, and games	41
Articles and reviews about travel	39
Advertisements	35
Real estate section	32
TV/movie/entertainment information and schedules	29
Personal advice columns	28
Society pages, weddings/engagements/births	24

NOTES: Based on respondents reading newspaper "just about every day" or "sometimes." Data reflect those saying they spent "some time" or "a lot of time" reading type of news in newspaper.

SOURCE: Pew Research Center for the People and the Press, Online papers modestly boost newspaper readership: Maturing Internet news audience broader than deep (30 July 2006), Biennial News Consumption Survey (27 April–22 May 2006), http://people-press.org/reports/display.php3?ReportID=282, accessed 26 April 2007.

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be interpreted as indicating relatively high S&T interest; at a minimum, these topics can spur readers to learn about human biology and advances in engineering. Conversely, interest in these topics may be limited to information that is immediately related to personal and family well-being or news about computer technology. The available data do not indicate how survey respondents themselves define the focus or scope of their interest.[4]

Since 1986, the Pew Research Center for the People and the Press has maintained a news interest index that tracks individual stories that make headlines. The index is based on frequent surveys that record the proportion of Americans who, when asked about a news story, say they are following it "very closely." Stories that attract considerable public interest are often included in several surveys, and results from each survey appear separately several times on the news interest index. For 2002–06, high gasoline prices, the impact of hurricanes Katrina and Rita, and debates on the war in Iraq comprise all but one of the top 20 items on the list (the Washington, DC area sniper shootings was the other item) (Pew Research Center for the People and the Press 2007a). If S&T content were what generated sustained high levels of public interest in a news story, a different set of stories would be at the top of the list.

However, top stories may not be the best indicator of public interest and exposure. S&T stories rarely feature the evolving human drama of wars and disasters or the immediate personal effects of gasoline prices, making it harder for them to capture widespread and sustained attention in the population at large. It is safe to say that all of the top stories at times focused public attention on S&T issues and that Americans who had a sounder understanding of S&T were better able to comprehend at least some aspects of them. Thus, the geology, chemical engineering, and economics involved in finding gasoline, refining it, and getting it to market are at times part of news coverage of gas prices; the atmospheric science, civil engineering, and sociology involved in disasters and disaster response are at times part of news coverage of hurricanes; and the chemistry and biology of weaponry and the political science of building democracy are at times part of the coverage of the Iraq war. The survey data cannot discriminate finely enough to determine how much the public engages with the more scientific and technological aspects of stories like these.

A different kind of news indicator is the amount of coverage news organizations devote to S&T. This indicator can involve either sheer quantity (e.g., newspaper space, broadcast time) or prominence (e.g., lead stories). For 20 years, the Tyndall Report has tracked the time that the three major broadcast networks devoted to 18 categories of news on their nightly newscasts (Tyndall Report 2007). Two categories with large S&T components are science, space, and technology, and biotechnology and basic medical research.[5] Neither category has ever occupied a large percentage of the approximately 15,000 minutes of newscast coverage on the networks; science, space, and technology, the larger of the two categories, garnered 752 minutes in its peak year (1999). Both categories began the period at relatively low levels of coverage, climbed sharply beginning some time in the mid to late 1990s, dropped off even more sharply very early in the new century, and then showed signs of rebounding, but ending well below their peak levels (figure 7-4). Trends in the science, space, and technology category, along with recent annual lists of leading individual stories in that category, suggest that the advent of the Internet and the significance of developments in the nation's space program affected the amount of news coverage (table 7-4). The importance of competing stories, such as terrorist attacks, also plays a role. Data on front-page newspaper stories suggest that science figured somewhat more prominently in 2004 than in 1977, when it was hardly visible (Project for Excellence in Journalism 2005).

International Comparisons

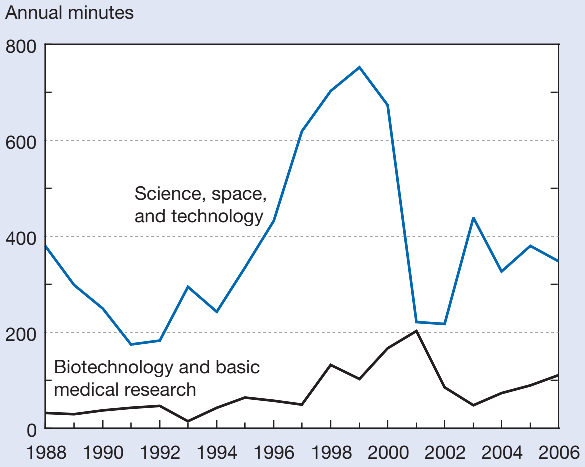
Recent surveys conducted in other countries indicate that the overall level of public interest in S&T is less than that in the United States. In 2005, 30% of survey respondents in Europe said they were very interested in new scientific discoveries, about half (48%) said they were moderately interested, and one-fifth said they were not at all interested. Comparable 2001 U.S. numbers were substantially higher for "very interested" and substantially lower for "not at all interested." The distribution of European responses about interest in new inventions and technologies was almost identical to that for scientific discoveries. There was considerable variation in interest among European countries, and the overall level of interest was down somewhat from 1992, the last time these questions were asked. Survey respondents who said they were not at all interested in either new scientific discoveries or new inventions and technologies most often gave "I don't understand it" or "I do not care about it" as reasons (European Commission 2005a). As in the United States, men in Europe showed more interest in S&T than women. Unlike in the United States, S&T interest in Europe appears to have declined between 1992 and 2005.

Residents of several Asian countries, including Japan, South Korea, and Malaysia, seem to express less interest than Americans and Europeans in S&T. However, China is a notable exception: interest levels for China were about the same as those for the United States (Chinese Ministry of Science and Technology 2002; European Commission 2005a, b; Korea Gallup 2007; Korea Science Foundation 2004; Malaysian Science and Technology Information Centre 2004; National Institute of Science and Technology Policy 2002).

Like Americans, Europeans are more interested in medicine than in S&T in general. In the United States, in particular, nearly everyone is interested in new medical discoveries. In contrast, interest in new medical discoveries seems to be much lower in Asian countries than in the West.

Relative to other topics, including S&T-related topics, interest in space exploration has consistently ranked low both in the United States and around the world. Surveys in Europe, Russia, China, and Japan document this general pattern.

Figure 7-4
Network nightly news coverage of science and technology: 1988–2006



NOTES: Data reflect annual minutes of story coverage on these topics by major networks ABC, CBS, and NBC out of approximately 15,000 total annual minutes on weekday nightly newscasts. Excluded from science, space, and technology are forensic science; math, science, and math education in schools; and media content. Excluded from biotechnology and basic medical research are stories on clinical research and medical technology.

SOURCE: Tyndall Report, special tabulations (March 2007), http://www.tyndallreport.com.

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Involvement

Involvement with S&T outside the classroom in informal, voluntary, and self-directed settings such as museums, science centers, zoos, and aquariums is an indicator of interest in S&T.[6] By offering visitors the flexibility to pursue individual curiosity, such institutions provide a kind of exposure to S&T that is well suited to helping people develop further interest. Professional scientists and engineers often stress the role of their informal S&T experiences in motivating them to pursue S&T careers (Bayer 2007).

Surveys conducted for the Pew Internet and American Life Project and the Institute for Museum and Library Services (IMLS) indicate that about three of five American adults visited an informal science institution in the year preceding the survey (Griffiths and King 2007; Horrigan 2006). In the Pew survey, almost half said they had visited a zoo or aquarium; the IMLS data indicate that a little more than one-third had done so.[7] The two surveys produced comparable estimates for "natural history museum" and "science or technology museum," with percentages in the low to mid-twenties. The IMLS survey reported similar attendance figures for "nature center" (28%), "arboretum or botanical garden" (23%), and "children's or youth" museum (20%). Fewer Americans (14% in the Pew survey) said they had visited a planetarium. Data from these surveys are generally consistent with NSF data collected between 1979 and 2001.[8]

When adults visit science-related informal learning institutions, they are more likely to be accompanied by family members and children than when they visit non-science-related institutions such as art or history museums. The IMLS survey asked parents who had visited a museum in the past year about whether their children had also made visits. For children between 3 and 17 years old, over two-thirds visited a zoo or aquarium in 2006. About half visited S&T museums, nature centers, and children's or youth museums. Comparable figures for history museums and historic sites were about 40%, and the percentage for art museums (22%) was even lower.[9] Although similar percentages of adults (almost half) visited S&T museums and art museums, a much larger percentage of the children of those adults visited S&T museums (55%) than art museums (22%) (Griffiths and King 2007).

Americans who have more years of formal education are more likely than others to engage in these informal science activities (figure 7-5). Whereas 76% of college graduates engaged in at least one of the four informal S&T-related activities during the year preceding the Pew survey, the comparable figures for adults in other education categories were well below this (Horrigan 2006). Similar education differences also exist among visitors to public libraries and art museums. Education patterns in the IMLS data are similar (Griffiths and King 2007). Among Americans who visit these informal science institutions, younger adults and parents of minor children were also somewhat overrepresented.

The IMLS survey found that nearly one-third of Americans visited science-related informal learning institutions remotely via the Internet, mostly in conjunction with their in-person visits. Slightly less than half watched television programs that contained content from these institutions. The percentages for non-science-related institutions are similar.

Table 7-4
Leading nightly news story lines on science and technology, by topic area: 2005 and 2006
(Annual minutes of coverage)

Topic area/leading story line	2005	Topic area/leading story line	2006
Science, space, and technology		Science, space, and technology	
NASA Space Shuttle program	146	NASA Space Shuttle program	59
Databases invade privacy: files on individuals	30	Internet used for social networking by teenagers	27
NASA Deep Impact astronomy probe studies comet	10	Digital media: videostreams shared viral networks	23
Internet online commerce volume increases	10	China censors Internet access, e-mail traffic	13
Internet hardcore pornography proliferates	9	Computer laptop batteries fire safety recall	12
Digital media: online downloadable music	8	Internet search engine private data sought	11
Computer executive Carly Fiorina fired	8	Solar system astronomy: Pluto disqualified as planet	10
NASA mulls renewed manned missions to moon	7	Cellular telephone use log privacy easily invaded	8
Digital media: online video on demand	7	Internet gambling Websites operate offshore	8
Computer privacy invaded by spyware software	6	NASA Hubble space telescope needs repair	7
Biotechnology/basic medical research		Biotechnology/basic medical research	
Human embryo stem cell biotechnology research	62	War on cancer basic research efforts	50
Animal cloning in agriculture research	8	Human embryo stem cell biotechnology research	36
Animals-to-humans organ transplant research	6	Animal cloning in agriculture research	9

NOTES: Data reflect annual minutes of story coverage on these topics by major networks ABC, CBS, and NBC, out of approximately 15,000 total annual minutes on weekday nightly newscasts. Shown are the 10 science, space, and technology story lines receiving most minutes of coverage in 2005 and 2006 and the 3 biotechnology and basic medical research story lines receiving more than 5 minutes of coverage. Excluded from science, space, and technology are stories on forensic science; math, science, and engineering education in schools; and media content. Excluded from biotechnology and basic medical research are stories on clinical research and medical technology.

SOURCE: Tyndall Report, special tabulations (March 2007), http://www.tyndallreport.com.

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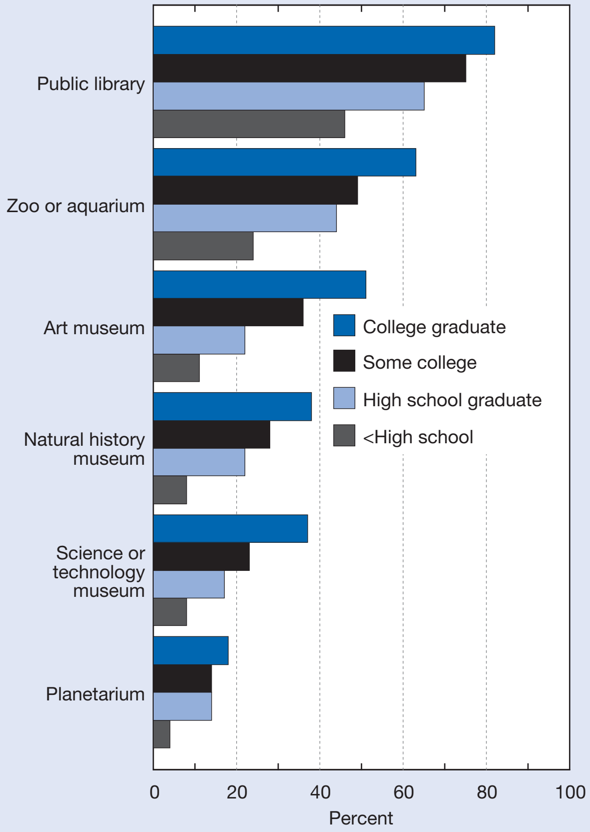
Fewer Europeans report visits to informal science institutions (European Commission 2005a). In the EU-25, about 27% of adults said they had visited a zoo or aquarium, 16% said they had visited a "science museum or technology museum or science centre," and 8% said they had attended a "science exhibition or science 'week'." As in the United States, older and less-educated Europeans reported less involvement in these activities. In addition, European adults in households with more inhabitants more often reported informal science activities; insofar as household size indicates the presence of minor children, this probably indicates another parallel with the United States. One demographic pattern is notably different between Europe and the United States: whereas European men (19%) are much more likely than women (13%) to visit informal science or technology museums and centers, in the United States visitors are drawn about equally from both sexes.

Europeans who said they had not visited S&T museums often mentioned lack of time (35%) or interest (22%) in doing so. Reasons relating to lack of awareness, for example, "I didn't think about it" (21%) and "I do not know where these museums are" (9%), also suggest an absence of strong interest in this kind of activity. However, lack of involvement can stem from factors unrelated to interest, too. Many respondents appeared to consider these institutions relatively inaccessible, either because they were "too far away" (23%) or too expensive (7%).[10]

Figure 7-5
Attendance at informal science institutions, by institution type and education level: 2006



SOURCE: Horrigan J, The Internet as a Resource for News and Information about Science, *Pew/Internet* (November 2006); and Pew Internet & American Life Project Survey (January 2006), http://www.pewinternet.org.

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Compared with the United States, visits to informal science institutions are also less common in Japan, South Korea, China, and, especially, Russia (Gokhberg and Shuvalova 2004). It is unclear to what degree these international variations are a result of differences in interest, differences in accessibility, or other factors.

Public Knowledge About S&T

As the scientific and technical content of modern life grows, citizens increasingly need to be more scientifically literate to make sound public policy and personal choices. In developing an internationally agreed upon approach to conceptualizing and measuring scientific literacy, the Organisation for Economic Co-operation and Development (OECD) (2003) noted that literacy had several components:

> Current thinking about the desired outcomes of science education for all citizens emphasizes the development of a general understanding of important concepts and explanatory frameworks of science, of the methods by which science derives evidence to support claims for its knowledge, and of the strengths and limitations of science in the real world. It values the ability to apply this understanding to real situations involving science in which claims need to be assessed and decisions made. . . .
>
> Scientific literacy is the capacity to use scientific knowledge, to identify questions and to draw evidence-based conclusions in order to understand and help make decisions about the natural world and the changes made to it through human activity. (pp. 132–33)

As the reference to changes made through human activity makes clear, the OECD definition encompasses an understanding of technology. In addition, OECD takes the view that literacy is a matter of degree and that people cannot be classified as either literate or not.

A good understanding of basic scientific terms, concepts, and facts; an ability to reason well about issues involving S&T; and a capacity to distinguish science from pseudoscience are indicators of scientific literacy. (For a different perspective on scientific literacy, see sidebar "Asset-Based Models of Knowledge").

Americans need to comprehend common scientific and technological terms such as *DNA* or *molecule* and recall commonly cited facts so they can make sense of what they read and hear about S&T-related matters. Whether they turn their attention to congressional debates over stem cell research or to instructional videos or pamphlets explaining how to use a newly purchased electronic device, the messages they get presuppose some basic knowledge of terms, concepts, and facts. For S&T, as for other topics, even people with superior reasoning and cognitive skills are at a disadvantage when they lack basic information, especially if others take such information for granted and make statements that build on it (Hirsch 2006).

Appreciating the scientific process can be even more important than knowing scientific facts. People often encounter claims that something is scientifically known. If they understand how science generates and assesses evidence bearing on these claims, they possess analytical methods and critical thinking skills that are relevant to a wide variety of facts and concepts and can be used in a wide variety of contexts.

Asset-Based Models of Knowledge

Many researchers and educators interested in the public's understanding of science advocate studying the assets people bring to bear on scientific issues that they deal with in their daily lives. Because individuals encounter S&T in different ways, they acquire different S&T knowledge "assets," which they then can use to make sense of unfamiliar issues. For researchers and educators who favor an asset-based model of scientific literacy, public understanding of science is less a "generalized body of knowledge and skills that every citizen should have by a certain age" than "a series of specific sets of only moderately overlapping knowledge and abilities that individuals construct over their lifetimes" (Falk, Storksdieck, and Dierking forthcoming). In education, asset-based perspectives on knowledge have been useful in helping teachers build on children's existing strengths to improve their performance.

Generalized assessments of S&T knowledge, by asking questions on topics that may be of little interest to many respondents, may underestimate the assets available to individuals when they deal with S&T matters of greater interest and consequence to them. In contrast, a knowledge assessment that is tailored to an S&T domain with which an individual is familiar might yield very different results. In addition, because people often use their knowledge assets in group interactions, such as a nature outing, some researchers question the value of individual assessments in a test or survey (Roth and Lee 2002).

National indicators that evaluate domain-specific knowledge or group problem-solving are not practical. Surveys cannot use different measures to enable gardeners, auto mechanics, and amateur astronomers to demonstrate their different S&T-related assets and then reliably aggregate the results from different S&T domains. Nonetheless, a perspective on scientific literacy that stresses domain-specific or group assets is useful in that it points to a significant limitation of generalized indicators of individual scientific literacy.

An additional indicator of how well people apply scientific principles in real world contexts is how they assess pseudoscientific claims, which adopt the trappings of science to present knowledge claims that are not grounded in the systematic methodology and testing associated with science.

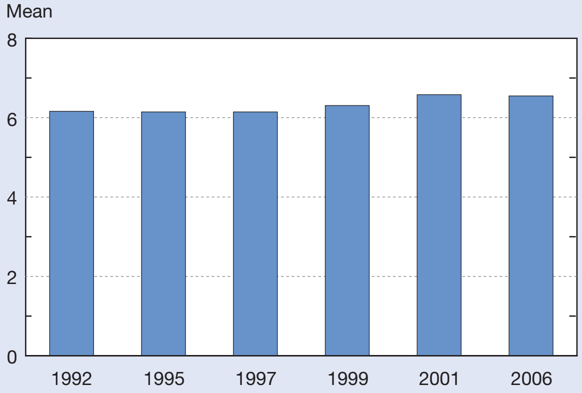
U.S. survey data indicate that many Americans cannot provide correct answers to basic questions about scientific facts and do not reason well about selected scientific issues. Residents of other countries, including highly developed ones, perform no better, on balance, when asked similar questions. In international comparisons of scientific knowledge and reasoning, then, American adults appear to rank somewhat better than American middle and high school students (see chapter 1, "Elementary and Secondary Education"). Any generalizations about Americans' knowledge of science must, however, be tentative, given the measurement-related uncertainties discussed elsewhere in this chapter.

Understanding Scientific Terms and Concepts

U.S. Patterns and Trends

U.S. data do not show much change over time in the public's level of factual knowledge about science.[11] Figure 7-6 shows the average numbers of correct answers to a series of mostly true-false science questions in different years (appendix table 7-4).[12] Although performance on individual

Figure 7-6
Correct answers to scientific literacy questions: 1992–2006



NOTES: Number correct of 12 questions. See notes to appendix table 7-4 for explanation of "factual knowledge of science scale 1" used for this figure. See appendix tables 7-5 and 7-6 for responses to individual scientific literacy questions included in scale. Table includes all years for which data collected.

SOURCES: National Science Foundation, Division of Science Resources Statistics, Survey of Public Attitudes Toward and Understanding of Science and Technology (1992–2001); and University of Chicago, National Opinion Research Center, General Social Survey (2006).

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Table 7-5

Correct answers to scientific literacy questions, by sex: 2001, 2004, and 2006

(Percent)

Question	2001	2004	2006
Physical science			
The center of the Earth is very hot. (True)			
Male	85	86	85
Female	76	72	75
All radioactivity is man-made. (False)			
Male	81	82	77
Female	71	66	64
Lasers work by focusing sound waves. (False)			
Male	61	59	62
Female	30	28	32
Electrons are smaller than atoms. (True)			
Male	52	52	61
Female	43	39	48
The universe began with a huge explosion. (True)			
Male	43	41	40
Female	24	27	27
The continents have been moving their location for millions of years and will continue to move. (True)			
Male	83	85	85
Female	74	71	75
Does the Earth go around the Sun, or does the Sun go around the Earth? (Earth around Sun)			
How long does it take for the Earth to go around the Sun? (One year)			
Male	66	NA[a]	66
Female	42	NA	46
Biological science			
It is the father's gene that decides whether the baby is a boy or a girl. (True)			
Male	58	51	55
Female	72	70	72
Antibiotics kill viruses as well as bacteria. (False)			
Male	46	49	50
Female	55	58	61
Human beings, as we know them today, developed from earlier species of animals. (True)			
Male	57	45	47
Female	50	40	40
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? (No)			
Male	85	83	90
Female	83	81	84
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 each of the couple's children will have the same risk of suffering from the illness? (Yes)			
Male	76	76	76
Female	74	71	74
Two scientists want to know if a certain drug is effective against high blood pressure. The first scientist wants to give the drug to 1,000 people with high blood pressure and see how many of them 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 second way because a control group is used for comparison)			
Male	39	49	42
Female	38	43	41

NA = not available

[a] Not asked in 2004, so composite percentage not computed.

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); and University of Chicago, National Opinion Research Center, General Social Survey (2006). See appendix tables 7-5 and 7-6.

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questions varies somewhat over time (appendix table 7-5), overall scores are relatively constant.

Factual knowledge of science is positively related to level of formal schooling, income level, and number of science and math courses taken. In addition, the oldest respondents are less likely than others to answer the questions correctly (appendix tables 7-4 and 7-6). Especially for questions outside the biological sciences, men tend to answer correctly more often than women (table 7-5).

The factual knowledge questions that have been repeatedly asked in U.S. surveys involve information that was being taught in grades K–12 when most respondents were young. Because science continually generates new knowledge that reshapes how people understand the world, scientific literacy requires lifelong learning so that citizens become familiar with terms, concepts, and facts that emerged after they completed their schooling. In 2006, the General Social Survey (GSS) asked Americans questions that tested their knowledge of two topics that historically have not been central to the standardized content of American science education: nanotechnology and the Earth's polar regions. For all but the youngest respondents, several of the questions concerned knowledge that was too new for them to have learned it in school. Nonetheless, survey respondents who scored relatively well on the questions that have been asked repeatedly over the years also exhibited greater knowledge of these two topics (figure 7-7).[13] Likewise, the educational and demographic characteristics associated with higher scores on the knowledge questions that have been repeatedly asked are also associated with higher scores for these two new topics (appendix table 7-7). These data suggest that the knowledge items used to measure trends, although focused on the kind of factual knowledge learned in school, are a reasonable indicator of factual science knowledge more generally, including knowledge that is acquired later in life.

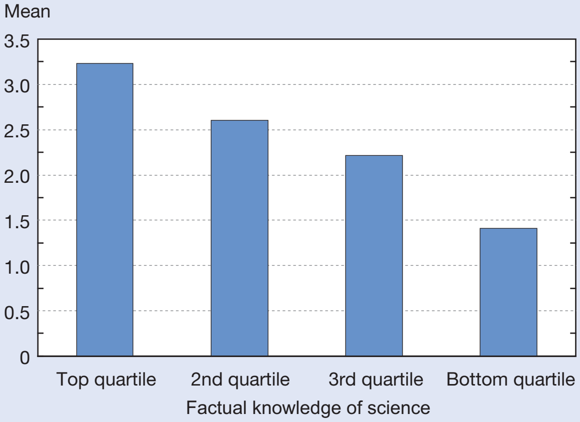
If Americans' performance in answering factual knowledge questions concerning science can be deemed disappointing, the same is true for their performance in other areas of knowledge (see sidebar, "Science Knowledge and Civic Knowledge"). Survey data of varying quality have been interpreted to indicate that Americans, especially the young, do not know enough about history, civics, geography, and politics, and are not sufficiently interested in these and other domains of knowledge that, like scientific knowledge, can serve as a foundation for understanding the world around them (Bauerlein 2006; Gravois 2006).

International Comparisons

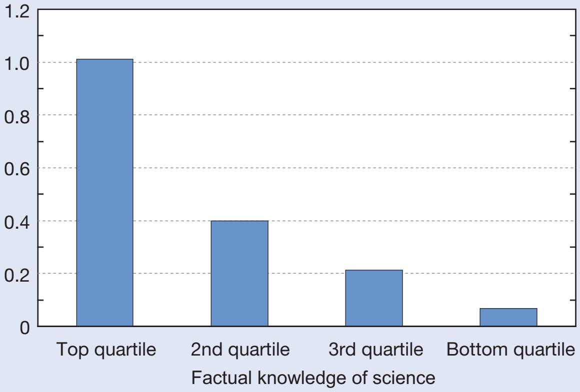
Adults in different countries and regions have been asked identical or substantially similar questions to test their factual knowledge of science.[14] Knowledge scores for individual items vary from country to country, and no country consistently outperforms the others (figure 7-8). For the widely asked questions reported in figure 7-8, knowledge scores are relatively low in Russia, China, and Malaysia. Compared with the United States and the highly developed countries in Europe, Japanese scores are also relatively low.[15]

Science knowledge scores vary considerably across the EU-25 countries (figure 7-9), with northern European countries, led by Sweden, recording the highest total scores on a set of 13 questions. For a smaller set of four items that were administered in both 1992 and 2005 in 12 European countries, each country performed better in 2005 (appendix table 7-8); in contrast, the U.S. data on science knowledge do not show upward trends over the same period. In Europe, as in the United States, men, younger people, and more highly educated people tend to score higher on these questions.

Figure 7-7
Correct answers to polar and nanotechnology questions, by factual knowledge of science: 2006



Polar



Nanotechnology

NOTES: Number correct of five polar questions and two nanotechnology questions. See notes to appendix table 7-4 for explanation of "factual knowledge of science scale 1." Respondents saying they had heard "nothing at all" about nanotechnology not asked two factual questions on nanotechnology; these respondents count as zero (0) correct in nanotechnology panel. See appendix table 7-7 for responses to polar and nanotechnology questions.

SOURCE: University of Chicago, National Opinion Research Center, General Social Survey (2006).

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Science Knowledge and Civic Knowledge

Political scientists have collected data on how much Americans know about U.S. civic institutions, politics, and history. In an exhaustive review of 50 years of research on civic knowledge, Delli Carpini and Keeter (1996) find patterns that are very similar to those in the distribution of scientific knowledge. More recent data give no indication that these patterns have changed (Pew Research Center for the People and the Press 2004, 2007b).

The following survey results, culled from a long list of knowledge questions about civic institutions and processes, give a flavor of what Americans do and do not know (Delli Carpini and Keeter 1996:70–1):

- Can correctly define Presidential veto (89% in 1989).
- Know that the First Amendment protects free press/speech (75% in 1985).
- Know that English is not the official national language (64% in 1986).
- Can state the substance of the *Brown v. Board of Education* decision (55% in 1986).
- Know that Congress declares war (45% in 1987).
- Know the length of a term of office in the U.S. House of Representatives (30% in 1978).

These data suggest that limited public mastery of fundamental factual information is not a problem that is unique to S&T.

Patterns in civic knowledge closely parallel those for science knowledge. Thus, much as individuals who demonstrate knowledge of the scientific process (see "Understanding the Scientific Process") also tend to score well on factual knowledge questions, people who are more familiar with the rules that govern civic institutions also tend to be more knowledgeable about political figures, parties, and the substance of public policy. The data on civic knowledge also parallel the data on science knowledge in other respects: political knowledge is strongly associated with formal education, women and minority group members tend to score somewhat less well on knowledge measures, more knowledgeable Americans tend to express more interest in political and civic matters and rely more on longer written sources of information, and political knowledge is associated with higher income.

There are some minor differences, too. Older Americans tend to be better informed about civic matters but not about science. Unlike science knowledge, Americans' civic knowledge shows no signs of increasing over time and appears to be slightly weaker than that in other developed countries.

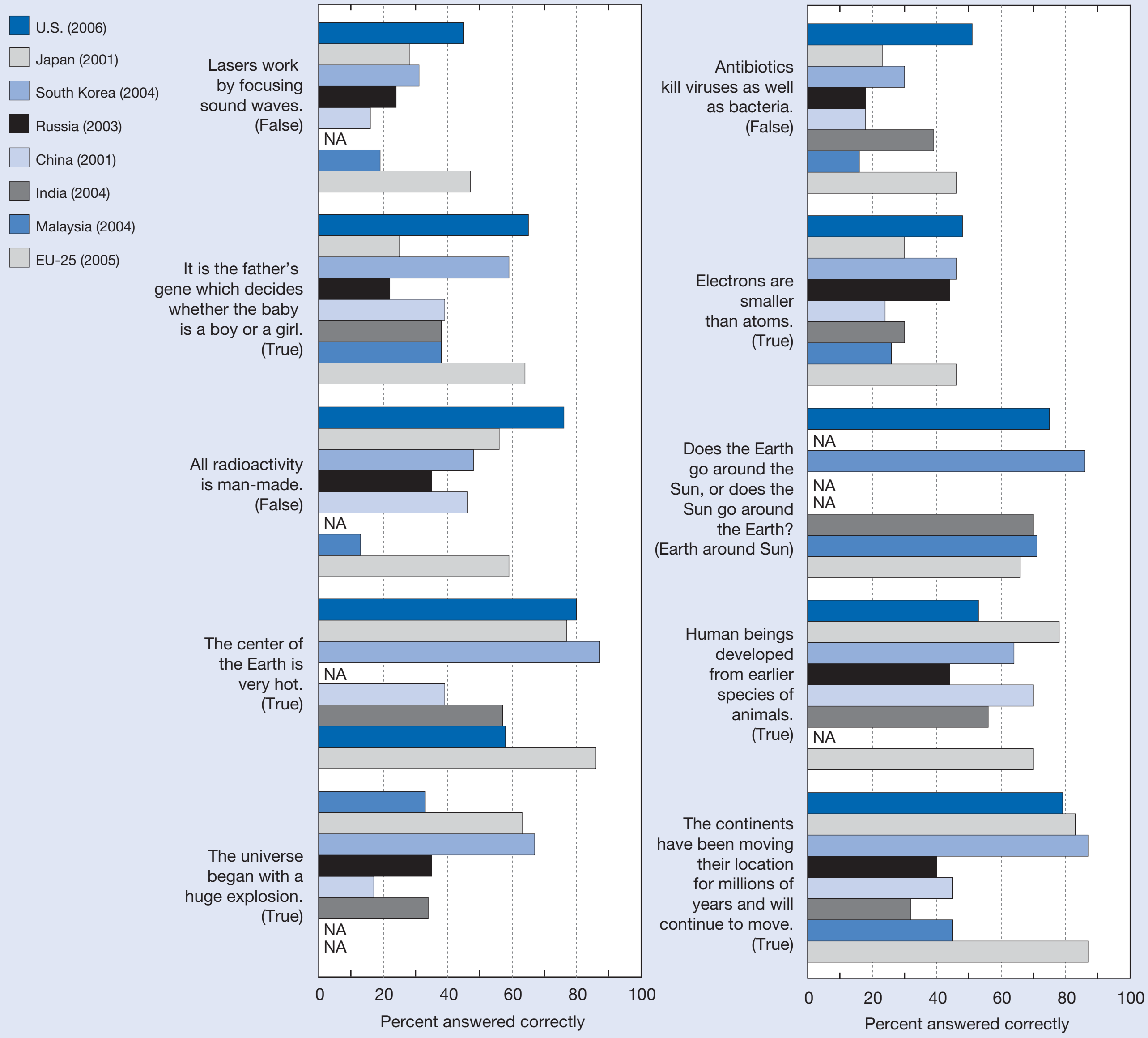
Divisions among scholars over the implications of data on Americans' civic and science knowledge follow similar lines (Delli Carpini and Keeter 1996; Lupia 2006; Nisbet 2003; Toumey 2006). Some stress that by trusting knowledgeable people, Americans can adequately perform necessary tasks without acquiring much civic or scientific knowledge. Others stress that considerable knowledge is required as context for deciding whom and what to trust. Similarly, for some scholars, singling out civic or scientific knowledge as distinctively valuable amounts to imposing elite preferences on people who would rather not spend time learning about either science or politics. To others, however, knowledge of these domains seems central to active problem-solving and participation in the shared cultural life of a modern society.

Evolution and the "Big Bang"

In international comparisons, U.S. scores on two science knowledge questions are significantly lower than those in almost all other countries where the questions have been asked. Americans were less likely 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, 43% of GSS respondents answered true to the first question in 2006, about the same percentage as in every year (except one) that the question has been asked. In other countries and in Europe, the comparable figures were substantially larger: 78% in Japan, 70% in China and Europe, and more than 60% in South Korea. Only in Russia did less than half of respondents (44%) answer true. Among the individual countries covered in the 2005 Eurobarometer survey, only Turkey's percentage answering true to this question was lower than the U.S. percentage (Miller, Scott, and Okamoto 2006). Similarly, Americans were less likely than other survey respondents (except the Chinese) to answer true to the big bang question. In the most recent surveys, less than 40% of Americans answered this question correctly compared with over 60% of Japanese and South Korean survey respondents.

Americans' responses to questions about evolution and the big bang appear to reflect factors beyond 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

Figure 7-8
Correct answers to scientific literacy questions, by country/region: Most recent year



NA = not available; EU = European Union

NOTE: NA indicates question not asked.

SOURCES: University of Chicago, National Opinion Research Center, General Social Survey (2006); Japan—Government of Japan, 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 and Technology in Japan (2002); South Korea—Korea Science Foundation, Survey of Public Attitudes Toward and Understanding of Science and Technology (2004); Russia—Gokhberg L and Shuvalova O, 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); China—Chinese Ministry of Science and Technology, China Science and Technology Indicators 2002 (2002); India—National Council of Applied Economic Research, India Science Survey (2004); Malaysia—Malaysian Science and Technology Information Centre, Public Awareness of Science and Technology Malaysia 2004 (2005); and EU—European Commission, Research Directorate-General, Eurobarometer 224/Wave 63.1: Europeans, Science and Technology (2005).

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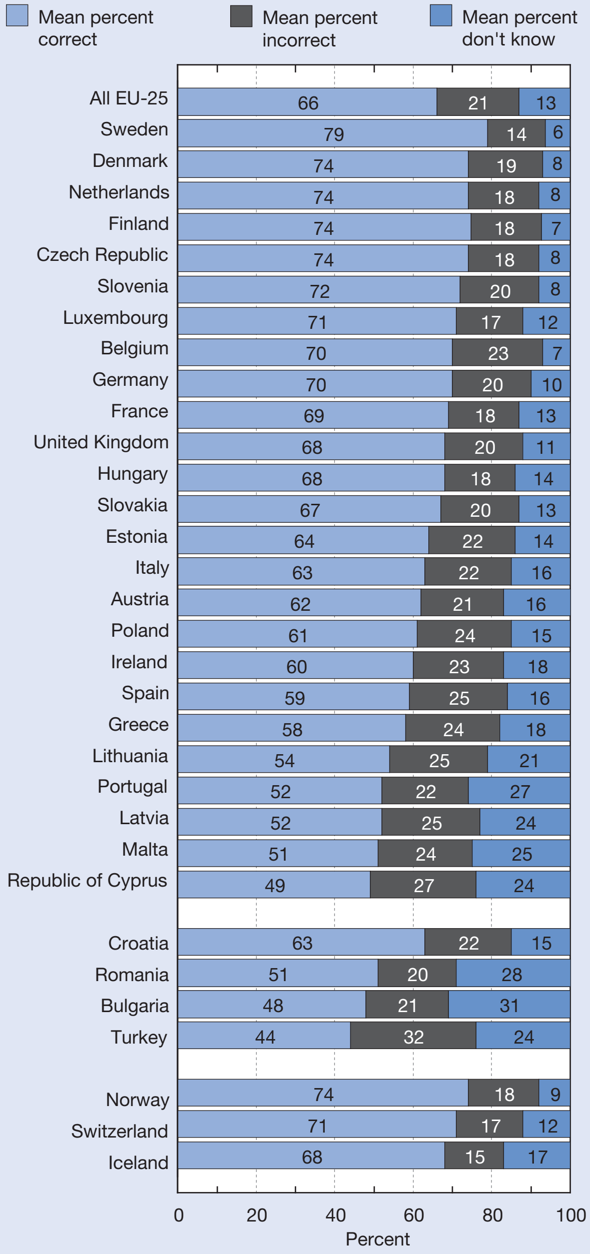
much more likely to answer correctly if the question was framed as being about scientific theories or ideas rather than as about the natural world. When the question about evolution was prefaced by "according to the theory of evolution," 74% answered true; only 42% answered true when it was not. Similarly, 62% agreed with the prefaced question about the big bang, but only 33% 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.

Figure 7-9

Scientific literacy in Europe: 2005



EU = European Union

NOTES: See appendix table 7-8. Mean percent for this figure based on responses to 13 factual science questions: (1) *The Sun goes around the Earth.* (True); (2) *The center of the Earth is very hot.* (True); (3) *The oxygen we breathe comes from plants.* (True); (4) *Radioactive milk can be made safe by boiling it.* (False); (5) *Electrons are smaller than atoms.* (True); (6) *The continents on which we live have been moving for millions of years and will continue to move in the future.* (True); (7) *It is the mother's genes that decide whether the baby is a boy or a girl.* (False); (8) *The earliest humans lived at the same time as the dinosaurs.* (False); (9) *Antibiotics kill viruses as well as bacteria.* (False); (10) *Lasers work by focusing sound waves.* (False); (11) *All radioactivity is man-made.* (False); (12) *Human beings, as we know them today, developed from earlier species of animals.* (True); (13) *It takes one month for the Earth to go around the Sun.* (False)

SOURCE: European Commission, Research Directorate-General, Eurobarometer 224/Wave 63.1 (3 January–15 February 2005): Europeans, Science and Technology (2005).

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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). 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 to be men (42%), have more years of education (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 (49%) 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, 46% 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 seven surveys) since the questions were first asked in 1982 (Newport 2006).

For almost a century, whether and how evolution should be taught in U.S. public school classrooms has been a frequent source of controversy (see sidebar, "Evolution and the Schools"). The role of alternative perspectives on human origins, including creationism and intelligent design, and their relevance to the teaching of science, has likewise been contentious. When Gallup asked survey respondents in 2005 whether they thought each of three "explanations about the origin and development of life on earth (evolution, creationism, and intelligent design) should or should not be taught in public school science classes" or whether they were "unsure," for each explanation more Americans chose "should" than chose either of the other alternatives (table 7-6).

In other developed countries, controversies about evolution in the schools have also occurred, but more rarely.

Table 7-6

American views on which explanations of human origins should be taught in public school science classes: 2005

(Percent)

Explanation of human origins	Should be taught	Should not be taught	Unsure
Evolution	61	20	19
Creationism	54	22	24
Intelligent design	43	21	36

NOTES: Responses to: *Do you think each of the following explanations about the origin and development of life on earth should or should not be taught in public school science classes, or are you unsure?* Question asked 8–11 August 2005.

SOURCE: Evolution, creationism, intelligent design, The Gallup Poll, http://www.galluppoll.com/content/?ci=21814&pg=1, accessed 25 January 2007.

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Evolution and the Schools

The American Association for the Advancement of Science (AAAS) gave its annual Award for Scientific Freedom and Responsibility for 2006 to 10 people "who have been on the front lines of the battle to prevent introduction of 'intelligent design' into science classrooms as an alternative to evolution" (AAAS 2007). According to Dr. John Marburger, the head of the White House Office of Science and Technology Policy, the theory of evolution is "the cornerstone of modern biology" (Bumiller 2005). In a March 4, 2005, letter to National Academy of Sciences (NAS) members, Dr. Bruce Alberts, then president of NAS, characterized the theory of evolution as "one of the foundations of modern science," urged America's leading scientists to help in their states and localities "to confront the increasing challenges to the teaching of evolution in the public schools," and cited the succession of NAS efforts devoted to ensuring that evolution is taught appropriately (Alberts 2005).

Yet, despite endorsements of evolution from these and other representatives of the scientific and political establishment, controversy over how evolution should be taught in public schools remains a perennial feature of American life and shows no sign of disappearing. Instead, the controversy is evolving.

Eight of the AAAS awardees were science teachers in the Dover, Pennsylvania, school district who fought their school board's decision to require that they read a disclaimer about the theory of evolution to their ninth grade biology students. After stating that evolution was a theory, not a fact, and had "gaps," the disclaimer directed students' attention to intelligent design, "an explanation of the origin of life that differs from Darwin's view."*

The Dover disclaimer was successfully challenged in court (*Kitzmiller* v. *Dover* 2005). The case turned on whether the disclaimer violated the Establishment Clause of the First Amendment to the U.S. Constitution, which deals with the relationship between government and religion. The court concluded that intelligent design was a religious view and not a scientific theory and that, because the school board's policy was animated by a religious purpose and had a religious effect, neither the policy nor the disclaimer that implemented it was constitutional.

In reaching this conclusion, the court reviewed the history of efforts to have biblical views of the origins of life taught in the public schools, the legal decisions that posed obstacles to these efforts, and the subsequent efforts to exclude the teaching of evolution from the schools or undermine the scientific status of the theory in the eyes of high school students. It traced a succession of legal conflicts in which the teaching of creationism and creation science had been found to violate the Establishment Clause and that had led to the development of intelligent design.

The Discovery Institute (2007), a Seattle policy and research organization, is the leading proponent of intelligent design. The Discovery Institute characterizes itself as a secular institution and maintains that intelligent design is not based on the Bible and is not the same as creationism. It does not advocate requiring that intelligent design be taught in schools. Rather, it "recommends that states and school districts focus on teaching students more about evolutionary theory, including telling them about some of the theory's problems." At the same time, it believes "there is nothing unconstitutional about discussing the scientific theory of design in the classroom." Framed in this way, intelligent design may appear to be more distant from religion and less vulnerable to legal challenge than doctrines such as creationism and creation science, which have failed to pass constitutional muster (for a discussion of framing, see sidebar, "Media Effects").

Even where, as in Dover, legal controversies over the teaching of evolution are resolved with affirmations of scientific evidence and criteria, thorough and substantive presentation of the theory of evolution in the schools is by no means guaranteed. The possibility that parents and students may object to the teaching of evolution, let alone evidence of organized efforts to resist it, may discourage some teachers from covering the topic in depth (Dean 2005). In addition, not all high school biology teachers subscribe to the accepted view of evolution or are well versed in the topic (Monastersky 2006).

Numerous efforts are under way in the scientific community to make materials available to middle and high school teachers that will help them do a better job presenting the scientific evidence about evolution (Holden 2006; Monastersky 2006). Niles Eldredge, a prominent researcher in evolutionary biology, has announced plans to initiate a new journal, *Evolution: Education and Outreach,* to serve as a resource for teachers at all levels who wish to improve their treatment of the topic. The journal is scheduled to begin publication in March 2008 (Monastersky 2007).

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*Intelligent design "holds that certain features of the universe and of living things are best explained by intelligent cause, not an undirected process such as natural selection." (www.discovery.org)

However, signs of opposition to the theory of evolution are emerging in Europe (*Nature* 2006).

Understanding the Scientific Process

U.S. surveys have used questions on three general topics to assess trends in Americans' understanding of the process of scientific inquiry. One set of questions tests how well respondents apply principles of probabilistic reasoning to a series of questions about a couple whose children have a one-in-four chance of suffering from an inherited disease.[16] A second set of questions deals with the logic of experimental design, asking respondents about the best way to design a test of a new drug for high blood pressure. An open-ended question probes what respondents think it means to "study something scientifically." Because probability, experimental design, and scientific method are all central to so much research that claims to be scientific, these questions are highly relevant to how respondents evaluate scientific evidence.

There appears to be a modest tendency for Americans to score better on these inquiry questions in recent years, especially when the questions are analyzed together in an inquiry index (appendix table 7-9). However, despite the use of identical coding instructions in different survey years, it is possible that year-to-year variations in coding practices for open-ended items and other subtle methodological differences may have affected this result. Performance on these questions is strongly associated with the different measures of science knowledge and education (appendix table 7-10). Older Americans and those with lower incomes, two groups that tend to have less education in the sciences, also tend to score less well on the inquiry measures.

Pseudoscience

The large numbers of Americans who regard astrology as at least somewhat scientific is an indicator that many Americans do not reliably distinguish between scientific and nonscientific knowledge claims. Available national data cannot differentiate those who misapply what they think are scientific criteria from those who in some respects reject conventional scientific criteria, even though they are familiar with them.

About one-third of Americans in 2006 said they believed that astrology was at least "sort of scientific." This proportion was almost exactly the same as in 2004. However, the 2004 and 2006 surveys indicate an apparent decline in the perception of astrology as scientific: the percentage of Americans who viewed astrology as not at all scientific was higher in these 2 years than it ever was in the 10 other times that this question was asked between 1979 and 2001 (appendix table 7-11). Respondents who have more years of formal education are less likely to perceive astrology to be at all scientific.

Public Attitudes About S&T in General

The U.S. S&E community hopes to improve society by developing knowledge and using it to solve problems and shape the world in which Americans live. U.S. national policy is built on this hope, which underlies the government's broad support for scientific research and technological development. The public's orientation toward S&T in general and toward institutions that are committed to S&T affects America's willingness and capacity to rely on S&T as a major strategy for improving the country's quality of life.

Generalized public support for S&T can make a difference in many ways. Public openness to technological change gives U.S. businesses opportunities to build a domestic customer base, create a foundation for worldwide technical competitiveness, and foster the national advantages that flow from pioneering innovations. Broad public and political support for long-term commitments to S&T research, especially in the face of pressing immediate needs, enables ambitious proposals for sustained federal S&T investments to reach fruition. Public confidence that S&E community leaders are trustworthy, S&E research findings are reliable, and S&E experts bring valuable judgment and knowledge to bear on public issues permits scientific knowledge to have influence over practical affairs. And, in an environment where positive public perceptions of S&E occupations predominate, promising young people are encouraged to pursue S&E careers.

To be sure, not all technological innovations, federal S&T investments, scientific pronouncements, or decisions to pursue S&E careers warrant support. It would be easy to cite instances in which scientific and technological optimism has been carried too far, and hard to dispute the idea that assertions that S&T-led social and economic progress will or has occurred in particular instances should be evaluated critically. But widespread, indiscriminate public skepticism about S&T, going beyond the reasoned examination of particular cases, would represent a radical and consequential change in American public opinion and would affect national strategies that link progress in S&T to overall national progress.

This section presents indicators of public attitudes and orientations toward S&T in general, in America and in other countries. It covers views of the promise of S&T and reservations about S&T; overall support for government funding of research; confidence in the leadership of the scientific community; perceptions of the proper influence of scientists over contested public issues about which the research community claims expertise; perceptions about what it means to be scientific and which disciplines and practices are scientific; and views of S&E as occupations. These indicators reflect general attitudes expressed in response to survey questions and disconnected from real-life decisions. How people apply these general views in practical situations, when attitudes toward science are only one of many considerations, is, of course, uncertain.

Attitudes and Question Wording

In the first paragraph of a May 16, 2006, press release, the Coalition for the Advancement of Medical Research (CAMR) reported that "nearly three-quarters of Americans support embryonic stem cell research." Two weeks later, the United States Conference of Catholic Bishops (USCCB) issued a press release. The first paragraph of that press release indicated that "48% of Americans oppose federal funding of stem cell research that requires destroying human embryos, while only 39% support such funding" (CAMR 2006; Levin 2006; Nisbet 2004; USCCB 2006).

How could two surveys, conducted by telephone 2 weeks apart and using similar methodologies, arrive at such different results?

The answer lies in wording and context (Schuman and Presser 1996). To their credit, later in their press releases, both organizations provided the wording of the actual questions respondents were asked:

CAMR question: I'm going to read you a brief description of embryonic stem cell research, and then get your reaction. Embryonic stem cells are special cells that can develop into every type of cell in the human body. The stem cells are extracted from embryonic cells produced in fertility clinics and then frozen days after fertilization. If a couple decides that the fertilized eggs are no longer needed, they can choose to donate the embryos for research or the clinic will throw the embryos away. Scientists have had success in initial research with embryonic stem cells and believe that they can be developed into cures for diseases such as cancer, Parkinson's, heart disease, juvenile diabetes, and spinal cord injuries. Having heard this description, do you strongly favor, somewhat favor, somewhat oppose, or strongly oppose medical research that uses stem cells from human embryos?

USCCB question: Stem cells are the basic cells from which all of a person's tissues and organs develop. Congress is considering the question of federal funding for experiments using stem cells from human embryos. The live embryos would be destroyed in their first week of development to obtain these cells. Do you support or oppose using your federal tax dollars for such experiments?

These two questions provide very different contextual information about stem cell research. To the organizations that sponsored the two surveys, the questions doubtless present the most relevant information for informed decisions. Most members of the public do not follow issues such as stem cell research very closely (Pew Research Center for the People and the Press 2006b), and the way questions are framed can influence their views.

Even neutral survey organizations ask questions in different ways and produce different results. Their questions, although generally more useful for scientific research on public attitudes, neither present a "correct" context, create a situation in which context plays no role in how people respond, nor establish a context that closely approximates the one in which most citizens make decisions. Because survey responses are affected by subtle differences in wording and context, thoughtful researchers pay attention to precisely how questions are asked, give more weight to patterns and trends in survey results than to the percentage of people who choose a particular response, and examine the degree to which responses are stable across different surveys on the same topic.

More than responses to questions about facts or behaviors, responses about attitudes are highly sensitive to the way questions are worded and the context in which they are placed (see sidebar, "Attitudes and Question Wording"). Although this sensitivity affects survey responses about the general attitudes covered in this section, it is probably even more important for the specific, controversial issues, such as stem cell research or global climate change, that are discussed in the next section.

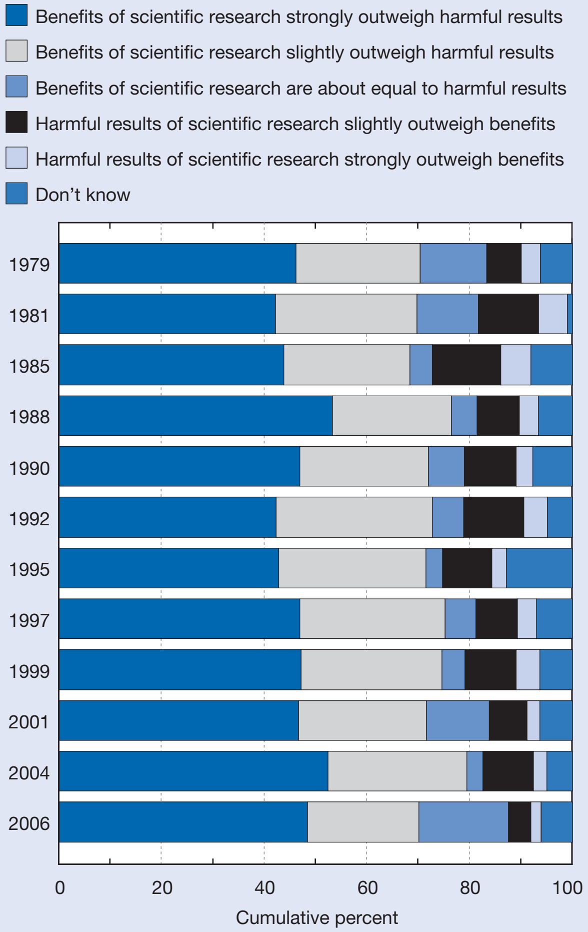
Promise and Reservations

Americans of all kinds—men and women, college graduates and high school dropouts, blacks and whites—consistently endorse the past achievements and future promise of S&T. In practically any major American social grouping, individuals who express serious doubt about the promise of science are a rare breed.

In six annual Virginia Commonwealth University (VCU) Life Science Surveys beginning in 2001, the percentage of respondents who agreed that "developments in science helped make society better" ranged between 85% and 90%. Responses for "developments in new technology" ranged between 83% and 88% in these same surveys. Similarly, between 2002 and 2006, the surveys asked respondents whether they believed "scientific research is essential for improving the quality of human lives" and found that agreement ranged between 87% and 92% (VCU Center for Public Policy 2006).

NSF surveys dating back to 1979 have yielded similar results. In 2006, about half (48%) of GSS respondents said that the benefits of scientific research strongly outweighed the harmful results. Substantial percentages said that benefits either slightly outweighed harms (22%) or volunteered that the two were about equal (17%), and only a small percentage (6%) said that harms either slightly or strongly outweighed benefits. The remainder said they did not know. These numbers were generally in keeping with those from earlier surveys (figure 7-10; appendix table 7-12).[17]

Figure 7-10
Public assessment of scientific research: 1979–2006



NOTE: Table includes all years for which data collected.

SOURCES: National Science Foundation, Division of Science Resources Statistics, Survey of Public Attitudes Toward and Understanding of Science and Technology (1979–2001); University of Michigan, Survey of Consumer Attitudes (2004); and University of Chicago, National Opinion Research Center, General Social Survey (2006). See appendix tables 7-12 and 7-13.

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Americans also overwhelmingly agree that S&T will foster "more opportunities for the next generation," with about 90% expressing agreement in the 2006 GSS. Agreement with this statement has been increasing moderately for over a decade.

Americans who have more years of formal education and score higher on measures of science knowledge express more favorable attitudes about S&T. A review of numerous surveys from around the world found, other things equal, a weak but consistent relationship between greater knowledge of science and more favorable attitudes toward it (see sidebar, "How Knowledge Relates to Attitudes").

Although data from other countries are not entirely comparable, they appear to indicate that Americans have somewhat more positive attitudes about the benefits of S&T than Europeans, Russians, and Japanese. Attitudes in China and South Korea, however, are comparable with and perhaps

How Knowledge Relates to Attitudes

In an analysis of data from almost 200 nationally representative surveys conducted in 40 countries between 1989 and 2003, Allum et al. (2008) examined how knowledge of science relates to attitudes toward S&T. Data are mostly from Europe and North America, but suitable surveys from countries in other regions were also included; these tended to be economically developed countries, such as Japan and New Zealand.

The analysis divided knowledge indicators into two groups depending on whether they involved general knowledge of scientific facts and processes or knowledge of a relatively specific scientific domain such as biology or genetics. It grouped attitude indicators by topic, distinguishing among science in general, nuclear power, genetic medicine, genetically modified food, and environmental science.

To isolate the relationship between knowledge and attitudes, the study used statistical techniques to control for factors that might be expected to influence both knowledge and attitudes, such as the age, sex, and education level of the respondent and the country in which the survey was conducted. Controlling for these influences, it reached several conclusions:

- There is "a small positive correlation between [favorable] general attitudes toward science and general knowledge of scientific facts and processes." Though small, this relationship appears consistently across countries.
- The relationship is stronger in the United States than in any of the other countries studied.
- The strength and nature of the relationship between knowledge and attitudes did not vary systematically over time during the period studied.
- Favorable attitudes about topics in a particular domain are more closely related to knowledge in that domain than to general science knowledge. Attitudes about genetically modified food, for example, show a stronger relationship to knowledge about biology and genetics than to general science knowledge.
- Contrary to findings in some other, less comprehensive studies, the relationship between knowledge and attitudes did not vary depending on differences in the level of economic development of the countries studied.

The study does not establish a causal link between knowledge and attitudes. Indeed, the authors conclude that "scholars have overlooked the need to provide a satisfactory account of how knowledge of science relates to preferences regarding its technological implementation in society," and recommend that researchers address "the social and psychological mechanisms that generate the associations we observe."

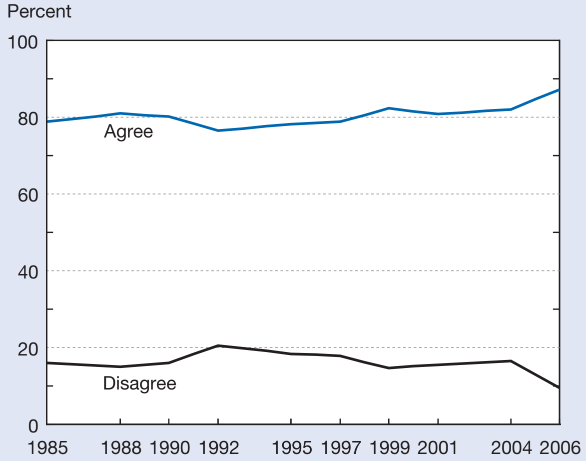
even more favorable than those in the United States (appendix table 7-13). In 2005, for example, Europeans were asked a question about the benefits and harms of science that was very similar to the U.S. question about the benefits and harms of scientific research.[18] The U.S. percentage for more benefits than harms was 18 points higher than the European number, and the European percentage for more harms than benefits was 8 points higher than the U.S. number. However, differentials are less evident for other questions. In all of the countries and regions where survey data exist, statements about the achievements and promise of science elicit substantially more agreement than disagreement.

Both in the United States and abroad, respondents also express reservations about S&T. For 6 years (2001–06), VCU Life Sciences Surveys have asked respondents whether they agree that "scientific research these days doesn't pay enough attention to the moral values of society." In each year, a majority has agreed. During this period, though, the percentage that agreed has dropped substantially, going from 73% in 2001 to 56% in 2006. In the 2006 GSS, large minorities of survey respondents registered agreement with other statements expressing reservations about science, including "science is too concerned with theory and speculation to be of much use in making concrete government policy decisions that will affect the way we live" (34% agree, 58% disagree) and "science makes our way of life change too fast" (44% agree, 53% disagree) (appendix tables 7-14 and 7-15). The latter question has been asked in numerous other countries (appendix table 7-13). Although levels of agreement with this statement in the United States appear to be similar to those in Russia, surveys in other countries record much higher levels of agreement.

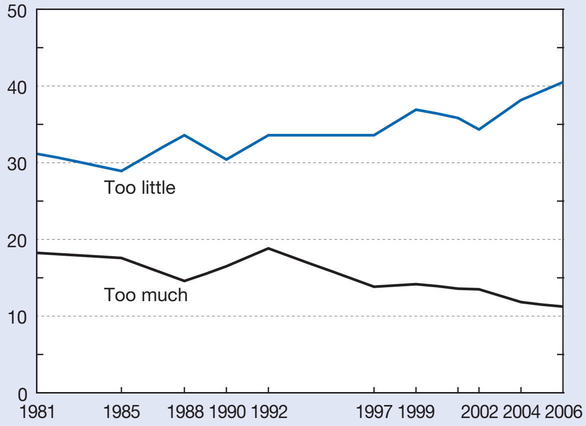
Federal Funding of Scientific Research

U.S. public opinion consistently and strongly supports federal spending on basic research. NSF surveys have repeatedly asked Americans whether "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." Since 1979, about 80% of Americans have registered agreement in response to this question. In the most recent survey, agreement was even higher than in the past, with 87% favoring federal support in 2006. Responses to a GSS question about federal spending on scientific research provide further evidence of increasing public support for federal spending on scientific research. For the decade beginning in 1992, the percentage of Americans who thought that the government was spending too little on scientific research hovered between 34% and 37%. This percentage then grew from the 34% registered in 2002 to 38% in 2004 and 41% in 2006. In the 2006 survey, only 11% said that the government was spending too much in this area, which is lower than the comparable figure in any of the other 10 NSF or GSS surveys in which this question has been asked since 1981 (figure 7-11; appendix tables 7-16, 7-17, 7-18, and 7-19).

Figure 7-11
Attitudes toward government funding of scientific research: 1981–2006



Government should fund basic research: 1985–2006



Assessment of government spending support for scientific research: 1981–2006

NOTES: Top panel: survey results in 1985, 1988, 1990, 1992, 1995, 1997, 1999, 2001, 2004, and 2006; other years interpolated. Bottom panel: survey results in 1981, 1985, 1988, 1990, 1992, 1997, 1999, 2001, 2002, 2004, and 2006; other years interpolated.

SOURCES: National Science Foundation, Division of Science Resources Statistics, Survey of Public Attitudes Toward and Understanding of Science and Technology (years through 2001); University of Michigan, Survey of Consumer Attitudes (2004 in top panel); and University of Chicago, National Opinion Research Center, General Social Survey (2006 in top panel, 2002–06 in bottom panel). See appendix tables 7-16 and 7-17 for top panel and appendix table 7-18 for bottom panel.

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Although support for federal research investment is at historically high levels, other kinds of federal spending generate even stronger public support (appendix table 7-18). Support for increased spending is greater in numerous program areas, including education (73%), health care (72%), assistance to the poor (68%), environmental protection (67%), and Social Security (61%). Scientific research ranks about on a par with mass transit (38%) and well ahead of space exploration (14%) and assistance to foreign countries (10%) in the proportion of the U.S. population favoring increased spending.

In other countries where similar though not precisely comparable questions have been asked, respondents also express strong support for government spending on basic scientific research. In 2005, 76% of Europeans agreed that "even if it brings no immediate benefits, scientific research which adds to knowledge should be supported by government," and only 7% disagreed. Because the European survey offered a middle option ("neither agree nor disagree"), both of these percentages are lower than figures for the United States, where no middle category was offered. Agreement in South Korea, China, Malaysia, and Japan reaches levels generally comparable to those in the United States and Europe. Support for increased government spending on scientific research appears to be relatively common in Europe as well. Over half of Europeans agreed in 2005 that their "government should spend more money on scientific research and less on other things." Although this proportion is nominally higher than the percentage of Americans who support more government spending, numerous context and wording differences between the questions leave responses open to substantially differing interpretations.[19] Public support for increased spending on scientific research was substantially greater in South Korea (67% in 2004) than in the United States (Korea Gallup 2007).

Confidence in the Science Community's Leadership

For the science-related decisions that citizens face, a comprehensive understanding of the relevant scientific research would require mastery and evaluation of more evidence than even working scientists could handle. In addition to relying on direct evidence from scientific studies, citizens who want to draw on scientific evidence must consult the judgments of leaders and other experts who they believe can speak authoritatively about the scientific knowledge that is relevant to an issue.

Numerous questions arise about how, when, and how well citizens rely on others to help shape their opinions on scientific issues. When it comes to scientific questions, do they trust the leaders of the scientific community to provide reliable information and advice? Whom else do they trust to speak with authority about such matters? How, and how well, do they distinguish widely respected experts and consensual views from marginal dissidents and idiosyncratic judgments? Do they recognize the relevance of scientific evidence as often as they should? Do they exaggerate its relevance in some cases? Insofar as they must trust others, do they do so blindly, or do they make critical, though inevitably partial, evaluations of whose scientific claims warrant their trust and what kinds of evidence make those claims trustworthy?

Public confidence in the leaders of the scientific community is one indicator of public willingness to rely on science. At a minimum, such confidence is ordinarily a prerequisite for taking scientific knowledge seriously in personal and public matters.

Since 1973, the GSS has tracked public confidence in the leadership of various institutions, including the scientific community. The GSS asks respondents whether they have "a great deal of confidence, only some confidence, or hardly any confidence at all" in institutional leaders. In 2006, the percentage of Americans expressing "a great deal of confidence" in leaders was higher for the scientific community than for any other institution except the military. Conversely, the percentage expressing "hardly any confidence at all" was lower for scientific leaders than for leaders of any other institution about which this question was asked (table 7-7).

Throughout the entire period in which this question has been asked, the percentage of Americans expressing a great deal of confidence in the leaders of the scientific community has fluctuated within a relatively narrow range, hovering between 35% and 45% (appendix table 7-20). In contrast, for some other institutions, confidence has been more sensitive to current events: the percentage of Americans professing a great deal of confidence in military leaders changed more between 2004 and 2006 than the comparable percentage for science leaders changed between 1973 and 2006.

Science has usually ranked second or third in the public confidence surveys, with medicine or the military ranking first. The consistently high confidence in the leadership of the scientific community is in contrast to a general decline in confidence in institutional leaders over the past three decades. The medical community, for example, has seen a long-term decline in confidence: whereas over half of Americans expressed a great deal of confidence in medical leaders in the mid-1970s, the number has been around 40% in recent years. Since 2002, science has scored as well as or better than medicine on this indicator, although the scores for the two fields remain close.

Influence on Public Issues

Government support for scientific research is predicated in significant measure on the idea that science can play a useful role in many public decisions. For science to play this role, it is helpful for the general public to support judicious efforts to bring scientific knowledge to bear on public matters and share the view that science ought to be considered relevant and influential.[20]

The 2006 GSS contained new batteries of questions that ask about the appropriate influence of science on four contested public issues to which scientific research might be considered relevant—global climate change, research using human embryonic stem cells, federal income taxes, and genetically modified foods. For each issue, survey respondents were asked how much influence a group of scientists with relevant expertise (e.g., medical researchers, economists) should have in deciding about the issue, how well the scientists understood the issue, and to what extent the scientists would "support what is best for the country as a whole versus what serves their own narrow interests."[21] The same questions were asked about elected officials and either religious leaders (for stem cell research) or business leaders (for the other issues). Respondents were also asked a question about their perception of the level of consensus among the scientists regarding a largely factual aspect of the issue and a question that probed their attitude regarding the issue.[22]

The GSS data indicate that Americans believe that scientists should have a relatively large amount of influence on public decisions concerning these issues (table 7-8).[23] For the four issues, the percentage who said that scientists should have either a great deal or a fair amount of influence ranged from 85% (global warming) to 72% (income taxes). For each issue, the

Table 7-7
Public confidence in institutional leaders: 2006
(Percent)

Type of institution	Level of confidence in leaders: A great deal	Some	Hardly any	Don't know
Military	47	39	12	2
Scientific community	41	48	6	5
Medicine	40	49	10	1
U.S. Supreme Court	33	49	15	4
Banks and financial institutions	30	56	13	1
Education	28	57	15	—
Organized religion	24	51	22	3
Major companies	18	62	18	2
Executive branch of federal government	16	45	37	2
Organized labor	12	56	28	5
Congress	12	53	33	2
Press	10	48	40	1
Television	9	49	41	1

— = ≤0.5% responded

NOTE: Detail may not add to total because of rounding.

SOURCE: University of Chicago, National Opinion Research Center, General Social Survey (2006). See appendix table 7-20.

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Table 7-8
Preferred groups for influencing decisions about public issues: 2006
(Percent)

Public issue/group	Preferred degree of influence: A great deal	A fair amount	A little	None at all	Don't know
Global warming					
Environmental scientists	47	38	7	3	4
Business leaders	10	22	38	25	5
Elected officials	17	33	33	13	4
Stem cell research					
Medical researchers	39	41	11	4	5
Religious leaders	8	21	36	29	6
Elected officials	11	35	32	15	6
Federal income taxes					
Economists	21	51	18	4	6
Business leaders	9	37	36	13	4
Elected officials	21	40	24	11	4
Genetically modified foods					
Medical researchers	41	40	10	3	5
Business leaders	3	16	41	35	5
Elected officials	7	30	37	21	5

NOTES: Responses to: *How much influence should each of the following groups have in deciding: global warming policy; government funding for stem cell research; reducing federal income taxes; restricting sale of genetically modified foods?* Detail may not add to total because of rounding.

SOURCE: University of Chicago, National Opinion Research Center, General Social Survey (2006). See appendix table 7-21.

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percentage was greater for scientists than for either of the other leadership groups. The contrast among the groups was more pronounced for the three issues that dealt with biological or geophysical phenomena than for income taxes, where elected officials ranked closely behind economists. Even for the tax issue, however, this appears to be as much or more because of greater willingness to accord elected officials substantial influence than because of greater skepticism about economists. Among the three issues in which respondents compared scientists, elected officials, and business leaders, the tax issue stands out as the one where the public believes elected officials and business leaders ought to have the most influence.

Americans also give scientists relatively high marks for understanding the four issues (table 7-9).[24] The GSS asked respondents to rate each leadership group's understanding of a largely factual aspect of each issue on a five-point scale ranging from "very well" to "not at all." For the three issues dealing with biological or geophysical phenomena, the difference in perceived understanding was big: between 64% and 74% of the public placed the relevant scientists in one of the top two categories, whereas only 9% to 14% placed any of the other groups in those categories. The contrast among groups was smaller for the tax issue, with economists (52%) ranking ahead of business leaders (44%) and elected officials (28%). As was the case for influence, this narrower gap among the groups is largely a matter of a relatively favorable perception of business leaders' and elected officials' understanding of the tax issue, although a less positive view of the economists' understanding also plays a role.

Patterns for the question about which groups would "support what is best for the country as a whole versus what serves their own narrow interests" were similar (table 7-10).[25] For each issue, Americans placed the scientific group in one of the top two categories much more often than they placed either of the other leadership groups in those categories. Differences were always at least 30 percentage points, even where comparisons concerned religious leaders, a group that might be expected to be perceived as less narrowly self-interested than elected officials or business leaders.

One factor that may limit the influence of scientific knowledge and the scientific community over public issues is the perception that significant scientific disagreement exists, making scientific knowledge uncertain (Krosnick et al. 2006). GSS respondents were asked to rate the degree of scientific consensus on a largely factual aspect of each of the four issues, using a five-point scale ranging from "near complete agreement" to "no agreement at all."[26] The "importance of stem cells for research" was the only item for which as many as half of respondents (52%) chose one of the two points near the complete agreement end of the scale. Just 20% of respondents chose one of these points when asked about the extent to which "economists agree on the effects of reducing federal income taxes." For all four issues, this set of questions generated many "don't know" responses and many responses at the midpoint of the scale, both of which are consistent with the idea that there is widespread public doubt about exactly how scientists view the issues (table 7-11).

Table 7-9
Perceived understanding of public issues by various groups: 2006
(Percent)

	Degree of understanding (on scale of 1 to 5)					
	Very well				Not at all	Don't
Public issue/group	5	4	3	2	1	know
Global warming						
Environmental scientists	44	22	22	4	4	4
Business leaders	4	8	30	32	22	4
Elected officials	5	7	31	29	24	4
Stem cell research						
Medical researchers	50	24	15	3	3	6
Religious leaders	6	8	26	29	25	6
Elected officials	3	7	35	26	22	6
Federal income taxes						
Economists	33	19	29	7	7	5
Business leaders	15	29	33	12	6	4
Elected officials	10	18	34	19	15	5
Genetically modified foods						
Medical researchers	32	32	18	8	5	6
Business leaders	4	7	24	31	28	6
Elected officials	3	6	24	33	29	5

NOTES: Responses to: *How well do the following groups understand: causes of global warming; importance of stem cell research; effects of reducing federal income taxes; risks posed by genetically modified foods?* Detail may not add to total because of rounding.

SOURCE: University of Chicago, National Opinion Research Center, General Social Survey (2006). See appendix table 7-22.

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With a few exceptions, responses to these questions do not differ markedly among demographic groups (appendix tables 7-21, 7-22, 7-23, and 7-24). Americans with higher incomes, more education, and more science knowledge tend to have more favorable perceptions of the knowledge, impartiality, and level of agreement among scientists. These differences are especially pronounced for perceptions of economists, despite the fact that the science knowledge and education measures do not test economic knowledge.

The interplay among the various indicators presented in this section cannot be understood without further research and analysis. It is not clear, for example, what mix of perceived attributes—knowledge, consensus, impartiality, or others—affects public perceptions of the appropriate influence of sci-

Table 7-10

Perceived impartiality of various groups in making policy recommendations about public issues: 2006

(Percent)

	Extent to which group would support (on scale of 1 to 5)					
	What is best for country				Own narrow interests	
Public issue/group	5	4	3	2	1	Don't know
Global warming						
Environmental scientists	40	27	17	6	6	5
Business leaders	6	4	22	27	36	5
Elected officials	9	10	25	24	28	5
Stem cell research						
Medical researchers	32	27	21	9	7	4
Religious leaders	13	12	22	20	26	6
Elected officials	8	7	32	23	25	5
Federal income taxes						
Economists	22	30	25	9	8	6
Business leaders	3	8	24	30	30	4
Elected officials	8	14	26	24	24	4
Genetically modified foods						
Medical researchers	34	29	19	7	6	5
Business leaders	2	4	25	32	32	5
Elected officials	6	10	32	25	21	5

NOTES: Responses to: *When making policy decisions about [public issue], to what extent do you think [group] would support doing what is best for the country as a whole or what serves their own narrow interests?* Detail may not add to total because of rounding.

SOURCE: University of Chicago, National Opinion Research Center, General Social Survey (2006). See appendix table 7-23.

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Table 7-11

Perceived scientific consensus on public issues: 2006

(Percent)

	Degree of consensus (on scale of 1 to 5)					
	Near complete agreement				No agreement at all	
Group/public issue	5	4	3	2	1	Don't know
Environmental scientists on existence and causes of global warming	14	28	35	9	6	9
Medical researchers on importance of stem cells for research	19	33	29	4	5	9
Economists on effects of reducing federal income taxes	5	15	40	14	13	13
Medical researchers on risks and benefits of genetically modified foods	9	19	41	11	7	13

NOTES: Responses to: *To what extent do [people in group] agree on [public issue]?* Detail may not add to total because of rounding.

SOURCE: University of Chicago, National Opinion Research Center, General Social Survey (2006). See appendix table 7-24.

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entists and scientific knowledge on public affairs. Likewise, it is not clear why public perceptions vary concerning different leadership groups or whether the interplay of attributes is the same in all segments of the public. In addition, the choice of factual examples raised in the questions may substantially affect responses. For example, it is possible that economists would be perceived very differently when the issue is foreign trade or environmental scientists when the issue is energy conservation. An alternative set of factual examples might also highlight the role of additional considerations that affect public views of who should influence public decisions.[27]

What Makes an Activity Scientific

The label "scientific" is usually considered a favorable one, and many claim it for their research or occupation. When research studies claim to be scientific, they claim to produce valid knowledge; when occupations claim to be scientific, they claim their practitioners have systematic expertise. Because not all claims to science are equally warranted, it is important for the public to scrutinize these claims critically and use reasonable criteria to judge them.

The 2006 GSS asked two batteries of questions that probed what characteristics Americans associate with scientific studies and what disciplines and practices Americans consider scientific. These indicators provide insight into how Americans discriminate between more and less scientific endeavors.

Attributes That Make Something Scientific

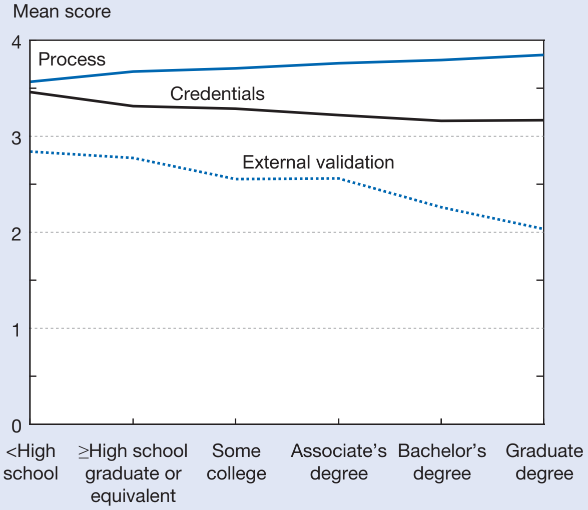
One group of questions asks how important each of eight characteristics is in "making something scientific." These characteristics can be divided into three groups—features of the research process, aspects of the credentials and institutional settings that lend credibility to the research, and external validation by other belief systems (i.e., religious and common sense beliefs). Americans were most likely to consider features of the research process to be very important (appendix table 7-25). Over two-thirds said that "conclusions based on solid evidence" (80%), "carefully examin[ing] different interpretations of the results" (73%), and replication of results by other scientists (67%) were very important in making something scientific.

Americans thought that researcher qualifications were almost as important, with 62% classifying "the people who do it have advanced degrees in their field" as very important. Institutional settings often associated with research, such as laboratories (41%) and universities (33%), ranked lower. For making research scientific, these settings were viewed as similar in importance to having results that were "consistent with common sense," a belief system that is not a part of science. Most Americans viewed consistency with religion, another belief system outside of science, as either not too important (31%) or not at all important (39%) to making something scientific.

Response patterns for this group of questions are related to education (figure 7-12; appendix table 7-26). Although Americans at all levels of education rated research process characteristics as most important, more highly educated Americans gave these the highest ratings. In contrast, individual credentials, institutional auspices, and consistency with other beliefs were less important among more highly educated respondents than among others. As a result of these divergent patterns, the gap in importance between process characteristics and other attributes is very wide at higher levels of education but relatively narrow for people with less schooling.

It is reasonable to interpret the relationship between education and a more dominant emphasis on process criteria for judging whether something is scientific as indicating that more education fosters a more critical, evidence-oriented approach to studies and conclusions that claim to be scientific. This interpretation would likewise suggest that less-educated people more often give weight to more questionable criteria that are either correlated with or unrelated to being scientific. However, other interpretations cannot be entirely ruled out. For example, people who internalize process-oriented understandings of science early in their schooling may be more successful academically and more likely to pursue advanced education. Another possibility is that additional schooling

Figure 7-12
Importance of process, credentials, and external validation to belief that something is scientific, by education level: 2006



NOTES: Responses to how important each of eight statements is to making something scientific—very important, pretty important, not too important, not important at all (where 4 = very important and 1 = not important at all). Mean importance scores for process, credentials, and external validation are computed averages of responses to all statements in category. Process statements: (1) *The conclusions are based on solid evidence;* (2) *The researchers carefully examine different interpretations of the results, even ones they disagree with;* (3) *Other scientists repeat the experiment, and find similar results.* Credentials statements: (1) *The people who do it have advanced degrees in their field;* (2) *It is done by scientists employed in a university setting;* (3) *The research takes place in a laboratory.* External validation statements: (1) *The results of the research are consistent with common sense;* (2) *The results of the research are consistent with religious beliefs.*

SOURCE: University of Chicago, National Opinion Research Center, General Social Survey (2006). See appendix tables 7-25 and 7-26.

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may lead individuals to adopt a conventional account of science in general without having a strong or consistent impact on how they actually evaluate knowledge claims.

Which Fields Are Scientific

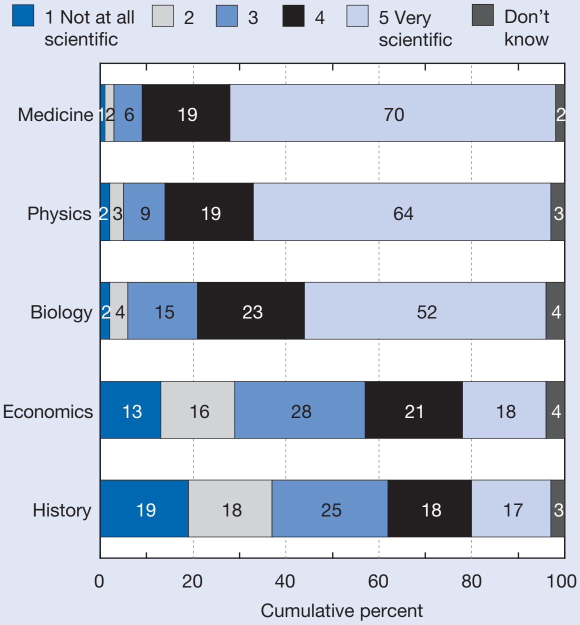
The 2006 GSS asked Americans about eight fields of research or practice and whether they were “very scientific, pretty scientific, not too scientific, or not scientific at all.” A similar question on the 2005 Eurobarometer about an overlapping set of fields allows some comparison between U.S. and European perspectives.

Practically all Americans perceived medicine as very or pretty scientific (table 7-12). Americans identified medicine most strongly with science even though it is focused more on practical service delivery and less on research than other fields on the list, including biology and physics. Nonetheless, both of these disciplines were also overwhelmingly seen as either very or pretty scientific. Americans with more years of education and more classroom exposure to science and mathematics more often believed that these two fields were relatively scientific (appendix table 7-27). This was especially true for physics. Engineering, which, like medicine, involves the application of scientific knowledge to practical problems, nonetheless ranked well below the other three fields on this measure. About 50% of Americans said that the two social science disciplines on the list (economics and sociology) were very or pretty scientific. Accounting and history were least often placed at the scientific end of the scale. About 30% of Americans consider each of these fields “not at all scientific,” a percentage that far exceeds that for any of the other fields. Survey respondents with less education were more likely than others to classify history as relatively scientific.

The 2005 Eurobarometer asked about five fields that were included in the 2006 GSS (figure 7-13). For these fields, Europeans and Americans had similar views: medicine was seen as the most scientific, with physics and biology following closely behind and, after a large gap, economics leading history. There were two minor differences. Europeans rated physics as somewhat more scientific than biology, whereas

Figure 7-13

European perceptions of scientific nature of various fields: 2005



NOTES: Responses to: *People have different opinions about what is scientific and what is not. I am going to read out a list of subjects. For each one tell me how scientific you think it is, on a scale from 1 to 5, where 5 means that you think it is “very scientific” and 1 that it is “not at all scientific.” The intermediate scores allow you to qualify your answer.* See table 7-12 for U.S. responses to similar question.

SOURCE: European Commission, Research Directorate-General, Eurobarometer 224/Wave 63.1 (3 January–15 February 2005): Europeans, Science and Technology (2005).

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Table 7-12

Perceptions of scientific nature of various fields: 2006

(Percent)

Field	Very scientific	Pretty scientific	Not too scientific	Not at all scientific	Haven’t heard of field	Don’t know
Medicine	81	16	1	—	—	1
Biology	70	24	2	1	—	2
Physics	69	21	3	1	2	4
Engineering	45	32	11	7	—	4
Economics	16	35	31	13	1	3
Sociology	8	41	29	9	8	6
Accounting	13	21	31	32	—	3
History	10	21	37	29	—	3

— = ≤0.5% responded

NOTES: Responses to: *How scientific is [field]?* Detail may not add to total because of rounding.

SOURCE: University of Chicago, National Opinion Research Center, General Social Survey (2006). See appendix table 7-27.

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Americans rated the two fields as about equal. Europeans saw history as more scientific than Americans did, and the gap between history and economics was wider in the United States than in Europe.

Views of S&E Occupations

Data on public esteem for S&E occupations may be an indicator of the attractiveness of these occupations and their ability to recruit talented people into their ranks. Such data may also have a bearing on the public's sense that S&E affect the nation's well being in the future.

For nearly 30 years, the Harris Poll (Harris Interactive 2006b) has asked about the prestige of a large number of occupations, including scientists and engineers (table 7-13). In 2006, over 50% of Americans said that scientists had "very great prestige," and about one-third expressed this view about engineers. Most occupations in the surveys rank below engineers.

The percentage of survey respondents attributing "very great prestige" to scientists has fluctuated between 51% and 59% in 11 surveys conducted since 1982 and for which results are available in its most recent Harris Poll summary of trends. During the same period, the percentage for engineers has also fluctuated in a relatively narrow range, moving between 28% and 37%. In neither case has there been a clear trend. In contrast, long-term trends are evident for other occupations, including teachers (up), military officers (up), and lawyers (down).

Scientists ranked higher in prestige than almost all occupations in the Harris surveys. In recent years, their ranking was comparable with that of nurses, doctors, and firefighters and slightly ahead of teachers and military officers. Although engineers are not in this top group, very few respondents say that engineers have "hardly any prestige at all." In 2006, only 4% of the public gave this response, which was about the same as for scientists and four other occupations; only medical doctors ranked noticeably better on the "hardly any prestige at all" measure, and 14 occupations ranked significantly lower.

Prestige appears to reflect perceived service orientation and public benefit more than high income or celebrity (Harris Interactive 2004). Americans are more likely to trust people in prestigious occupations (including scientists) to tell the truth (Harris Interactive 2006a).

Some evidence suggests that Americans rate scientific careers more positively than is the case in at least some other countries. In 2004, a little over 50% of South Koreans said they would feel happy if their son or daughter wanted to become a scientist, but 80% of Americans surveyed in 2001 expressed this feeling. Among Chinese, however, science ranked second to medicine as an occupation that survey respondents would like for their children (NSB 2006).

Table 7-13
Prestige of various occupations: Selected years, 1977–2006
(Percent)

Occupation	1977	1982	1992	1997	1998	2000	2001	2002	2003	2004	2005	2006
Doctor	61	55	50	52	61	61	61	50	52	52	54	58
Scientist	66	59	57	51	55	56	53	51	57	52	56	54
Teacher	29	28	41	49	53	53	54	47	49	48	47	52
Military officer	NA	22	32	29	34	42	40	47	46	47	49	51
Police officer	NA	NA	34	36	41	38	37	40	42	40	40	43
Priest/minister/clergyman	41	42	38	45	46	45	43	36	38	32	36	40
Engineer	34	30	37	32	34	32	36	34	28	29	34	34
Member of Congress	NA	NA	24	23	25	33	24	27	30	31	26	28
Architect	NA	NA	NA	NA	26	26	28	27	24	20	27	27
Athlete	26	20	18	21	20	21	22	21	17	21	23	23
Lawyer	36	30	25	19	23	21	18	15	17	17	18	21
Entertainer	18	16	17	18	19	21	20	19	17	16	18	18
Accountant	NA	13	14	18	17	14	15	13	15	10	13	17
Banker	17	17	17	15	18	15	16	15	14	15	15	17
Journalist	17	16	15	15	15	16	18	19	15	14	14	16
Union leader	NA	NA	12	14	16	16	17	14	15	16	15	12
Business executive	18	16	19	16	18	15	12	18	18	19	15	11

NA = not available, question not asked

NOTES: 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: Firefighters, doctors and nurses top list as "most prestigious occupations," according to latest Harris Poll, The Harris Poll #58, Harris Interactive (26 July 2006), http://www.harrisinteractive.com/harris_poll/index.asp?PID=685, accessed 7 August 2006.

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Public Attitudes About Specific S&T-Related Issues

Public attitudes can affect the speed and direction of S&T development. When science plays a substantial role in a national policy controversy, more than the specific policies under debate may be at stake. The policy debate may also shape public opinion and government decisions about investments in general categories of research. Less directly, a highly visible debate involving science may shape overall public impressions of either the credibility of science or the proper role of science in other, less visible public decisions. Likewise, public attitudes about emerging areas of research and new technologies can have an impact on innovation. The climate of opinion concerning new research areas can influence levels of public and private investment in related technological innovations and, eventually, the adoption of new technologies and the growth of industries based on these technologies.

For these reasons, survey responses about policy controversies involving science, specific research areas, and emerging technologies are worthy of attention. In addition, responses about relatively specific matters provide a window into the practical decisions through which citizens translate more general attitudes into actions, although, like all survey responses, how these responses relate to actual behavior remains uncertain. More generally, even in democratic societies, public opinion about new scientific and technological developments does not translate directly into actions or policy. Instead, it filters through institutions that selectively measure what the public believes and either magnify or minimize the effects of divisions in public opinion on public discourse and government policy (see sidebar, "Designs on Nature").

Policy attitudes always involve a multitude of factors and not just knowledge or understanding of relevant science. Values, morals, judgments of prudence, and numerous other factors can come strongly into play, and judgments about scientific fact are often secondary. In assessing the same issue, different people may find different considerations relevant.

This section begins with data on environmental issues, especially global climate change. It then covers attitudes toward recent and novel technologies, including medical biotechnology, agricultural biotechnology (i.e., genetically modified food), and nanotechnology. Data on cloning and stem cell research follow, and the section concludes with some recent data on attitudes toward science and mathematics education.

Environment and Climate Change

The Gallup Organization's annual survey on environmental issues indicates that Americans have recently become somewhat more concerned about environmental quality (figure 7-14). Between 2005 and 2007, the percentage of Americans expressing "a great deal" of worry about the "quality of the environment" rose from 35% to 43%, returning to approximately its 2001 level after 4 years (2002–05) at about 35% (Saad 2006a, 2007).

Figure 7-14
Worry about quality of environment: 2001–07

NOTE: Poll conducted annually in March.

SOURCES: Saad L, Americans See Environment as Getting Worse, The Gallup Poll (20 April 2006), http://www.galluppoll.com/content?ci=22471, accessed 4 March 2007; and special tabulation (2007).

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Despite this rise in concern, however, worry about the environment ranked somewhere in the middle among the 12 issues about which Gallup asked in 2007. Between 70% and 80% of Americans expressed either a great deal or a fair amount of worry about environment and most other issues (Social Security, drug use, crime and violence, future terrorist attacks, the economy, hunger and homelessness, and availability and affordability of energy); only availability and affordability of healthcare (83%) ranked above this range, and only illegal immigration (68%), unemployment (59%), and race relations (51%) ranked below it. In 2006 Gallup surveys, most Americans (62%) believed that the government spent too little to protect the environment and only a handful thought it spent too much (4%) (Gallup Organization 2007a). These numbers are in keeping with 2006 GSS responses to a similar question. Support for additional government spending, after dropping between 1992 to 2003, has rebounded in recent years, rising 11 percentage points between 2003 and 2006. Nonetheless, the trend in support for environmental protection is less evident when Americans are asked about tradeoffs between environmental protection and economic growth (figure 7-15). Indeed, as gasoline prices increased, public support for oil exploration in the Alaskan Arctic National Wildlife Refuge and expanded use of nuclear energy rose substantially between 2003 and 2006. However, support dropped significantly in Gallup's 2007 survey (Gallup Organization 2007a).

Global warming has recently become more prominent among environmental issues for the American public. In 2004, 2006, and 2007, Gallup asked Americans how much they worry about 10 environmental issues. The percentage of Americans who said they worried "a great deal" about

Designs on Nature

In *Designs on Nature* (2005), Sheila Jasanoff analyzed how the United States, Great Britain, and Germany have grappled with recent developments in biotechnology. Her study sought to explain numerous differences among these three leading S&T powers in the kind of political dynamics spawned by biotechnology:

- Agricultural biotechnology generated much more concern in British public life than in either Germany or the United States.
- Embryo research was relatively uncontested in Britain, publicly divisive in the United States, and debated in institutionalized governmental forums in Germany without becoming a salient political issue for a wider public.
- Patenting life forms was seen as an ethical issue in Europe but not in the United States.
- All three nations considered bioethics important, but each understood it very differently.

For Jasanoff, differences in public opinion do not, for the most part, account for these political differences. Rather, differences in political culture and institutions shape when, whether, and how public opinion is mobilized in the political arena and becomes a significant force affecting biotechnology issues. Often, elite deliberations are relatively insulated from public attitudes, and elite politics plays a large role in how the public defines and responds to new scientific issues.

Jasanoff points to differences in how knowledge becomes publicly validated in the three countries, differences that affect "national discourses of risk and safety, naturalness and artificiality, innovation and ownership, constitutional rights, and bioethics" (Jasanoff 2005, pp. 20–1). Differences in public discourse, combined with differences in regulatory approaches, legal institutions, and styles of managing conflict, affect how these countries respond to the new ethical and policy challenges posed by biotechnology. Although countries tend to respond in accordance with long-standing cultural and institutional patterns, Jasanoff observed that countries also alter and adapt these patterns to deal with the novel issues that biotechnology raises.

For each country she studied, Jasanoff identified a dominant cultural and institutional paradigm that characterizes its general approach to issues at the intersection of science and politics:

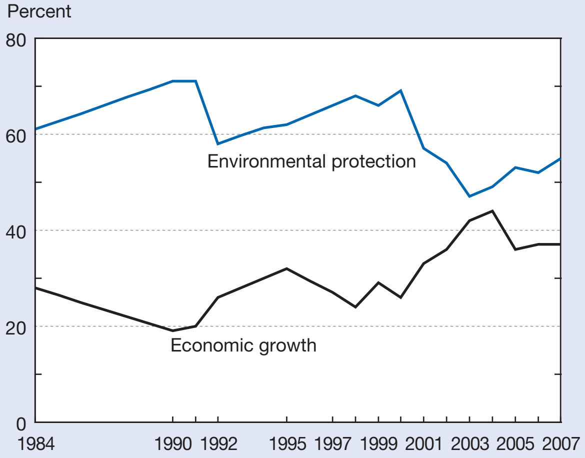
- **United States.** In a predominantly "contentious," adversary process, groups with competing interests vie to define relevant knowledge. Courts loom unusually large as arbiters of disputes, and federal administrators are relatively passive. Public optimism about technology creates an environment that is open to experimentation unless there are demonstrated risks or pre-existing regulatory barriers. New technologies often validate themselves only after they are introduced, by not causing unacceptable harms. Skepticism about expertise makes it difficult to resist demands for quantified measures, formal credentials, and transparent decision processes. Science is viewed as a sphere of objective knowledge separate from "the contaminating touch of politics" (Jasanoff 2005, p. 288).
- **Great Britain.** Biotechnology policy is developed in an atmosphere in which the credibility of state-regulated science has been damaged by the nation's experience with mad cow disease. Public trust in experts imbued with an ethic of public service and a reputation for character and judgment, although damaged, remains a key resource for validating scientific knowledge. Scientific experts associated with the government are trusted to be able to consult with affected parties, gather relevant information, and reach objective decisions that "discern the public's needs" (Jasanoff 2005, p. 268). Transparency is more an option than a requirement.
- **Germany.** Decisionmaking is consensus oriented, with interested parties participating in institutionalized deliberative processes organized by the federal government. Public debate is largely restricted to matters of values, and technical and factual issues are reserved for expert committees whose work is largely removed from public view. Committee members derive their stature from public trust in the institutions they represent. The public assumes that the state can assemble competent expert bodies composed of reasonable individuals who, although they reflect diverse interests and perspectives, can negotiate a shared view of the public interest.

Jasanoff emphasized that these patterns, though resilient, are not rigid, and that actual political processes are more fluid than the central tendencies she described.

global warming rose by 15 points during this period, more than for any of the other issues (Carroll 2006, 2007). Even with this increase, however, global warming still ranked eighth among these issues. At 36%, the percentage of Americans worrying a great deal about this issue was 10 or more points below the comparable figure for "pollution of drinking water" (58%), "pollution of rivers, lakes, and reservoirs" (53%), "contamination of soil and water by toxic waste" (52%), and "maintenance of the nation's fresh water supply for household needs" (51%).

Recent data show other signs that awareness concerning global warming is increasing. After 5 consecutive years

Figure 7-15
Public priorities for environmental protection versus economic growth: 1984–2007



NOTES: 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?* Poll conducted in 1984, 1990–92, 1995, 1997–2006; other years interpolated.

SOURCE: Gallup's Pulse of Democracy: Environment, Gallup Brain, http://brain.gallup.com/content?ci=1615, accessed 24 May 2007.

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without any significant change, 2006 and 2007 Gallup surveys registered a small increase in the percentage of Americans who say they understand the global warming issue very well (Gallup Organization 2007a; Saad 2006b). In addition, the number of Americans who say that the effects of global warming have already begun to occur was higher in 2006 and 2007 than it had been in a decade of surveys (Gallup Organization 2007a; Saad 2006b). The percentage of Americans who believe that most scientists think global warming is occurring has also been rising for over a decade (Nisbet and Myers 2007). However, although most Americans think that global warming is mostly the result of human activities rather than natural changes, public opinion on this question has been stable since 2001 (Gallup Organization 2007a).

Biotechnology and Its Medical Applications

Recent advances in recombinant DNA technology enable the manipulation of genetic material to produce plants and animals with more desirable characteristics. Americans, Canadians, and Europeans have similarly favorable attitudes toward biotechnology in general and medical applications in particular.

In 2005, over two-thirds of Americans said that they either strongly supported (19%) or supported (52%) "the use of products and processes that involve biotechnology." Less than one-fourth expressed opposition. In Canada, support for biotechnology had been lower than in the United States in 2003, but climbed to 67% in 2005, closely resembling the U.S. figure (Canadian Biotechnology Secretariat 2005).[28] Similarly, in 2005 almost two-thirds of Europeans, when asked about either biotechnology or genetic engineering,[29] said that this technology would have a positive effect on their way of life in the next 20 years (European Commission 2005b).

Americans and Canadians also held similar views of biotechnology's potential in the field of medicine. In 2005, more than 8 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).

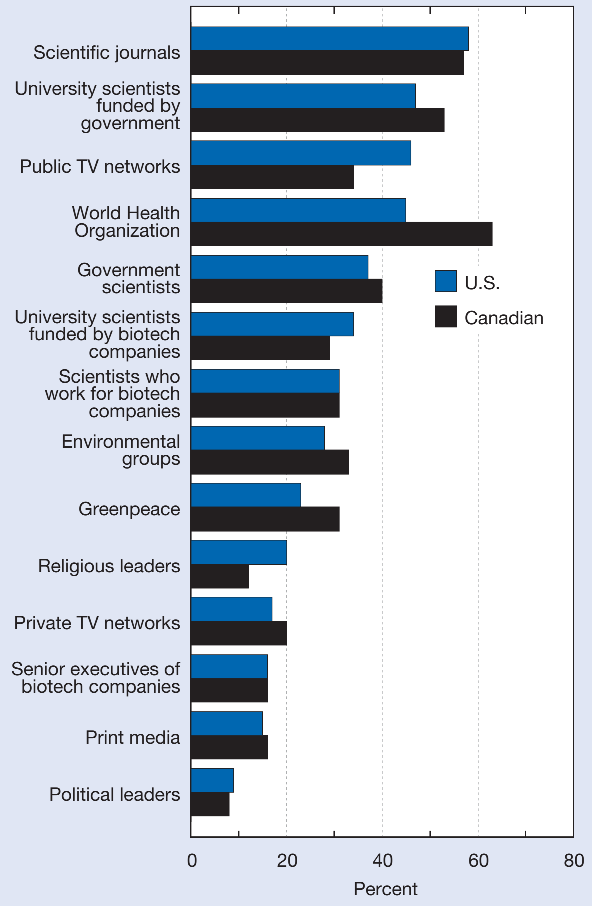
Few Americans (about 1 in 10) consider themselves "very familiar" with biotechnology. Overall, Canadians report even less familiarity, although this difference is small. Without a strong knowledge base to use in evaluating information, their assessment of the credibility of information sources is an important element in forming their judgments about information on this topic. The Canada-U.S. Survey on Biotechnology asked respondents in both countries to rate their trust in various institutions that could provide information about biotechnology. It found similar results for both Canada and the United States. In both countries, scientific journals and government-funded scientists placed at or near the top of the list. Conversely, privately owned mass media, biotechnology company executives, and religious and political leaders ranked near the bottom in both countries (figure 7-16).

Genetically Modified Food

Although the introduction of genetically modified (GM) crops has provoked much less controversy in the United States than in Europe, U.S. popular support for this application of biotechnology is limited and does not explain the difference (see sidebar, "Designs on Nature"). In a series of five surveys conducted between 2001 and 2006, the Pew Initiative on Food and Biotechnology (Mellman Group, Inc. 2006) has consistently found that only about one-fourth of Americans favor "the introduction of genetically modified foods into the U.S. food supply." Although opposition to GM food declined to 46% in the most recent survey, opposition remains much more common than support. The Canada-U.S. Survey on Biotechnology (Canadian Biotechnology Secretariat 2005) reported a similar finding. The proportion of U.S. survey respondents reporting a negative reaction to the phrase "genetically modified food" (44%) was more than twice the 20% that reported a positive reaction. Nonetheless, an analysis of public opinion on GM food concluded that Americans express more favorable views than Europeans, with Canadians falling somewhere in between (Gaskell et al. 2006).

Pew Initiative on Food and Biotechnology data (Mellman Group, Inc. 2006) suggest that misconceptions about GM food are widespread in the United States. Most Americans (60%) believe they have not eaten GM foods, even though processed foods in the United States commonly contain GM ingredients. This number has not shown a clear trend in the 5 years since Pew began asking this question. People who claim to have heard more about GM foods are more likely to say that they have eaten them. Although this survey found

Figure 7-16
U.S. and Canadian views on 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?* Data reflect responses of 4 or 5.

SOURCE: Canadian Biotechnology Secretariat, Canada-U.S. Survey on Biotechnology (2005).

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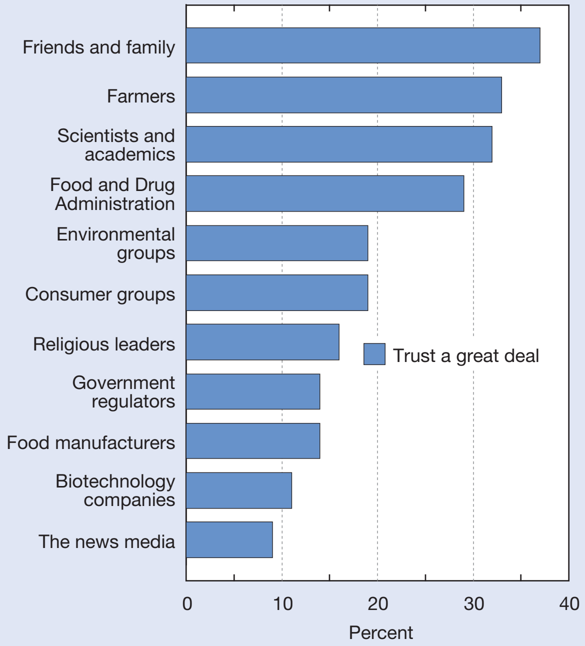
Americans were fairly evenly divided about the safety of GM foods—34% believed they are basically safe, 29% believed they are basically unsafe, and 37% said they had no opinion—opinions change when people have more information. Thus, when Americans are told that GM food is already widely used in commonly purchased groceries, the percentage judging them to be safe rises by about 10 points.[30]

As with biotechnology in general, Americans are apt to rely on trusted sources of information concerning GM food, about which their knowledge is also limited. Among sources listed in both the Pew survey on GM food and the Canadian Biotechnology Secretariat survey on biotechnology, American attitudes are generally consistent: scientists and government rank relatively high and biotechnology companies and the news media rank relatively low. In the Pew survey, more Americans (37%) expressed a great deal of trust in friends and family than in any other group. Although Americans' level of trust in farmers as sources of information on GM food was comparable with that for scientists and academics, others involved in commercial food production, including food manufacturers and biotechnology companies, were near the bottom of the list (figure 7-17).

Surveys have generally found that Americans are even more wary of genetic modification of animals than they are of genetic modification of plants (Mellman Group, Inc. 2005). Stronger ethical and safety concerns appear to play a role in people's concern, and concern is greater among women than among men, although this gender gap has been declining. Many Americans express support for regulatory responses, including labeling foods with GM ingredients, but this support appears to be quite sensitive to the way issues are framed. Thus, whereas 29% of Americans expressed a great deal of confidence in "the Food and Drug Administration or FDA," only about half as many expressed the same confidence when the question was posed about "government regulators." In addition, the proportion that expressed great confidence in the FDA dropped by 12 percentage points between 2001 and 2006 (Mellman Group, Inc. 2006).

Additional findings from earlier U.S. surveys can be found in *Science and Engineering Indicators 2006* (NSB 2006).

Figure 7-17
Trust in information sources about genetically modified foods: 2006



NOTES: Responses to: *Please tell me how much you trust what each group or organization says about genetically modified foods. Do you trust what they have to say about genetically modified foods a great deal, some, not too much, or not at all?* Data reflect responses of "a great deal."

SOURCE: The Mellman Group, memorandum to the Pew Initiative on Food and Biotechnology (16 November 2006) on results of poll conducted for Pew in October 2006.

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Nanotechnology

Nanotechnology involves manipulating matter at unprecedentedly small scales to create new or improved products that can be used in a wide variety of ways. Nanotechnology has been the focus of relatively large public and private investments for almost a decade, and innovations based on nanotechnology are increasingly common. Even relative to other new technologies, nanotechnology is still in an early stage of development.

The general public remains relatively unfamiliar with nanotechnology. Among 2006 GSS respondents, over half (54%) had heard "nothing at all" about it. An additional 25% had heard "just a little," and smaller proportions had heard either "some" (15%) or "a lot" (5%) (appendix table 7-28). These numbers are similar to those that Cobb and Macoubrie (2004) reported in a survey done 2 years earlier. Familiarity with nanotechnology was at about the same level in Europe in 2005, where 44% of survey respondents said they had heard of it (Gaskell et al. 2005).

Even among the minority of GSS respondents who had heard of nanotechnology, knowledge levels do not appear to be high (appendix table 7-7). Over half (57%) correctly responded true when asked whether "nanotechnology involves manipulating extremely small units of matter, such as individual atoms, in order to produce better materials," but many (36%) said they did not know, and a few (7%) thought this statement was false. About half (51%) did not know whether or not "the properties of nanoscale materials often differ fundamentally and unexpectedly from the properties of the same materials at larger scales." For this question, 39% correctly answered true and the remaining 9% answered false.

When nanotechnology is defined in surveys, Americans express favorable expectations for it. After receiving a brief explanation of nanotechnology, GSS respondents were asked about the likely balance between the benefits and harms of nanotechnology. About 40% said the "benefits will outweigh the harmful results," 19% expected the two to be about equal, and only 9% expected the harms to predominate (appendix table 7-29). The fact that about half of respondents either gave a neutral response (19%) or said they didn't know (32%) suggests that opinion may be open to change as Americans become more familiar with this technology. In a 2005 survey that asked Americans and Canadians about risks and benefits in two separate questions, about half of Americans foresaw substantial benefit or some benefit from nanotechnology, compared with 14% who saw substantial risk or some risk; Canadian responses were almost as optimistic (Canadian Biotechnology Secretariat 2005). Eurobarometer data, though not precisely comparable, indicate that European opinion is generally consistent with that of Americans (European Commission 2005b). In the 2005 Eurobarometer, 48% of Europeans expected nanotechnology to have "a positive effect on our way of life in the next 20 years," whereas only 8% expected a negative effect. Although familiarity with nanotechnology is similar in Europe and the United States, more Europeans than Americans said they did not know whether or not this new technology would have a positive effect.

Among Americans, favorable expectations for nanotechnology are associated with more education, greater science knowledge, and greater familiarity with nanotechnology. Men are also somewhat more likely to have favorable expectations than women (appendix table 7-29). Patterns are similar to those for responses concerning S&T generally. Unlike in Canada, where younger people's views of nanotechnology are significantly more positive than the views of older people, Americans of all ages have similar opinions (Canadian Biotechnology Secretariat 2005).

Stem Cell Research and Human Cloning

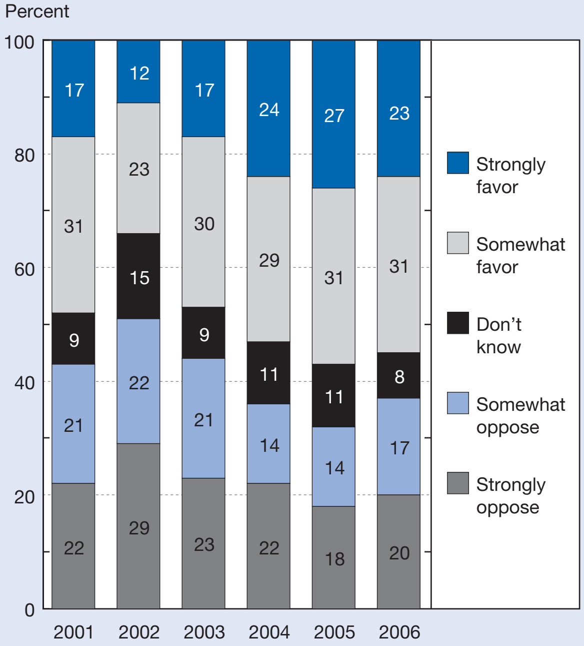
Unlike most issues involving scientific research, studies using embryonic stem cells have generated considerable public controversy. In the case of stem cell research, strongly held views about moral fundamentals determine many people's attitudes. There is little reason to believe that this is the case for certain other S&T issues, such as nanotechnology.

Although a majority of the public supports such research, a significant minority is opposed. When surveys ask about medical technologies to be derived from stem cell research in the context of expected health benefits, public response is relatively positive. But technologies that involve cloning human embryos evoke consistently strong and negative responses.

Since 2004, the majority of the American public has favored "medical research that uses stem cells from human embryos" (VCU Center for Public Policy 2006). Support grew continuously from 2002 (35% in favor) to 2005 (58% in favor), before returning to about the 2004 level in 2006 (figure 7-18). In five annual Gallup surveys between 2002 and 2006, the percentage of Americans who found such research "morally acceptable" in general climbed from 52% to 61%, while the percentage saying it was "morally wrong" in general correspondingly dropped from 39% to 30% (Gallup Organization 2007b). Likewise, a consistent majority in three Pew surveys conducted between December 2004 and July 2006 agreed that it was "more important to continue stem cell research that might produce new medical cures than to avoid destroying the human embryos used in the research"; about one-third of Americans said not destroying embryos was more important (Pew Research Center for the People and the Press 2006b).

In some circumstances, support for medical technologies derived from stem cell research can be even stronger than support for the research itself. When the question is framed as an emotionally compelling personal issue ("If you or a member of your family had a condition such as Parkinson's Disease, or a spinal cord injury, would you support the use of embryonic stem cells in order to pursue a treatment for that condition?"), 70% of Americans support treatments that use stem cells, and only 21% do not (VCU Center for Public Policy 2006). Responses become more mixed when questions mention "cloning technology" and decidedly negative when the technology is characterized as "used to create human embryos" (table 7-14).

Figure 7-18
Public attitudes toward stem cell research: 2001–06



NOTE: Responses to: *On the whole, how much do you favor or oppose medical research that uses stem cells from human embryos?* Question most recently asked 7-21 November 2006.

SOURCE: Virginia Commonwealth University (VCU), VCU Center for Public Policy, Survey and Evaluation Research Laboratory, Opinions Shifting on Stem Cell Research; Opposition to Cloning Continues, VCU Life Sciences Survey (2006), http://www.vcu.edu/lifesci/centers/cen_lse_surveys.html.

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Americans are overwhelmingly opposed to reproductive cloning. In a Research!America survey, the idea of using "cloning technology to produce a child" is rejected by about 4 of 5 people, and VCU Center for Public Policy and other surveys produce very similar results (Center for Genetics and Society 2006; Research!America 2006). In six annual VCU surveys, at least 60% of Americans said they were "strongly opposed" to "cloning or genetically altering" humans (VCU Center for Public Policy 2006).

The specter of reproductive cloning can generate apprehension about therapeutic cloning. Asked how concerned they were that "the use of human cloning technology to create stem cells for human therapeutic purposes will lead to a greater chance of human reproductive cloning," over two-thirds of Americans say they are either very (31%) or somewhat (38%) concerned (VCU Center for Public Policy 2006).

Public attitudes toward stem cell research and cloning are not grounded in a strong grasp of the difference between reproductive and therapeutic cloning, however. Most Americans say they are "not very clear" (35%) or "not clear at all" (35%) about this distinction, with 22% saying they are "somewhat clear" and only 7% characterizing themselves as "very clear" about it. Since VCU began asking this question in 2002, the number of Americans who profess greater comprehension has declined, despite, or perhaps because of, the increased visibility of stem cell research as a public issue.

Support for stem cell research is strongest among people with more years of formal education. Americans who are more religious, more conservative, and older are more likely to oppose such research (Gallup Organization 2007b; Pew Research Center for the People and the Press 2006b; VCU Center for Public Policy 2006).

Table 7-14
Public opinion on medical technologies derived from stem cell research: Most recent year
(Percent)

Question	Favor	Oppose
1. *If you or a member of your family had a condition such as Parkinson's Disease, or a spinal cord injury, would you support the use of embryonic stem cells in order to pursue a treatment for that condition? (yes or no)*	70	21
2. *Therapeutic cloning is the use of cloning technology to help in the search for possible cures and treatments for diseases and disabilities. Do you think that research into therapeutic cloning should be allowed? (yes or no)*	59	35
3. *Do you favor or oppose using human cloning technology IF it is used ONLY to help medical research develop new treatments for disease? (strongly favor, somewhat favor, somewhat oppose, or strongly oppose)*	45	51
4. *Do you favor or oppose using human cloning technology IF it is used to create human embryos that will provide stem cells for human therapeutic purposes? (strongly favor, somewhat favor, somewhat oppose, or strongly oppose)*	35	57

NOTES: Questions 1, 3, and 4 asked 7–21 November 2006. Question 2 asked in 2005. Detail does not add to total because "don't know" responses not shown.

SOURCES: Questions 1, 3, and 4, Virginia Commonwealth University (VCU), Center for Public Policy, Survey and Evaluation Research Laboratory, VCU Life Sciences Survey (2006), http://www.vcu.edu/lifesci/centers/cen_lse_surveys.html; and Question 2, Research!America, America Speaks! Poll Data Summary, vol. 7, p. 20 (March 2006), *PARADE*/Research!America Health Poll (2005), www.researchamerica.org.

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Canadian attitudes toward stem cell research are very similar (Canadian Biotechnology Secretariat 2005). Although European survey questions about stem cell research, medical applications, and cloning are sufficiently different from U.S. and Canadian data to make direct comparisons impossible, overall patterns and levels of support appear similar to those in North America (European Commission 2005b; Gaskell et al. 2006).

S&T Education

In much public discourse about how Americans will fare in an increasingly S&T-driven world, education in science, mathematics, engineering, and technology is seen as crucial preparation for adult life. Perhaps because education is more a local issue than a national one, however, national public opinion data about education in science and related subjects are lacking. A recent national survey of parents with school-age children indicates that most believe that "greatly increasing the number and quality of math and science courses students take in high schools" would do "a lot" or "quite a bit" to improve high school education in America (67%) and that it is "crucial" for most students to "learn higher level math skills like advanced algebra and calculus" (62%) (Public Agenda 2006). Nevertheless, when questions are personalized to their own children, a majority of these parents are satisfied with the amount of science their children are being taught in the schools. The percentage of Americans who believe that "kids are not taught enough math and science" is either a very or somewhat serious problem in their local public schools (32%) is 20 points lower than it was when this question was asked in 1994.

Conclusion

In assessing public knowledge and attitudes concerning S&T, two kinds of standards for judgment are possible. One standard is some conception of what a technologically advanced society requires, either currently or in the future, to be well prepared to compete in the world economy and enable its citizens to live satisfying lives. The other standard involves comparison with the past or with other countries.

By the first standard, individual judgments will inevitably vary, but it is safe to say that most proponents of S&T will find at least some of the data disquieting. They might view as causes for concern the significant minorities of Americans who cannot answer relatively simple knowledge questions about S&T, the proportion of Americans who express basic misconceptions about emerging technologies such as biotechnology and nanotechnology, or the proportion who believe relatively great scientific uncertainty surrounds global climate change. For many, some attitudes might appear problematic, too, such as the sizable parts of the population who express serious reservations about the place of morality in science or the speed of technological change, or who favor coverage of nonscientific material about human origins in public school science classes.

Trend analyses that use past U.S. data as a basis for comparison paint a different picture. Relative to Americans in the recent past, today's Americans score as well on factual knowledge and somewhat better on understanding the process of scientific inquiry, are more skeptical about scientific claims for astrology, and are at least as optimistic about new technology and favorably disposed to increased government investment in science. When Americans compare science with other institutions, science's relative ranking appears to be as or more favorable than in the past. The survey data provide little or no evidence of declining knowledge or increasingly negative attitudes.

When the data are examined using other countries as a benchmark, the United States compares favorably. Compared with adult residents of other developed countries, Americans appear to know as much or more about science, and they express as much or more optimism about technology. The only circumstance in which the United States scores below other countries on science knowledge comparisons is when, as with beliefs about human evolution, many Americans experience a conflict between accepted scientific knowledge and their religious beliefs.

Regardless of the standard used in assessing public knowledge and attitudes, one strong and persistent pattern in the data stands out: more highly educated Americans tend to know more about S&T, express more favorable attitudes about S&T, and make discriminations that are more consistent with those likely to be made by scientists and engineers themselves. Thus, for example, they focus more heavily on process criteria for evaluating whether something is scientific, and their classification of fields as more and less scientific more closely resembles a classification that would be found in a university catalog. Along with their formal schooling, they appear to have acquired perspectives, attitudes, and knowledge akin to those found among the proponents of S&T. Whether or in what sense this association is causal is uncertain: although greater knowledge may affect attitudes and perspectives, pre-existing attitudes and perspectives may affect whether or not people acquire the kinds of knowledge available to them in school. What is clear, across a variety of indicators, is that Americans with relatively more years of education and more science knowledge also have perspectives and attitudes that more closely mirror those articulated by the leaders of the American S&E community.

Notes

1. The patterns in the use of data sources do not necessarily mean that people are getting information from less-detailed sources. Newspapers and the Internet include long articles, and the Internet contains links to additional sources of information. In addition, declining reliance on magazines may result from short-term causes, such as a few S&T magazines going out of business without new ones immediately filling the market niche, rather than from a long-term change in information-seeking patterns.

2. Like most survey data, General Social Survey (GSS) data, used in figure 7-3 and elsewhere in this chapter, are weighted to make them correspond more closely to known parameters in the general population, such as sex and race distributions. In tables and figures that compare different survey years, the data are presented using a weighting formula that can be applied to all years. In tables that present only 2006 survey results, numbers are calculated using a new weighting formula that is designed to produce more accurate figures for that year. As a result, there may be minor discrepancies between the 2006 GSS results that appear in different tables and figures.

3. A survey that called attention to particular sources of information on the Internet, such as Weblogs, might well produce different results.

4. Although health news and science and technology news may appear to be closely related categories, the profile of people who follow each type of news closely is different: 63% of Americans who follow health closely are women, whereas 69% of Americans who follow S&T news closely are men (Pew Research Center for the People and the Press 2006a). Many researchers stress that both interest in and knowledge about S&T are often specific to individually defined domains within this broad category and do not generalize to the category as a whole (see sidebar, "Asset-Based Models of Knowledge").

5. Science, space and technology includes manned and unmanned space flight, astronomy, scientific research, computers, the Internet, and telecommunications media. It excludes forensic science, S&E education, and telecommunications media content. Biotechnology and basic medical research includes stem cells, genetic research, cloning, and agribusiness bioengineering. It excludes clinical research and medical technology. Stories often do not fall neatly into a single category.

6. People can become involved with S&T through many other non-classroom activities. Participating in government policy processes, going to movies that feature S&T, bird watching, and building computers are a few examples. Data on this sort of involvement with S&T are unavailable.

7. It is possible that the substantial difference between Pew and IMLS estimates for "zoos or aquariums" is the result of differences in the categories the two surveys offered to respondents. Both surveys asked about zoos and aquariums, but IMLS also asked about nature centers and children's or youth museums, whereas Pew did not. Pew respondents who visited these kinds of museums may have reasoned that "zoo or aquariums" was the most closely comparable category in the survey and classified their visits accordingly.

8. The NSF surveys asked respondents the number of times in the past year that they have visited an art museum, a natural history museum, a science or technology museum, a zoo or aquarium, or a public library. The Pew survey asks them whether or not they have visited one of the institutions, and includes planetarium in the list. For the S&T-related institutions in the list, the historic NSF numbers are about 4 percentage points higher than the Pew numbers, but the difference may have to do with how the questions were asked. Some research suggests that when surveys ask for the number of times respondents have engaged in an activity, the percentage saying they have engaged in the activity at least once is larger than the percentage who would answer "yes" if asked whether they had engaged in the activity at all, probably because some respondents experience the first type of question as implying that the activity is common or acceptable (Knauper 1998; Sterngold, Warland, and Herrmann 1994). The IMLS survey's institution categories are sufficiently different from the NSF categories to make focused comparisons over time problematic.

9. The IMLS survey only asked about children's museum visits in households where adults had visited a museum in 2006, either in-person or remotely via the Internet. Because IMLS assumed that children in other households did not visit museums, there is reason to believe that the actual percentages are somewhat higher than the IMLS estimates.

10. One possible explanation for differences between Europe and the United States in attendance at informal science institutions is that adult leisure patterns reflect patterns that developed in childhood, when, especially for older Europeans, informal science institutions were less readily available than in the United States. The available national data do not permit a test of this explanation.

11. Survey items that test factual knowledge sometimes use readily comprehensible language even at the cost of some scientific imprecision. This may prompt some highly knowledgeable respondents to feel that the items blur or neglect important distinctions, and in a few cases may lead respondents to answer questions incorrectly. In addition, the items do not reflect the ways that even established scientific knowledge evolves as scientists accumulate new evidence. Although the text of the factual knowledge questions may suggest a fixed body of knowledge, it is more accurate to see scientists as making continual, often subtle, modifications in how they understand existing data in light of new evidence.

12. Early NSF surveys used additional factual knowledge indicators, which were combined to form an aggregate indicator. Bann and Schwerin (2004) performed statistical analyses on this and other groups of indicators to produce shorter scales that involved fewer questions and required less time to administer, but were functionally equivalent to the scales that used additional items (e.g., had similar measurement properties and yielded performance patterns that correlated with similar demographic characteristics). For factual knowledge, Bann and Schwerin produced two alternative scales that, except for one item, used identical questions. One of these scales was administered in 2004, and the other was substituted in 2006. Appendix table 7-4 presents trend data using each scale. To enable aggregated comparisons of 2004 and 2006 results, it includes the average numbers of correct answers to the group of overlapping items from those 2 years.

13. The two nanotechnology questions were asked only of respondents who said they had some familiarity with nanotechnology, and a sizable majority of the respondents who ventured a substantive answer (i.e., not "don't know") answered the questions correctly. To measure nanotechnology knowledge more reliably, researchers would prefer a scale with more than two questions.

14. Even small, apparently nonsubstantive differences in question wording can affect survey responses. U.S. surveys, for example, have asked respondents whether or not it is true that "it is the father's gene that decides whether the baby is a boy or a girl." In contrast, the 2005 Eurobarometer asked whether or not it is true that "it is the mother's genes that decide whether the baby is a boy or a girl." To a scientifically knowledgeable respondent, these questions are equivalent. To other respondents, however, they may not be. Research has shown that some survey respondents have an "acquiescence bias"—when given the opportunity to do so, they tend to provide positive responses to questions and are therefore more likely to answer true than false (Schaeffer and Presser 2003). Thus, the U.S. question is probably easier to answer correctly than the Eurobarometer question; in other words, in two equally knowledgeable populations, more people would get the U.S. question right. Although Americans score better on this topic than Europeans, it is possible that this has as much or more to do with acquiescence bias as it does with scientific knowledge.

15. In its own international comparison of scientific literacy, Japan ranked itself 10th among the 14 countries it evaluated (National Institute of Science and Technology Policy 2002).

16. Early NSF surveys used additional questions to measure understanding of probability. Through a process similar to that described in endnote 12, Bann and Schwerin (2004) identified a smaller number of questions that could be administered to develop a comparable indicator. These questions were administered in 2004 and 2006, and appendix tables 7-9 and 7-10 record combined probability responses using these questions; appendix table 7-9 also shows responses to individual probability questions in each year.

17. Methodological issues make fine-grained comparisons of data from different survey years suspect. Although the question content and interviewer instructions were identical in 2004 and 2006, for example, the percentage of respondents who volunteered "about equal" was substantially different. This difference may have been produced by the change from telephone interviews in 2004 to in-person interviews in 2006 (though telephone interviews in 2001 produced results that are similar to those in 2006). More likely, customary interviewing practices in the three different organizations that administered the surveys affected their interviewers' willingness to accept responses other than those that were specifically offered on the interview form, including "don't know" responses.

18. The English version of the European question reads, "The benefits of science are greater than any harmful effects it may have." Respondents can strongly agree, tend to agree, neither agree nor disagree, tend to disagree, strongly disagree, or say that they do not know. The U.S. question is prefaced by the statement that "People have frequently noted that scientific research has produced benefits and harmful results" and asks the respondent, "Would you say that, on balance, the benefits of scientific research have outweighed the harmful results, or have the harmful results of scientific research been greater than the benefits." Respondents who say that the benefits are greater are then asked whether "the balance has been strongly in favor of the benefits, or only slightly." Respondents who say the harmful results are greater are asked a parallel question to distinguish strongly from slightly. Some respondents are recorded as saying that the benefits and harmful results are "about equal" when they volunteer this response.

Although these questions differ in their references to "science" and "scientific research," "effects" and "results," and in the exact wording of the response categories, they are similar in their overall thrust and in the availability of a middle category ("neither agree nor disagree," "about equal"). For other questions that are worded similarly in the 2005 Eurobarometer and either the 2004 or 2006 NSF surveys, the presence of a middle category in Europe and the absence of one in the United States makes direct comparison problematic. This lengthy, though incomplete, comparison regarding a single question pair should provide some indication of why international attitude comparisons should be treated with caution.

19. Unlike the U.S. question, the European question joins two logically independent ideas—more spending on science and less spending on other priorities. In addition, because nations begin from different levels of spending, survey responses cannot be read as indicating different views about the proper level of spending in this area, nor do they indicate the strength of sentiment in different countries. Differences in the connotations of questions posed in different languages add further complexities. Perhaps for some or all of these reasons, variations among European countries in responses to this question are large, with about two-thirds of respondents agreeing in Italy, Spain, and France, but less than one-third in Finland and the Netherlands.

20. Some Americans may think that science can resolve differences over what to value or settle policy questions without requiring value judgments. This view accords science a kind of influence that goes beyond what the scientific community thinks it can properly exercise. There are no survey data that indicate how many Americans accord science too much influence in this regard.

21. Although these questions treat economists as scientists and compare them to other categories of scientists, data reported later in this chapter indicate that many Americans do not consider economics to be very scientific. To understand public perceptions of the role of science and scientists in dealing with contested public issues, it helps to have indicators both for disciplines that the public almost universally

sees as scientific and for disciplines whose scientific status is less secure in the public's eyes. Many social scientists (e.g., Gieryn 1999) believe that much can be learned from research on how institutional boundaries are defined and maintained. Universities overwhelmingly categorize economics as a social science.

22. These question batteries were designed as indicators of public views regarding the appropriate influence of science on public issues generally. Questions were posed concerning specific issues both because (1) this is likely to increase the degree to which respondents think of similar situations when they make judgments and (2) because views about the appropriate role of science are likely to depend heavily on context. A study of any one of the specific issues would likely make somewhat different distinctions and ask more and different questions about the topic.

Three other issues are worthy of mention: (1) Because survey respondents are variably familiar with the issues posed in these questions, certain categories are characterized with significant imprecision. For example, "medical researchers" is not an optimal characterization of the kind of researchers who are experts on the health effects of genetically modified foods. (2) Judgments that affect trust in leaders may be difficult to capture in survey questions. A concept such as disinterestedness, for example, (in the sense of a judgment made and expressed in light of appropriate collective interests and independent of personal interests that are not supposed to be given any weight) likely cannot be stated in language that can be used in a survey. (3) Comparable data on other issues is lacking, which makes generalizing observed patterns to other issues hazardous. Just as it is uncertain how attitudes that are highly general shape concrete judgments, it is uncertain how more specific judgments generalize beyond the terms in which they are posed. Because different attitude indicators have different limitations, it can be valuable to have indicators with complementary strengths and flaws. In all cases, it is worth keeping the actual question wording in mind when interpreting the significance of patterns in the data.

23. The questions were worded as follows:

- "How much influence should each of the following groups have in deciding what to do about global warming? a. Environmental scientists. Would you say a great deal of influence, a fair amount, a little influence, or none at all?" This wording was then repeated in the next two questions, except that "elected officials" and "business leaders" were substituted for environmental scientists.
- "How much influence should each of the following groups have in deciding about government funding for stem cell research? a. Medical researchers. Would you say a great deal of influence, a fair amount, a little influence, or none at all?" This wording was then repeated in the next two questions, except that "religious leaders" and "elected officials" were substituted for medical researchers.
- "How much influence should each of the following groups have in deciding whether to reduce federal income taxes? a. Economists. Would you say a great deal of influence, a fair amount, a little influence, or none at all?" This wording was then repeated in the next two questions, except that "business leaders" and "elected officials" were substituted for economists.
- "Some say that the government should restrict the sale of genetically modified foods. Others say there is no need for such restrictions. How much influence should each of the following groups have in deciding whether to restrict the sale of genetically modified foods? a. Medical researchers. Would you say a great deal of influence, a fair amount, a little influence, or none at all?" This wording was then repeated in the next two questions, except that "elected officials" and "business leaders" were substituted for medical researchers.

24. The questions were worded as follows: "On a scale of 1 to 5, where 1 means "very well" and 5 means "not at all," how well do the following groups understand" each of four public issues: "the causes of global warming," "stem cell research," "the likely effects of reducing federal taxes," and "the risks posed by genetically modified foods." For global warming, respondents were asked about environmental scientists, elected officials, and business leaders. For stem cell research, respondents were asked about medical researchers, religious leaders, and elected officials. For federal taxes, respondents were asked about economists, business leaders, and elected officials. For genetically modified foods, respondents were asked about medical researchers, elected officials, and business leaders.

25. The questions were worded as follows: "When making policy recommendations about" each of four public issues "on a scale of 1 to 5, to what extent do you think the following groups would support what is best for the country as a whole versus what serves their own narrow interests?" The issues were "global warming," "stem cell research," "federal income taxes," and "genetically modified foods." If asked about what narrow interests meant, interviewers were instructed to respond "Well, someone might gain financially if a certain policy were adopted or it might advance his or her career."

26. Three of the four questions were worded as follows: "On a scale of 1 to 5, where 1 means "near complete agreement" and 5 means "no agreement at all," to what extent do" groups of scientists "agree on" an issue. The groups and issues were "environmental scientists/the existence and causes of global warming," "medical researchers/the importance of stem cells for research," "economists/the effects of reducing federal income taxes" and "medical researchers/the risks and benefits of genetically modified foods." The global warming question read "agree among themselves about" instead of "agree on."

27. Among the considerations that might be considered relevant are the role of ordinary citizens whose interests are specially affected by a decision and the institutional context for a decision (e.g., public versus private, different branches or levels of government). There is an extensive literature, analyz-

ing mostly qualitative and nonnational data, that explores the complexities in when and why the public treats scientists and others as having the authority to influence or make decisions. Although attempts to synthesize that literature and clarify its relationship to what can be learned from national surveys would be welcome, this kind of multivariate analysis and interpretation goes well beyond the scope of this document.

28. A 2006 Canadian survey showed little or no change from 2005 (Decima Research 2006).

29. Although experts generally consider these two terms to be synonymous, survey results for "biotechnology" are generally more favorable than for "genetic engineering" (Gaskell et al. 2006).

30. Food safety concerns are not the only reason that people oppose use of genetically modified foods. Other concerns include the environmental effects of genetically modified crops and the power that large corporations that manufacture genetically modified seed gain over the food supply.

Glossary

Biotechnology: The use of living things to make products.

EU-25: Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, United Kingdom.

Genetically modified food: A food product containing some quantity of any genetically modified organism as an ingredient.

Nanotechnology: Manipulating matter at unprecedentedly small scales to create new or improved products that can be used in a wide variety of ways.

Therapeutic cloning: Refers to the use of cloning technology in medical research to develop new treatments for diseases; differentiated from human reproductive cloning.

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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 chapter devoted to the subject was introduced in the 2004 edition of *Science and Engineering Indicators.* The chapter focuses on the S&T indicators for individual states and the District of Columbia. It has been expanded in the 2008 edition from the original 24 state indicators to 47.

The reader is cautioned that all of the indicators are broad measures, and several rely on sample estimates that have a margin of error that may be substantial for some states; this is called out in appropriate places. In any case, small differences in state values generally carry no useful information.

The 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-seven 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. Additional information on gender and racial/ethnic performance has been added in appendix tables 8-1 through 8-12 for those indicators reporting mathematics and science results for fourth and eighth graders. 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.

Comparable state-level performance data are not available for high school students. Instead, mastery of college-level material through performance on Advanced Placement Exams has been included as a measure of the skills being developed by the top-performing high school students. Other indicators in education focus on state spending, teacher salaries, student costs, and undergraduate and graduate degrees in S&E. Three new indicators have been added to measure the level of education in the population of individual states.

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 Experimental Program to Stimulate Competitive Research (EPSCoR program) is a federal program aimed at building R&D capacity in states that have historically been less competitive in receiving federal R&D funding. Because this program does not cover all states and is basically focused on academic institutions, it is covered in chapter 5, Academic Research and Development, in the sidebar, "EPSCoR—the Experimental Program to Stimulate Competitive Research."

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 Bureau of Labor Statistics and is based on the percentage of employment in technology-oriented occupations. See "Technical Note: Defining High-Technology Industries."

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.

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 were available. This helps the reader quickly grasp geographic patterns. 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. Differences in states at the margins of adjacent quartiles will often not be substantively meaningful.

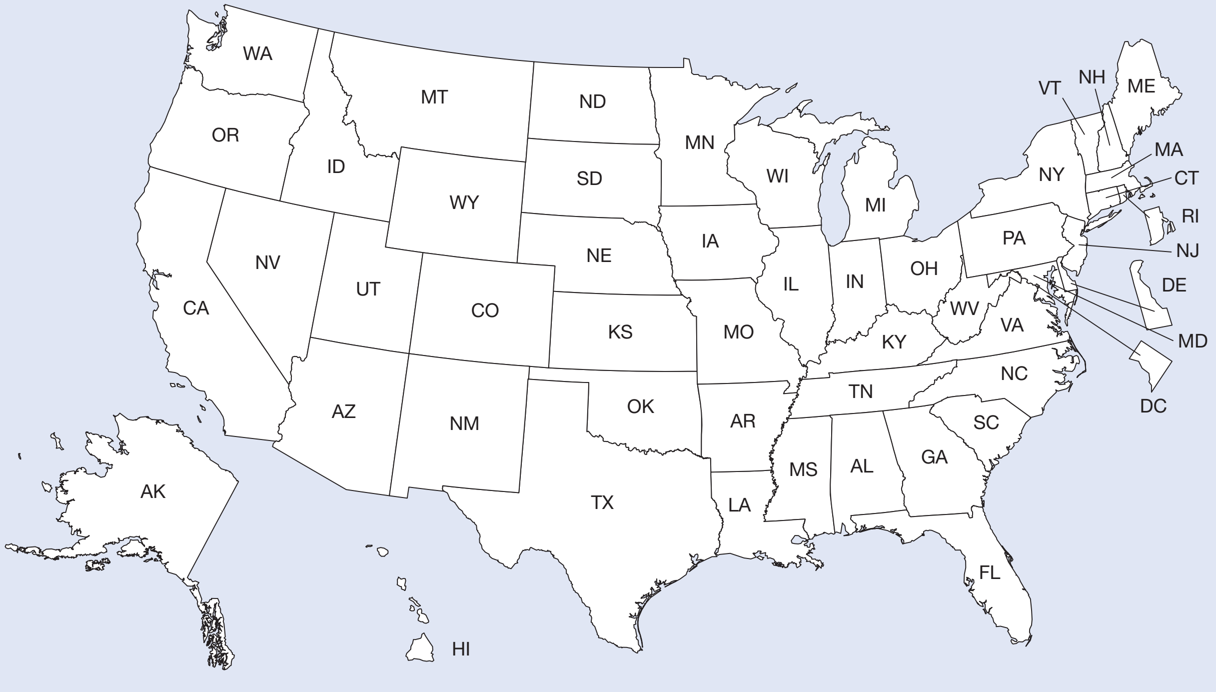
The third element, at the bottom of the map box, is a short citation for the data source. The full citation appears under the table on the facing page.

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.

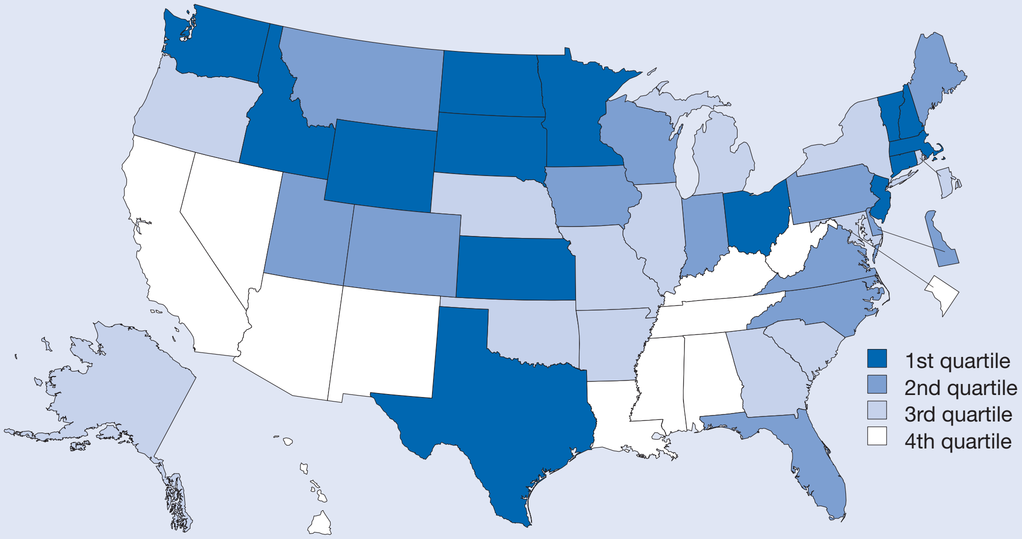
U.S. Map and List of Abbreviations



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: 2005



1st quartile (247–242)	2nd quartile (241–239)	3rd quartile (238–233)	4th quartile (232–211)
Connecticut	Colorado	Alaska	Alabama
Idaho	Delaware	Arkansas	Arizona
Kansas	Florida	Georgia	California
Massachusetts	Indiana	Illinois	District of Columbia
Minnesota	Iowa	Maryland	Hawaii
New Hampshire	Maine	Michigan	Kentucky
New Jersey	Montana	Missouri	Louisiana
North Dakota	North Carolina	Nebraska	Mississippi
Ohio	Pennsylvania	New York	Nevada
South Dakota	Utah	Oklahoma	New Mexico
Texas	Virginia	Oregon	Tennessee
Vermont	Wisconsin	Rhode Island	West Virginia
Washington		South Carolina	
Wyoming			

SOURCE: National Center for Education Statistics, National Assessment of Educational Progress (various years). See table 8-1.

Findings

- In 2005, the nationwide average mathematics score of fourth grade public school students was 237, a significant increase from 224 in 2000.
- For the 41 jurisdictions that participated in both the 2000 and 2005 mathematics assessments, the average score for public school fourth graders showed a statistically significant increase between 2000 and 2005. Only the District of Columbia reported a 2005 average score below the 2000 national average of 224.
- The entire fourth grade student sample, including students performing at the 10th, 25th, 50th, 75th, and 90th percentiles, demonstrated statistically significant gains in mathematics scores between 2000 and 2005.
- The gaps in mathematics scores between white fourth graders and black or Hispanic fourth graders narrowed between 2000 and 2005. The fourth grade gender gap in mathematics scores, although much smaller, decreased slightly between 2000 and 2005.

This indicator reports each state's average score on the National Assessment of Educational Progress (NAEP) in mathematics for its fourth grade students in public schools. High scores indicate that fourth graders are demonstrating a solid foundation for adult mathematics competency. The NAEP mathematics assessment is a federally authorized assessment of student performance in which all 50 states and the District of Columbia participated in 2005. Student performance is described in terms of average scores on a scale from 0 to 500.

Several recent changes to the NAEP methodology affect yearly comparisons. Beginning in 2002, NAEP obtained a national sample by aggregating the samples from each state rather than by selecting it independently; the increased national sample size makes smaller differences statistically significant. In 2005, NAEP included in the definition of the national sample all international Department of Defense schools.

NAEP allows students with disabilities or limited English proficiency to use certain accommodations (e.g., extended time, individual testing, or small group testing). All data presented here represent scores from tests taken with accommodations offered.

Table 8-1
Fourth grade mathematics performance, by state: 2000, 2003, and 2005
(Score)

State	2000	2003	2005
United States	224	234	237
Alabama	217	223	225
Alaska	NA	233	236
Arizona	219	229	230
Arkansas	216	229	236
California	213	227	230
Colorado	NA	235	239
Connecticut	234	241	242
Delaware	NA	236	240
District of Columbia	192	205	211
Florida	NA	234	239
Georgia	219	230	234
Hawaii	216	227	230
Idaho	224	235	242
Illinois	223	233	233
Indiana	233	238	240
Iowa	231	238	240
Kansas	232	242	246
Kentucky	219	229	231
Louisiana	218	226	230
Maine	230	238	241
Maryland	222	233	238
Massachusetts	233	242	247
Michigan	229	236	238
Minnesota	234	242	246
Mississippi	211	223	227
Missouri	228	235	235
Montana	228	236	241
Nebraska	225	236	238
Nevada	220	228	230
New Hampshire	NA	243	246
New Jersey	NA	239	244
New Mexico	213	223	224
New York	225	236	238
North Carolina	230	242	241
North Dakota	230	238	243
Ohio	230	238	242
Oklahoma	224	229	234
Oregon	224	236	238
Pennsylvania	NA	236	241
Rhode Island	224	230	233
South Carolina	220	236	238
South Dakota	NA	237	242
Tennessee	220	228	232
Texas	231	237	242
Utah	227	235	239
Vermont	232	242	244
Virginia	230	239	240
Washington	NA	238	242
West Virginia	223	231	231
Wisconsin	NA	237	241
Wyoming	229	241	243
Puerto Rico	NA	NA	NA

NA = not available

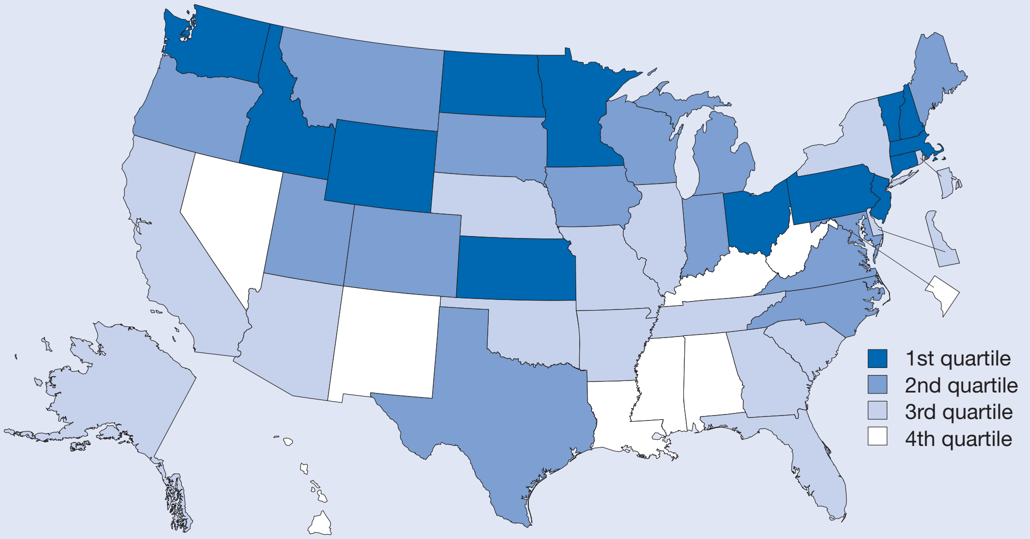
NOTES: National average for United States is reported value in National Assessment of Educational Progress (NAEP) reports. NAEP grade 4 mathematics scores for public schools only.

SOURCE: National Center for Education Statistics, NAEP (various years).

Science & Engineering Indicators 2008

Fourth Grade Mathematics Proficiency

Figure 8-2
Fourth grade mathematics proficiency: 2005



1st quartile (49%–41%)	2nd quartile (40%–37%)	3rd quartile (36%–28%)	4th quartile (27%–9%)
Connecticut	Colorado	Alaska	Alabama
Idaho	Indiana	Arizona	District of Columbia
Kansas	Iowa	Arkansas	Hawaii
Massachusetts	Maine	California	Kentucky
Minnesota	Maryland	Delaware	Louisiana
New Hampshire	Michigan	Florida	Mississippi
New Jersey	Montana	Georgia	Nevada
North Dakota	North Carolina	Illinois	New Mexico
Ohio	Oregon	Missouri	West Virginia
Pennsylvania	South Dakota	Nebraska	
Vermont	Texas	New York	
Washington	Utah	Oklahoma	
Wyoming	Virginia	Rhode Island	
	Wisconsin	South Carolina	
		Tennessee	

SOURCE: National Center for Education Statistics, National Assessment of Educational Progress (various years). See table 8-2.

Findings

- In 2005 nationwide, 35% of fourth grade public school students performed at or above the proficient level in mathematics, which represents a significant increase from 22% in 2000.
- Of the 41 jurisdictions that participated in both the 2000 and 2005 assessments, all showed increases in mathematics proficiency levels for public school fourth graders in 2005. In 2005, only 3 states and the District of Columbia had mathematics proficiency percentages below the 2000 national average of 22% compared with 20 jurisdictions below 22% in 2000.
- Substantial differences in mathematics proficiency exist between racial/ethnic groups of fourth graders. The gaps increased between 2000 and 2005 as blacks and Hispanics failed to match the gains made in mathematics proficiency by whites. The gender gap in proficiency among fourth graders is much smaller and remained unchanged between 2000 and 2005.

This indicator is the proportion of a state's fourth grade students in public schools that have achieved proficiency in mathematics. High indicator values show that a high percentage of a state's fourth graders has demonstrated a solid foundation for adult mathematics competency. Proficiency is based on achievement levels in the National Assessment of Educational Progress (NAEP) that reflect performance standards set by the National Assessment Governing Board to provide a context for interpreting student performance on NAEP. Approximately 172,000 fourth grade students in 8,700 schools participated in the 2005 NAEP mathematics assessment.

For the fourth grade, the basic level (scores of 214–248) denotes partial mastery of knowledge and skills that are prerequisite for proficient work. The proficient level (249–281) represents solid academic performance and demonstrates competency over challenging subject matter knowledge, its application to real-world situations, and mastery of appropriate analytical skills. The advanced level (282–500) signifies superior performance.

Table 8-2

Fourth grade mathematics proficiency, by state: 2000, 2003, and 2005

(Percent)

State	2000	2003	2005
United States	22	31	35
Alabama	13	19	21
Alaska	NA	30	34
Arizona	16	25	28
Arkansas	14	26	34
California	13	25	28
Colorado	NA	34	39
Connecticut	31	41	43
Delaware	NA	31	36
District of Columbia	5	7	9
Florida	NA	31	36
Georgia	17	27	30
Hawaii	14	23	27
Idaho	20	31	41
Illinois	20	32	32
Indiana	30	35	38
Iowa	26	36	37
Kansas	29	41	47
Kentucky	17	22	27
Louisiana	14	21	24
Maine	23	34	39
Maryland	21	31	38
Massachusetts	31	41	49
Michigan	28	34	37
Minnesota	33	42	47
Mississippi	9	17	19
Missouri	23	30	31
Montana	24	31	39
Nebraska	24	34	36
Nevada	16	23	26
New Hampshire	NA	43	47
New Jersey	NA	39	46
New Mexico	12	17	19
New York	21	33	36
North Carolina	25	41	40
North Dakota	25	34	41
Ohio	25	36	43
Oklahoma	16	23	28
Oregon	23	33	37
Pennsylvania	NA	36	41
Rhode Island	22	28	31
South Carolina	18	32	36
South Dakota	NA	34	40
Tennessee	18	24	28
Texas	25	33	40
Utah	23	31	37
Vermont	29	42	43
Virginia	24	36	40
Washington	NA	36	42
West Virginia	17	24	26
Wisconsin	NA	35	40
Wyoming	25	39	42
Puerto Rico	NA	NA	NA

NA = not available

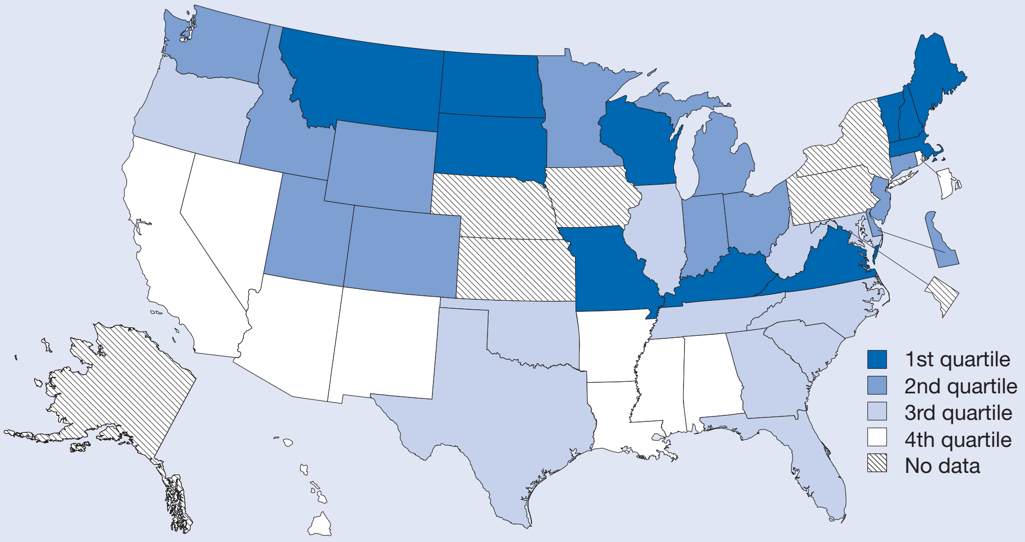
NOTES: National average for United States is reported value in National Assessment of Educational Progress (NAEP) reports. NAEP grade 4 mathematics scores for public schools only.

SOURCE: National Center for Education Statistics, NAEP (various years).

Science & Engineering Indicators 2008

Fourth Grade Science Performance

Figure 8-3
Fourth grade science performance: 2005



1st quartile (161–158)	2nd quartile (157–152)	3rd quartile (151–148)	4th quartile (147–133)	No data
Kentucky	Colorado	Florida	Alabama	Alaska
Maine	Connecticut	Georgia	Arizona	District of Columbia
Massachusetts	Delaware	Illinois	Arkansas	Iowa
Missouri	Idaho	Maryland	California	Kansas
Montana	Indiana	North Carolina	Hawaii	Nebraska
New Hampshire	Michigan	Oklahoma	Louisiana	New York
North Dakota	Minnesota	Oregon	Mississippi	Pennsylvania
South Dakota	New Jersey	South Carolina	Nevada	
Vermont	Ohio	Tennessee	New Mexico	
Virginia	Utah	Texas	Rhode Island	
Wisconsin	Washington	West Virginia		
	Wyoming			

SOURCE: National Center for Education Statistics, National Assessment of Educational Progress (various years). See table 8-3.

Findings

- In 2005, the nationwide average science score of fourth grade public school students was 149, an increase from 145 in 2000.
- Of the 36 states that participated in both the 2000 and 2005 science assessments, 20 reported numerical increases in average scores of their public school fourth graders, but only 9 of these increases were statistically significant. Likewise, although 11 states reported lower scores in 2005, none of these declines was statistically significant, resulting in no states with lower average scores in 2005 than in 2000.
- Students performing at the 10th, 25th, and 50th percentiles demonstrated gains in science scores between 2000 and 2005, whereas students performing at the 75th and 90th percentiles showed no statistically significant change in average score.
- The gaps in science scores between white fourth graders and black or Hispanic fourth graders narrowed significantly between 2000 and 2005. The fourth grade gender gap in science scores, although much smaller, remained unchanged between 2000 and 2005.

This indicator reports each state's average score on the National Assessment of Educational Progress (NAEP) in science for its fourth grade students in public schools. High scores indicate that fourth graders are demonstrating a solid foundation for adult science competency. The NAEP science assessment is a federally authorized assessment of student performance in which 44 states participated in 2005. Student performance is described in terms of average scores on a scale from 0 to 300.

Several recent changes to the NAEP methodology affect yearly comparisons. Beginning in 2002, NAEP obtained the national sample by aggregating the samples from each state rather than by selecting it independently; the increased national sample size makes smaller differences statistically significant. In 2005, NAEP included in the definition of the national sample all international Department of Defense schools.

NAEP allows students with disabilities or limited English proficiency to use certain accommodations (e.g., extended time, individual testing, or small group testing). All data presented here represent scores from tests taken with accommodations offered.

Table 8-3

Fourth grade science performance, by state: 2000 and 2005

(Score)

State	2000	2005
United States	145	149
Alabama	143	142
Alaska	NA	NA
Arizona	140	139
Arkansas	145	147
California	129	137
Colorado	NA	155
Connecticut	156	155
Delaware	NA	152
District of Columbia	NA	NA
Florida	NA	150
Georgia	142	148
Hawaii	136	142
Idaho	152	155
Illinois	150	148
Indiana	154	152
Iowa	159	NA
Kansas	NA	NA
Kentucky	152	158
Louisiana	139	143
Maine	161	160
Maryland	145	149
Massachusetts	161	160
Michigan	152	152
Minnesota	157	156
Mississippi	133	133
Missouri	157	158
Montana	160	160
Nebraska	150	NA
Nevada	142	140
New Hampshire	NA	161
New Jersey	NA	154
New Mexico	140	141
New York	148	NA
North Carolina	147	149
North Dakota	160	160
Ohio	155	157
Oklahoma	151	150
Oregon	148	151
Pennsylvania	NA	NA
Rhode Island	148	146
South Carolina	140	148
South Dakota	NA	158
Tennessee	145	150
Texas	145	150
Utah	154	155
Vermont	160	160
Virginia	155	161
Washington	NA	153
West Virginia	149	151
Wisconsin	NA	158
Wyoming	156	157
Puerto Rico	NA	NA

NA = not available

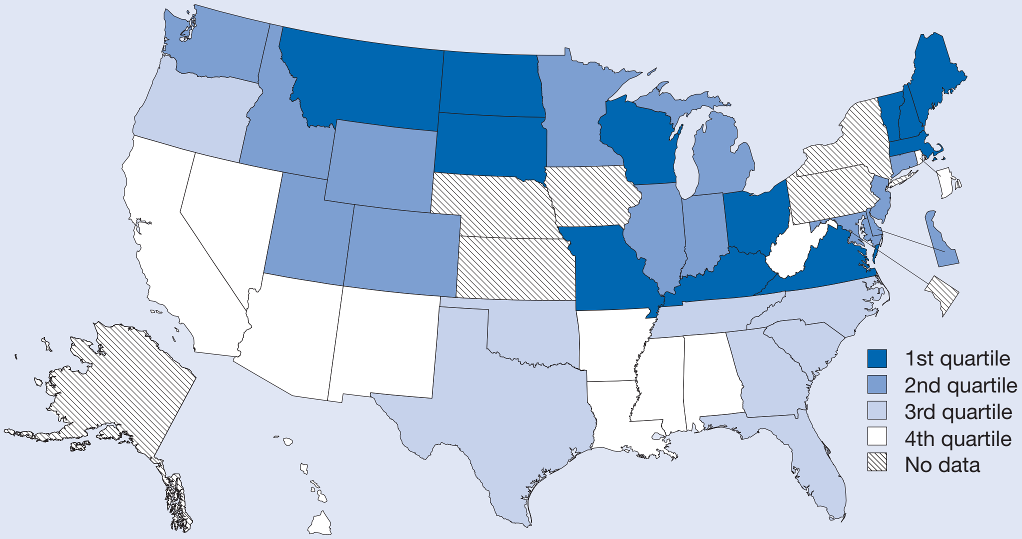
NOTES: National average for United States is reported value in National Assessment of Educational Progress (NAEP) reports. NAEP grade 4 science scores for public schools only. In 2000, California, Georgia, Hawaii, Kentucky, Maryland, South Carolina, Tennessee, Texas, and Virginia significantly different from 2005 when only one jurisdiction or the nation is examined. In 2005, Alaska, District of Columbia, Iowa, Kansas, Nebraska, New York, and Pennsylvania did not participate.

SOURCE: National Center for Education Statistics, NAEP (various years).

Science & Engineering Indicators 2008

Fourth Grade Science Proficiency

Figure 8-4
Fourth grade science proficiency: 2005



1st quartile (40%–35%)	2nd quartile (33%–27%)	3rd quartile (26%–25%)	4th quartile (24%–12%)	No data
Kentucky	Colorado	Florida	Alabama	Alaska
Maine	Connecticut	Georgia	Arizona	District of Columbia
Massachusetts	Delaware	North Carolina	Arkansas	Iowa
Missouri	Idaho	Oklahoma	California	Kansas
Montana	Illinois	Oregon	Hawaii	Nebraska
New Hampshire	Indiana	South Carolina	Louisiana	New York
North Dakota	Maryland	Tennessee	Mississippi	Pennsylvania
Ohio	Michigan	Texas	Nevada	
South Dakota	Minnesota		New Mexico	
Vermont	New Jersey		Rhode Island	
Virginia	Utah		West Virginia	
Wisconsin	Washington			
	Wyoming			

SOURCE: National Center for Education Statistics, National Assessment of Educational Progress (various years). See table 8-4.

Findings

- In 2005 nationwide, 27% of fourth grade public school students performed at or above the proficient level in science, which showed little change from 26% in 2000.
- Of the 36 states that participated in both the 2000 and 2005 science assessments, 18 states showed numerical increases in science proficiency for public school fourth graders in 2005, although only 4 of these increases were statistically significant. Likewise, although 13 states showed numerical decreases in 2005, none of these declines was statistically significant.
- Among fourth graders in public schools in 2005, proficiency in mathematics was more widespread than in science, a reversal of the 2000 results.
- Substantial differences in science proficiency exist between racial/ethnic groups of fourth graders, but these narrowed between 2000 and 2005. The gender gap is much smaller and remained unchanged between 2000 and 2005.

This indicator is the proportion of a state's fourth grade students in public schools that have achieved proficiency in science. High indicator values show that a high percentage of a state's fourth graders has demonstrated a solid foundation for adult science competency. Proficiency is based on achievement levels in the National Assessment of Educational Progress (NAEP) that reflect performance standards set by the National Assessment Governing Board to provide a context for interpreting student performance on NAEP. 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. Approximately 147,700 fourth grade students in 8,500 schools participated in the 2005 NAEP science assessment.

For the fourth grade, the basic level (scores of 138–169) denotes partial mastery of knowledge and skills that are prerequisite for proficient work. The proficient level (170–204) represents solid academic performance and demonstrates competency over challenging subject matter knowledge, its application to real-world situations, and mastery of appropriate analytical skills. The advanced level (205–300) signifies superior performance.

Table 8-4
Fourth grade science proficiency, by state: 2000 and 2005
(Percent)

State	2000	2005
United States	26	27
Alabama	22	21
Alaska	NA	NA
Arizona	22	18
Arkansas	23	24
California	13	17
Colorado	NA	32
Connecticut	35	33
Delaware	NA	27
District of Columbia	NA	NA
Florida	NA	26
Georgia	23	25
Hawaii	16	19
Idaho	29	29
Illinois	31	27
Indiana	32	27
Iowa	36	NA
Kansas	NA	NA
Kentucky	28	36
Louisiana	18	20
Maine	37	36
Maryland	24	27
Massachusetts	42	38
Michigan	32	30
Minnesota	34	33
Mississippi	13	12
Missouri	34	36
Montana	36	37
Nebraska	26	NA
Nevada	19	17
New Hampshire	NA	37
New Jersey	NA	32
New Mexico	17	18
New York	24	NA
North Carolina	23	25
North Dakota	36	36
Ohio	31	35
Oklahoma	26	25
Oregon	27	26
Pennsylvania	NA	NA
Rhode Island	25	23
South Carolina	20	25
South Dakota	NA	35
Tennessee	24	26
Texas	23	25
Utah	31	33
Vermont	38	38
Virginia	32	40
Washington	NA	28
West Virginia	24	24
Wisconsin	NA	35
Wyoming	31	32
Puerto Rico	NA	NA

NA = not available

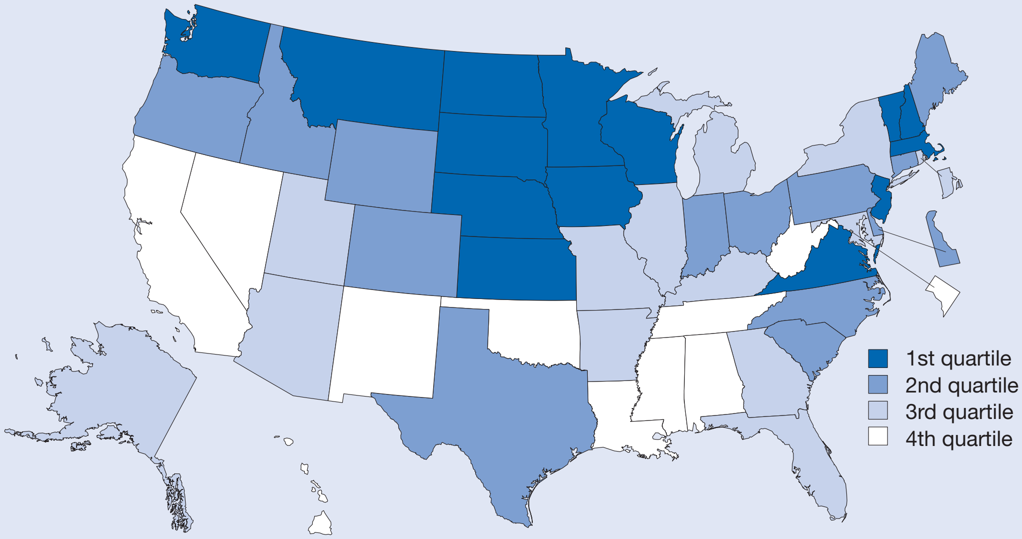
NOTE: National average for United States is reported value in National Assessment of Educational Progress (NAEP) reports. NAEP grade 4 science scores for public schools only. In 2000, California, Georgia, Hawaii, Kentucky, Maryland, South Carolina, Tennessee, Texas, and Virginia significantly different from 2005 when only one jurisdiction or the nation is examined. In 2005, Alaska, District of Columbia, Iowa, Kansas, Nebraska, New York, and Pennsylvania did not participate.

SOURCE: National Center for Education Statistics, NAEP (various years).

Science & Engineering Indicators 2008

Eighth Grade Mathematics Performance

Figure 8-5
Eighth grade mathematics performance: 2005



1st quartile (292–284)	2nd quartile (283–281)	3rd quartile (280–272)	4th quartile (271–245)
Iowa	Colorado	Alaska	Alabama
Kansas	Connecticut	Arizona	California
Massachusetts	Delaware	Arkansas	District of Columbia
Minnesota	Idaho	Florida	Hawaii
Montana	Indiana	Georgia	Louisiana
Nebraska	Maine	Illinois	Mississippi
New Hampshire	North Carolina	Kentucky	Nevada
New Jersey	Ohio	Maryland	New Mexico
North Dakota	Oregon	Michigan	Oklahoma
South Dakota	Pennsylvania	Missouri	Tennessee
Vermont	South Carolina	New York	West Virginia
Virginia	Texas	Rhode Island	
Washington	Wyoming	Utah	
Wisconsin			

SOURCE: National Center for Education Statistics, National Assessment of Educational Progress (various years). See table 8-5.

Findings

- In 2005, the nationwide average mathematics score of eighth grade public school students was 278, an increase from 272 in 2000.
- Of the 41 jurisdictions that participated in both the 2000 and 2005 mathematics assessments, 37 reported increases in the average score for public school eighth graders, but only 28 of these increases were statistically significant. A single state reported a decline in test scores between 2000 and 2005 for public school eighth graders, but this decline was not statistically significant, meaning that no state showed a statistically significant decline in test scores during this period.
- The entire eighth grade student sample, including students performing at the 10th, 25th, 50th, 75th, and 90th percentiles, demonstrated statistically significant gains in mathematics scores between 2000 and 2005.
- The gaps in mathematics scores between white eighth graders and black or Hispanic eighth graders narrowed significantly between 2000 and 2005. The eighth grade gender gap in mathematics scores, although much smaller, remained unchanged between 2000 and 2005.

This indicator reports each state's average score on the National Assessment of Educational Progress (NAEP) in mathematics for its eighth grade students in public schools. High scores indicate that eighth graders are demonstrating a solid foundation for adult mathematics competency. The NAEP mathematics assessment is a federally authorized assessment of student performance in which all 50 states and the District of Columbia participated in 2005. Student performance is described in terms of average scores on a scale from 0 to 500.

Several recent changes to the NAEP methodology affect yearly comparisons. Beginning in 2002, NAEP obtained the national sample by aggregating the samples from each state rather than by selecting it independently; the increased national sample size makes smaller differences statistically significant. In 2005, NAEP included in the definition of the national sample all international Department of Defense schools.

NAEP allows students with disabilities or limited English proficiency to use certain accommodations (e.g., extended time, individual testing, or small group testing). All data presented here represent scores from tests taken with accommodations offered.

Table 8-5

Eighth grade mathematics performance, by state: 2000, 2003, and 2005

(Score)

State	2000	2003	2005
United States	272	276	278
Alabama	264	262	262
Alaska	NA	279	279
Arizona	269	271	274
Arkansas	257	266	272
California	260	267	269
Colorado	NA	283	281
Connecticut	281	284	281
Delaware	NA	277	281
District of Columbia	235	243	245
Florida	NA	271	274
Georgia	265	270	272
Hawaii	262	266	266
Idaho	277	280	281
Illinois	275	277	278
Indiana	281	281	282
Iowa	NA	284	284
Kansas	283	284	284
Kentucky	270	274	274
Louisiana	259	266	268
Maine	281	282	281
Maryland	272	278	278
Massachusetts	279	287	292
Michigan	277	276	277
Minnesota	287	291	290
Mississippi	254	261	262
Missouri	271	279	276
Montana	285	286	286
Nebraska	280	282	284
Nevada	265	268	270
New Hampshire	NA	286	285
New Jersey	NA	281	284
New Mexico	259	263	263
New York	271	280	280
North Carolina	276	281	282
North Dakota	282	287	287
Ohio	281	282	283
Oklahoma	270	272	271
Oregon	280	281	282
Pennsylvania	NA	279	281
Rhode Island	269	272	272
South Carolina	265	277	281
South Dakota	NA	285	287
Tennessee	262	268	271
Texas	273	277	281
Utah	274	281	279
Vermont	281	286	287
Virginia	275	282	284
Washington	NA	281	285
West Virginia	266	271	269
Wisconsin	NA	284	285
Wyoming	276	284	282
Puerto Rico	NA	NA	NA

NA = not available

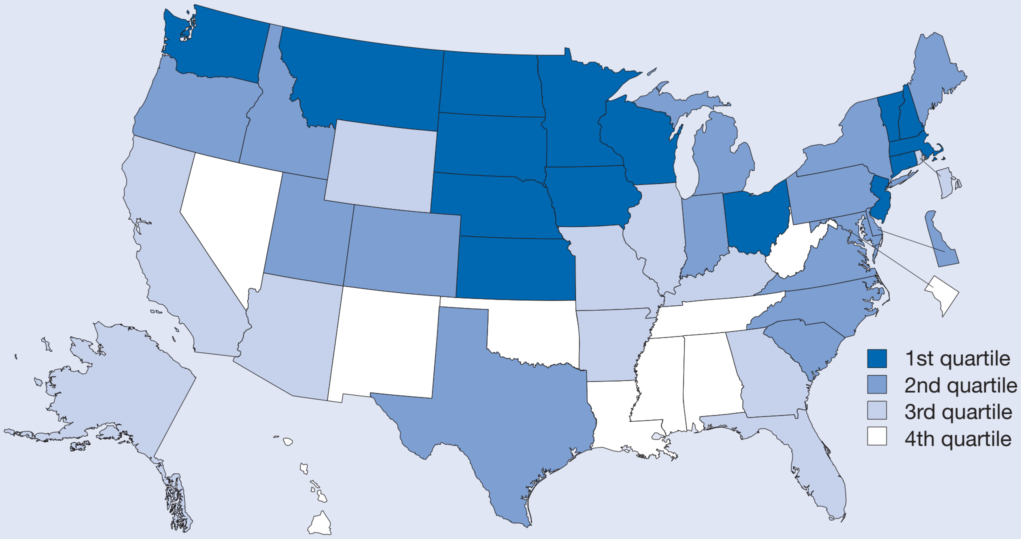
NOTES: National average for United States is reported value in National Assessment of Educational Progress (NAEP) reports. NAEP grade 8 mathematics scores for public schools only.

SOURCE: National Center for Education Statistics, NAEP (various years).

Science & Engineering Indicators 2008

Eighth Grade Mathematics Proficiency

Figure 8-6
Eighth grade mathematics proficiency: 2005



1st quartile (43%–34%)	2nd quartile (33%–30%)	3rd quartile (29%–22%)	4th quartile (21%–7%)
Connecticut	Colorado	Alaska	Alabama
Iowa	Delaware	Arizona	District of Columbia
Kansas	Idaho	Arkansas	Hawaii
Massachusetts	Indiana	California	Louisiana
Minnesota	Maine	Florida	Mississippi
Montana	Maryland	Georgia	Nevada
Nebraska	Michigan	Illinois	New Mexico
New Hampshire	New York	Kentucky	Oklahoma
New Jersey	North Carolina	Missouri	Tennessee
North Dakota	Oregon	Rhode Island	West Virginia
Ohio	Pennsylvania	Wyoming	
South Dakota	South Carolina		
Vermont	Texas		
Washington	Utah		
Wisconsin	Virginia		

SOURCE: National Center for Education Statistics, National Assessment of Educational Progress (various years). See table 8-6.

Findings

- In 2005 nationwide, 29% of eighth grade public school students performed at or above the proficient level in mathematics, which represents a significant increase from 25% in 2000.
- Of the 39 states that participated in both the 2000 and 2005 assessments, 35 showed increases in mathematics proficiency among public school eighth graders in 2005. In 2005, 14 states and the District of Columbia had mathematics proficiency percentages below the 2000 national average of 25% compared with 21 jurisdictions in 2000.
- In 2005, all states showed higher proficiency in mathematics among fourth grade public school students than among eighth grade public school students.
- Substantial differences in mathematics proficiency exist between racial/ethnic groups of eighth graders, but these remained unchanged between 2000 and 2005. The gender gap in proficiency among eighth graders is much smaller and also remained unchanged between 2000 and 2005.

This indicator is the proportion of a state's eighth grade students in public schools that have achieved proficiency in mathematics. High indicator values show that a high percentage of a state's eighth graders has demonstrated a solid foundation for adult mathematics competency. Proficiency is based on achievement levels in the National Assessment of Educational Progress (NAEP) that reflect performance standards set by the National Assessment Governing Board to provide a context for interpreting student performance on NAEP. Approximately 161,600 eighth graders in 6,500 schools participated in the 2005 NAEP mathematics assessment.

For the eighth grade, the basic level (scores of 262–298) denotes partial mastery of knowledge and skills that are prerequisite for proficient work. The proficient level (299–332) represents solid academic performance and demonstrates competency over challenging subject matter knowledge, its application to real-world situations, and mastery of appropriate analytical skills. The advanced level (333–500) signifies superior performance.

Table 8-6

Eighth grade mathematics proficiency, by state: 2000, 2003, and 2005

(Percent)

State	2000	2003	2005
United States	25	27	29
Alabama	16	16	15
Alaska	NA	30	29
Arizona	20	21	26
Arkansas	13	19	22
California	17	22	22
Colorado	NA	34	32
Connecticut	33	35	35
Delaware	NA	26	30
District of Columbia	6	6	7
Florida	NA	23	26
Georgia	19	22	23
Hawaii	16	17	18
Idaho	26	28	30
Illinois	26	29	28
Indiana	29	31	30
Iowa	NA	33	34
Kansas	34	34	34
Kentucky	20	24	22
Louisiana	11	17	16
Maine	30	29	30
Maryland	27	30	30
Massachusetts	30	38	43
Michigan	28	28	30
Minnesota	39	44	43
Mississippi	9	12	13
Missouri	21	28	26
Montana	36	35	36
Nebraska	30	32	35
Nevada	18	20	21
New Hampshire	NA	35	35
New Jersey	NA	33	36
New Mexico	12	15	14
New York	24	32	31
North Carolina	27	32	32
North Dakota	30	36	35
Ohio	30	30	34
Oklahoma	18	20	20
Oregon	31	32	33
Pennsylvania	NA	30	31
Rhode Island	22	24	23
South Carolina	17	26	30
South Dakota	NA	35	36
Tennessee	16	21	21
Texas	24	25	31
Utah	25	31	30
Vermont	31	35	38
Virginia	25	31	33
Washington	NA	32	36
West Virginia	17	20	17
Wisconsin	NA	35	36
Wyoming	23	32	29
Puerto Rico	NA	NA	NA

NA = not available

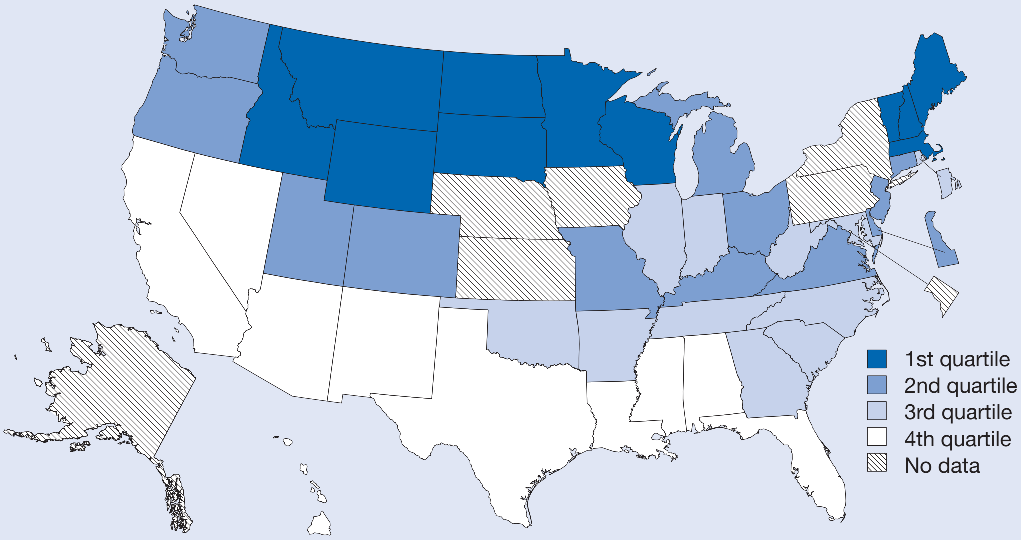
NOTES: National average for United States is reported value in National Assessment of Educational Progress (NAEP) reports. NAEP grade 8 mathematics scores for public schools only.

SOURCE: National Center for Education Statistics, NAEP (various years).

Science & Engineering Indicators 2008

Eighth Grade Science Performance

Figure 8-7
Eighth grade science performance: 2005



1st quartile (163–158)	2nd quartile (155–152)	3rd quartile (150–144)	4th quartile (143–132)	No data
Idaho	Colorado	Arkansas	Alabama	Alaska
Maine	Connecticut	Georgia	Arizona	District of Columbia
Massachusetts	Delaware	Illinois	California	Iowa
Minnesota	Kentucky	Indiana	Florida	Kansas
Montana	Michigan	Maryland	Hawaii	Nebraska
New Hampshire	Missouri	North Carolina	Louisiana	New York
North Dakota	New Jersey	Oklahoma	Mississippi	Pennsylvania
South Dakota	Ohio	Rhode Island	Nevada	
Vermont	Oregon	South Carolina	New Mexico	
Wisconsin	Utah	Tennessee	Texas	
Wyoming	Virginia	West Virginia		
	Washington			

SOURCE: National Center for Education Statistics, National Assessment of Educational Progress (various years). See table 8-7.

Findings

- In 2005, the nationwide average science score of eighth grade public school students was 147, a decrease from 148 in 2000.
- Of the 36 states that participated in both the 2000 and 2005 science assessments, 13 reported higher average scores for public school eighth graders in 2005, and 10 of these increases were statistically significant. Lower average scores were reported by 16 states in 2005, 4 of which were statistically significant.
- The gaps in science scores between white eighth graders and black or Hispanic eighth graders did not increase between 2000 and 2005.

This indicator reports each state's average score on the National Assessment of Educational Progress (NAEP) in science for its eighth grade students in public schools. High scores indicate that eighth graders are demonstrating a solid foundation for adult science competency. The NAEP science assessment is a federally authorized assessment of student performance in which 44 states participated in 2005. Student performance is described in terms of average scores on a scale from 0 to 300.

Several recent changes to the NAEP methodology affect yearly comparisons. Beginning in 2002, NAEP obtained a national sample by aggregating the samples from each state rather than by selecting it independently; the increased national sample size makes smaller differences statistically significant. In 2005, NAEP included in the definition of the national sample all international Department of Defense schools.

NAEP allows students with disabilities or limited English proficiency to use certain accommodations (e.g., extended time, individual testing, or small group testing). All data presented here represent scores from tests taken with accommodations offered.

Table 8-7

Eighth grade science performance, by state: 2000 and 2005

(Score)

State	2000	2005
United States	148	147
Alabama	143	138
Alaska	NA	NA
Arizona	145	140
Arkansas	142	144
California	129	136
Colorado	NA	155
Connecticut	153	152
Delaware	NA	152
District of Columbia	NA	NA
Florida	NA	141
Georgia	142	144
Hawaii	130	136
Idaho	158	158
Illinois	148	148
Indiana	154	150
Iowa	NA	NA
Kansas	NA	NA
Kentucky	150	153
Louisiana	134	138
Maine	158	158
Maryland	146	145
Massachusetts	158	161
Michigan	155	155
Minnesota	159	158
Mississippi	134	132
Missouri	154	154
Montana	164	162
Nebraska	158	NA
Nevada	141	138
New Hampshire	NA	162
New Jersey	NA	153
New Mexico	139	138
New York	145	NA
North Carolina	145	144
North Dakota	159	163
Ohio	159	155
Oklahoma	149	147
Oregon	154	153
Pennsylvania	NA	NA
Rhode Island	148	146
South Carolina	140	145
South Dakota	NA	161
Tennessee	145	145
Texas	143	143
Utah	154	154
Vermont	159	162
Virginia	151	155
Washington	NA	154
West Virginia	146	147
Wisconsin	NA	158
Wyoming	156	159
Puerto Rico	NA	NA

NA = not available

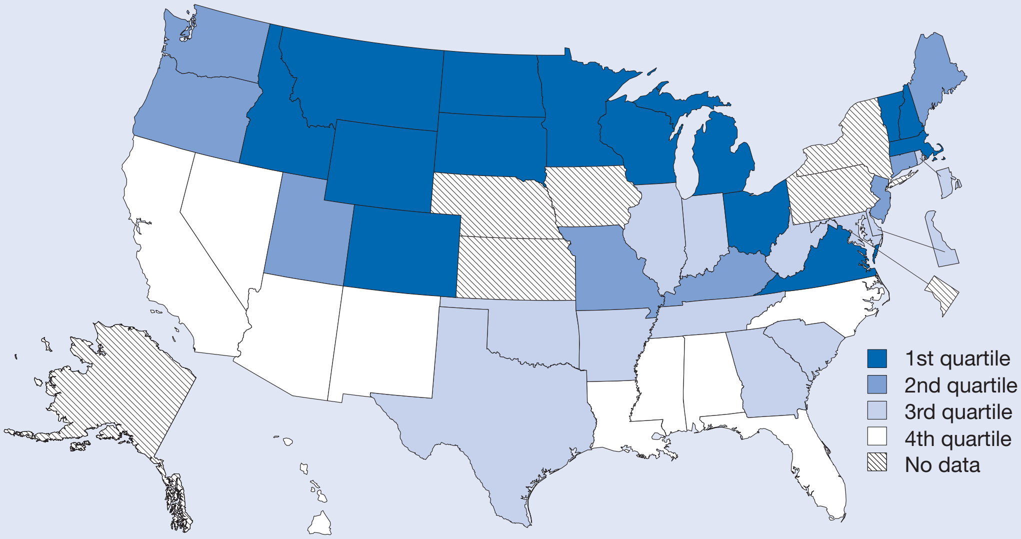
NOTES: National average for United States is reported value in National Assessment of Educational Progress (NAEP) reports. NAEP grade 8 science scores for public schools only. In 2000, Alaska, Colorado, Delaware, District of Columbia, Florida, Iowa, Kansas, New Hampshire, New Jersey, Pennsylvania, South Dakota, Washington, and Wisconsin did not participate or did not meet reporting standards. In 2000, Alabama, Arizona, California, Hawaii, Indiana, Kentucky, Louisiana, Massachusetts, Nevada, North Dakota, South Carolina, Vermont, Virginia, and Wyoming significantly different from 2005 when only one jurisdiction or the nation is examined. In 2005, Alaska, District of Columbia, Iowa, Kansas, Nebraska, New York, and Pennsylvania did not participate.

SOURCE: National Center for Education Statistics, NAEP (various years).

Science & Engineering Indicators 2008

Eighth Grade Science Proficiency

Figure 8-8
Eighth grade science proficiency: 2005



1st quartile (43%–35%)	2nd quartile (34%–31%)	3rd quartile (29%–23%)	4th quartile (22%–14%)	No data
Colorado	Connecticut	Arkansas	Alabama	Alaska
Idaho	Kentucky	Delaware	Arizona	District of Columbia
Massachusetts	Maine	Georgia	California	Iowa
Michigan	Missouri	Illinois	Florida	Kansas
Minnesota	New Jersey	Indiana	Hawaii	Nebraska
Montana	Oregon	Maryland	Louisiana	New York
New Hampshire	Utah	Oklahoma	Mississippi	Pennsylvania
North Dakota	Washington	Rhode Island	Nevada	
Ohio		South Carolina	New Mexico	
South Dakota		Tennessee	North Carolina	
Vermont		Texas		
Virginia		West Virginia		
Wisconsin				
Wyoming				

SOURCE: National Center for Education Statistics, National Assessment of Educational Progress (various years). See table 8-8.

Findings

- In 2005 nationwide, 27% of eighth grade public school students performed at or above the proficient level in science, a decline from 29% in 2000.
- Of the 36 states that participated in both the 2000 and 2005 science assessments, 13 showed increases in science proficiency for public school eighth graders in 2005, 4 of which were statistically significant. Nineteen states showed numerical declines in science proficiency among public school eighth graders in 2005, although none of the declines was statistically significant.
- Among eighth graders in public schools in 2005, proficiency in mathematics was more widespread than proficiency in science, a reversal of the 2000 results.
- The nationwide percentage of students who performed at or above the proficient level in science was identical for fourth and eighth graders in 2005.

This indicator is the proportion of a state's eighth grade students in public schools that have achieved proficiency in science. High indicator values show that a high percentage of a state's eighth graders has demonstrated a solid foundation for adult science competency. Proficiency is based on achievement levels in the National Assessment of Educational Progress (NAEP) that reflect performance standards set by the National Assessment Governing Board to provide a context for interpreting student performance on NAEP. 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. Approximately 143,400 eighth grade students in 6,400 schools participated in the 2005 NAEP science assessment.

For the eighth grade, the basic level (scores of 143–169) denotes partial mastery of knowledge and skills that are prerequisite for proficient work. The proficient level (170–207) represents solid academic performance and demonstrates competency over challenging subject matter knowledge, its application to real-world situations, and mastery of appropriate analytical skills. The advanced level (208–300) signifies superior performance.

Table 8-8

Eighth grade science proficiency, by state: 2000 and 2005

(Percent)

State	2000	2005
United States	29	27
Alabama	23	19
Alaska	NA	NA
Arizona	23	20
Arkansas	22	23
California	14	18
Colorado	NA	35
Connecticut	35	33
Delaware	NA	29
District of Columbia	NA	NA
Florida	NA	21
Georgia	23	25
Hawaii	14	15
Idaho	37	36
Illinois	29	27
Indiana	33	29
Iowa	NA	NA
Kansas	NA	NA
Kentucky	28	31
Louisiana	18	19
Maine	35	34
Maryland	27	26
Massachusetts	39	41
Michigan	35	35
Minnesota	41	39
Mississippi	15	14
Missouri	33	33
Montana	44	42
Nebraska	38	NA
Nevada	22	19
New Hampshire	NA	41
New Jersey	NA	33
New Mexico	20	18
New York	28	NA
North Carolina	25	22
North Dakota	38	43
Ohio	39	35
Oklahoma	25	25
Oregon	34	32
Pennsylvania	NA	NA
Rhode Island	27	26
South Carolina	20	23
South Dakota	NA	41
Tennessee	24	25
Texas	23	23
Utah	34	33
Vermont	39	41
Virginia	29	35
Washington	NA	33
West Virginia	24	23
Wisconsin	NA	39
Wyoming	34	37
Puerto Rico	NA	NA

NA = not available

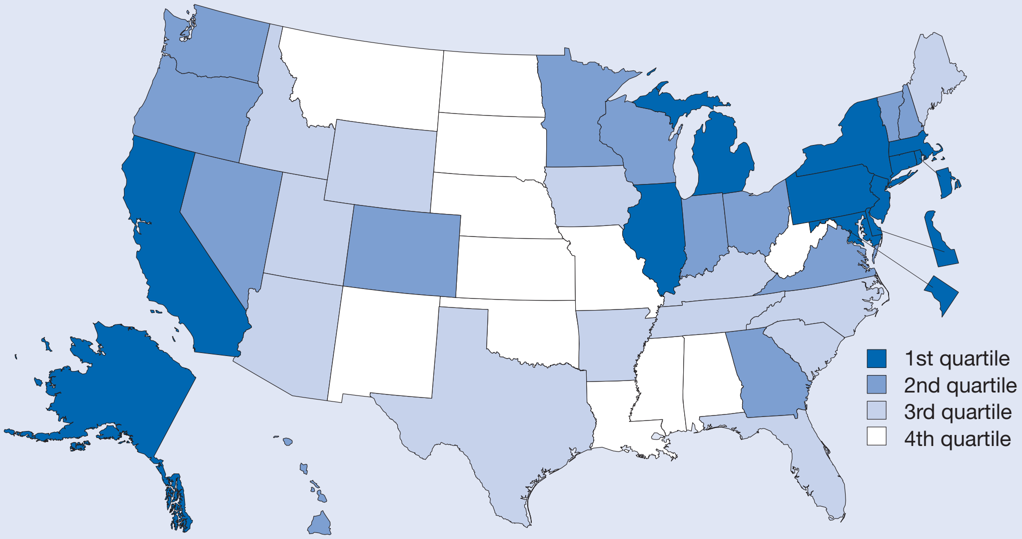
NOTES: National average for United States is reported value in National Assessment of Educational Progress (NAEP) reports. NAEP grade 8 science scores for public schools only. In 2000, Alaska, Colorado, Delaware, District of Columbia, Florida, Iowa, Kansas, New Hampshire, New Jersey, Pennsylvania, South Dakota, Washington, and Wisconsin did not participate or did not meet reporting standards. In 2000, Alabama, Arizona, California, Hawaii, Indiana, Kentucky, Louisiana, Massachusetts, Nevada, North Dakota, South Carolina, Vermont, Virginia, and Wyoming significantly different from 2005 when only one jurisdiction or the nation is examined. In 2005, Alaska, District of Columbia, Iowa, Kansas, Nebraska, New York, and Pennsylvania did not participate.

SOURCE: National Center for Education Statistics, NAEP (various years).

Science & Engineering Indicators 2008

Public School Teacher Salaries

Figure 8-9
Public school teacher salaries: 2005



1st quartile ($58,688–$50,869)	2nd quartile ($50,790–$43,394)	3rd quartile ($43,313–$39,965)	4th quartile ($39,456–$34,040)
Alaska	Colorado	Arizona	Alabama
California	Georgia	Arkansas	Kansas
Connecticut	Hawaii	Florida	Louisiana
Delaware	Indiana	Idaho	Mississippi
District of Columbia	Minnesota	Iowa	Missouri
Illinois	Nevada	Kentucky	Montana
Maryland	New Hampshire	Maine	Nebraska
Massachusetts	Ohio	North Carolina	New Mexico
Michigan	Oregon	South Carolina	North Dakota
New Jersey	Vermont	Tennessee	Oklahoma
New York	Virginia	Texas	South Dakota
Pennsylvania	Washington	Utah	West Virginia
Rhode Island	Wisconsin	Wyoming	

SOURCE: National Center for Education Statistics, *Digest of Education Statistics* (various years). See table 8-9.

Findings

- During the 2004–05 academic year, salaries for public school teachers nationwide averaged $47,750, ranging from a state high of $58,688 to a low of $34,040.
- Over the past decade, average teacher salaries across the nation rose by 30% in terms of current dollars. Average teacher salaries remained essentially flat when expressed in constant dollars based on the Consumer Price Index.
- California and Illinois moved into the upper ranks of teacher salaries with increases of more than 40% between 1995 and 2005.
- High salaries for public school teachers do not necessarily correspond to high student achievement scores on the NAEP mathematics and science tests.

This indicator measures the income public school teachers receive for their work. The average salary represents the average base salary of all full-time public school teachers. Figures are given in current dollars. The year is the latter date of the academic year. The average includes both recent college graduates and seasoned veterans. Their educational credentials may encompass provisional certification through bachelor's, master's, or doctoral degrees.

Public school teacher salaries may reflect a range of factors, including the value placed on primary and secondary education, a state's cost of living, the experience and educational attainment of the teachers, and the local supply and demand in the job market. Relatively low teacher salaries may hinder recruitment into the teaching profession.

Table 8-9

Public school teacher salaries, by state: 1995, 2000, and 2005

(Dollars)

State	1995	2000	2005
United States	36,685	41,807	47,750
Alabama	31,144	36,689	38,863
Alaska	47,951	46,462	52,424
Arizona	32,574	36,902	42,905
Arkansas	28,934	33,386	40,495
California	41,078	47,680	57,876
Colorado	34,571	38,163	44,161
Connecticut	50,045	51,780	58,688
Delaware	39,076	44,435	50,869
District of Columbia	43,700	47,076	58,456
Florida	32,588	36,722	41,081
Georgia	32,291	41,023	46,526
Hawaii	38,518	40,578	44,273
Idaho	29,783	35,547	42,122
Illinois	39,431	46,486	55,629
Indiana	36,785	41,850	46,851
Iowa	31,511	35,678	40,347
Kansas	34,652	34,981	39,190
Kentucky	32,257	36,380	41,002
Louisiana	26,461	33,109	38,880
Maine	31,972	35,561	40,940
Maryland	40,661	44,048	52,331
Massachusetts	40,718	46,580	54,596
Michigan	41,895	49,044	55,693
Minnesota	35,948	39,802	46,906
Mississippi	26,818	31,857	36,590
Missouri	31,189	35,656	38,971
Montana	28,785	32,121	38,485
Nebraska	30,922	33,237	39,456
Nevada	34,836	39,390	43,394
New Hampshire	34,720	37,734	43,941
New Jersey	47,038	52,015	56,600
New Mexico	28,493	32,554	39,328
New York	47,612	51,020	56,200
North Carolina	30,793	39,404	43,313
North Dakota	26,327	29,863	36,449
Ohio	36,802	41,436	48,692
Oklahoma	28,172	31,298	37,141
Oregon	38,555	42,336	50,790
Pennsylvania	44,510	48,321	52,700
Rhode Island	40,729	47,041	53,473
South Carolina	30,279	36,081	42,207
South Dakota	25,994	29,071	34,040
Tennessee	32,477	36,328	41,527
Texas	31,223	37,567	41,009
Utah	29,082	34,946	39,965
Vermont	35,406	37,758	44,535
Virginia	33,987	38,744	44,763
Washington	36,151	41,043	45,712
West Virginia	31,944	35,009	38,360
Wisconsin	37,746	41,153	43,466
Wyoming	31,285	34,127	40,392
Puerto Rico	NA	NA	NA

NA = not available

NOTES: National average for United States is reported value in *Digest of Education Statistics*. Average salaries reported in current dollars.

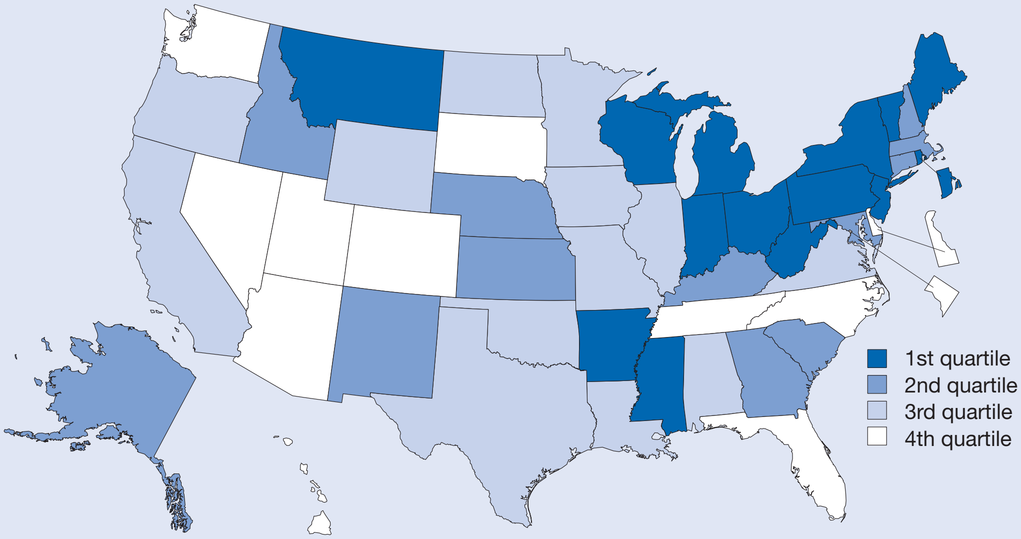
SOURCE: National Center for Education Statistics, *Digest of Education Statistics* (various years).

Science & Engineering Indicators 2008

Elementary and Secondary Public School Current Expenditures as Share of Gross Domestic Product

Figure 8-10

Elementary and secondary public school current expenditures as share of gross domestic product: 2005



1st quartile (5.11%–3.85%)	2nd quartile (3.79%–3.47%)	3rd quartile (3.42%–3.05%)	4th quartile (3.04%–1.24%)
Arkansas	Alaska	Alabama	Arizona
Indiana	Connecticut	California	Colorado
Maine	Georgia	Illinois	Delaware
Michigan	Idaho	Iowa	District of Columbia
Mississippi	Kansas	Louisiana	Florida
Montana	Kentucky	Minnesota	Hawaii
New Jersey	Maryland	Missouri	Nevada
New York	Massachusetts	North Dakota	North Carolina
Ohio	Nebraska	Oklahoma	South Dakota
Pennsylvania	New Hampshire	Oregon	Tennessee
Rhode Island	New Mexico	Texas	Utah
Vermont	South Carolina	Virginia	Washington
West Virginia		Wyoming	
Wisconsin			

SOURCES: National Center for Education Statistics (NCES), NCES Common Core of Data, National Public Education Financial Survey (various years); and Bureau of Economic Analysis, Gross Domestic Product data (various years). See table 8-10.

Findings

- The 2005 national average for spending on elementary and secondary education was 3.43% of the GDP, a slight increase from 3.37% in 1995.
- Among individual states, the value for this indicator ranged from 2.29% to 5.11% of the state's GDP in 2005, indicating that some states were directing a much higher percentage of their resources toward elementary and secondary education. The District of Columbia was an outlier at 1.24%.
- States spending the highest percentage of their GDP 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 GDP.
- Spending for elementary and secondary current expenditures as a share of the state's GDP decreased in 24 states and the District of Columbia during the 1995–2005 period as spending for primary and secondary education failed to keep pace with growth in the local economy.

This indicator measures the relative amount of resources that local, state, and federal governments direct toward public education in prekindergarten through grade 12. It is calculated by dividing the current expenditures of elementary and secondary public schools by the gross domestic product (GDP). Current expenditures include instruction and instruction-related costs, student support services, administration, and operations and exclude funds for school construction and other capital outlays, debt services, and programs outside of public elementary and secondary education. State and local support represent the largest sources of revenue for elementary and secondary education.

Financial data on public elementary and secondary education are reported by the National Center for Educational Statistics, Department of Education. These 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 approximately 94,000 public elementary and secondary schools and 14,000 school districts. Current expenditures are expressed in actual dollars. The year is the latter date of the academic year. For example, data for 2005 represent costs for the 2004–05 academic year. The District of Columbia and Hawaii each have only one school district; therefore, data for these two jurisdictions are not comparable to other states.

Table 8-10

Elementary and secondary public school current expenditures as share of gross domestic product, by state: 1995, 2000, and 2005

	Public school expenditures ($thousands)			State GDP ($millions)			School expenditures/ GDP (%)		
State	1995	2000	2005	1995	2000	2005	1995	2000	2005
United States	243,877,582	323,888,508	424,562,096	7,232,723	9,749,104	12,372,847	3.37	3.32	3.43
Alabama	3,026,287	4,176,082	5,164,406	94,021	114,576	151,342	3.22	3.64	3.41
Alaska	1,020,675	1,183,499	1,442,269	24,805	27,034	39,394	4.11	4.38	3.66
Arizona	3,144,540	4,288,739	6,451,870	104,036	158,533	212,312	3.02	2.71	3.04
Arkansas	1,873,595	2,380,331	3,546,999	53,303	66,801	87,004	3.51	3.56	4.08
California	25,949,033	38,129,479	50,918,654	908,963	1,287,145	1,616,351	2.85	2.96	3.15
Colorado	3,232,976	4,401,010	5,994,440	108,043	171,862	214,337	2.99	2.56	2.80
Connecticut	4,247,328	5,402,836	7,080,396	120,800	160,436	193,496	3.52	3.37	3.66
Delaware	694,473	937,630	1,299,349	27,507	41,472	56,731	2.52	2.26	2.29
District of Columbia	666,938	780,192	1,023,952	47,123	58,699	82,628	1.42	1.33	1.24
Florida	11,019,735	13,885,988	19,042,877	340,501	471,316	666,639	3.24	2.95	2.86
Georgia	6,136,689	9,158,624	12,528,856	199,138	290,887	358,365	3.08	3.15	3.50
Hawaii	1,028,729	1,213,695	1,648,086	36,572	40,202	54,773	2.81	3.02	3.01
Idaho	951,350	1,302,817	1,618,215	27,099	34,989	45,891	3.51	3.72	3.53
Illinois	10,640,279	14,462,773	18,658,428	359,723	464,194	555,599	2.96	3.12	3.36
Indiana	5,243,761	7,110,930	9,108,931	147,984	194,419	236,357	3.54	3.66	3.85
Iowa	2,622,510	3,264,336	3,808,200	71,905	90,186	117,635	3.65	3.62	3.24
Kansas	2,406,580	2,971,814	3,718,153	63,699	82,812	105,228	3.78	3.59	3.53
Kentucky	2,988,892	3,837,794	4,812,591	90,459	111,900	138,616	3.30	3.43	3.47
Louisiana	3,475,926	4,391,189	5,554,766	109,153	131,520	180,336	3.18	3.34	3.08
Maine	1,281,706	1,604,438	2,056,266	27,648	35,542	44,906	4.64	4.51	4.58
Maryland	5,083,380	6,545,135	8,682,586	137,391	180,367	244,447	3.70	3.63	3.55
Massachusetts	6,062,303	8,564,039	11,357,857	195,277	274,949	320,050	3.10	3.11	3.55
Michigan	10,440,206	13,994,294	16,353,921	251,017	337,235	372,148	4.16	4.15	4.39
Minnesota	4,622,930	6,140,442	7,310,284	131,357	185,093	231,437	3.52	3.32	3.16
Mississippi	1,921,480	2,510,376	3,243,888	53,816	64,266	79,786	3.57	3.91	4.07
Missouri	4,275,217	5,655,531	7,115,207	137,528	176,708	215,073	3.11	3.20	3.31
Montana	844,257	994,770	1,193,182	17,393	21,366	29,915	4.85	4.66	3.99
Nebraska	1,594,928	1,926,500	2,512,914	44,505	55,478	72,242	3.58	3.47	3.48
Nevada	1,186,132	1,875,467	2,722,264	48,974	73,719	110,158	2.42	2.54	2.47
New Hampshire	1,053,966	1,418,503	2,021,144	32,149	43,518	54,119	3.28	3.26	3.73
New Jersey	10,776,982	13,327,645	19,669,576	266,724	344,824	427,654	4.04	3.87	4.60
New Mexico	1,441,078	1,890,274	2,554,638	41,459	50,725	69,692	3.48	3.73	3.67
New York	22,989,629	28,433,240	38,866,853	594,444	777,157	961,385	3.87	3.66	4.04
North Carolina	5,440,426	7,713,293	9,567,000	191,579	273,698	350,700	2.84	2.82	2.73
North Dakota	534,632	638,946	786,870	14,515	17,752	24,935	3.68	3.60	3.16
Ohio	10,030,956	12,974,575	17,167,866	293,260	372,006	442,243	3.42	3.49	3.88
Oklahoma	2,763,721	3,382,581	4,161,024	69,580	89,757	121,558	3.97	3.77	3.42
Oregon	2,948,539	3,896,287	4,458,028	80,099	112,438	141,831	3.68	3.47	3.14
Pennsylvania	11,587,027	14,120,112	18,711,100	314,504	389,619	486,139	3.68	3.62	3.85
Rhode Island	1,050,969	1,393,143	1,825,900	25,666	33,609	43,623	4.09	4.15	4.19
South Carolina	2,920,230	4,087,355	5,312,739	86,053	112,514	140,088	3.39	3.63	3.79
South Dakota	612,825	737,998	916,563	17,807	23,099	30,541	3.44	3.19	3.00
Tennessee	3,540,682	4,931,734	6,446,691	135,655	174,851	224,995	2.61	2.82	2.87
Texas	17,572,269	25,098,703	31,919,107	507,441	727,233	989,333	3.46	3.45	3.23
Utah	1,618,047	2,102,655	2,627,022	46,303	67,568	88,364	3.49	3.11	2.97
Vermont	665,559	870,198	1,177,478	13,892	17,782	23,056	4.79	4.89	5.11
Virginia	5,750,318	7,757,598	10,705,162	185,490	260,743	350,692	3.10	2.98	3.05
Washington	5,138,928	6,399,885	7,870,979	151,338	221,961	271,381	3.40	2.88	2.90
West Virginia	1,758,557	2,086,937	2,527,767	36,362	41,476	53,091	4.84	5.03	4.76
Wisconsin	5,422,264	6,852,178	8,435,359	134,096	175,737	216,985	4.04	3.90	3.89
Wyoming	577,144	683,918	863,423	14,567	17,331	27,246	3.96	3.95	3.17
Puerto Rico	1,501,485	2,086,414	2,865,945	42,647	61,702	82,650	3.52	3.38	3.47

GDP = gross domestic product

NOTES: Public school expenditures for Missouri, Tennessee, and Washington for 2005 affected by redistribution of reported values to correct for missing data items. GDP reported in current dollars.

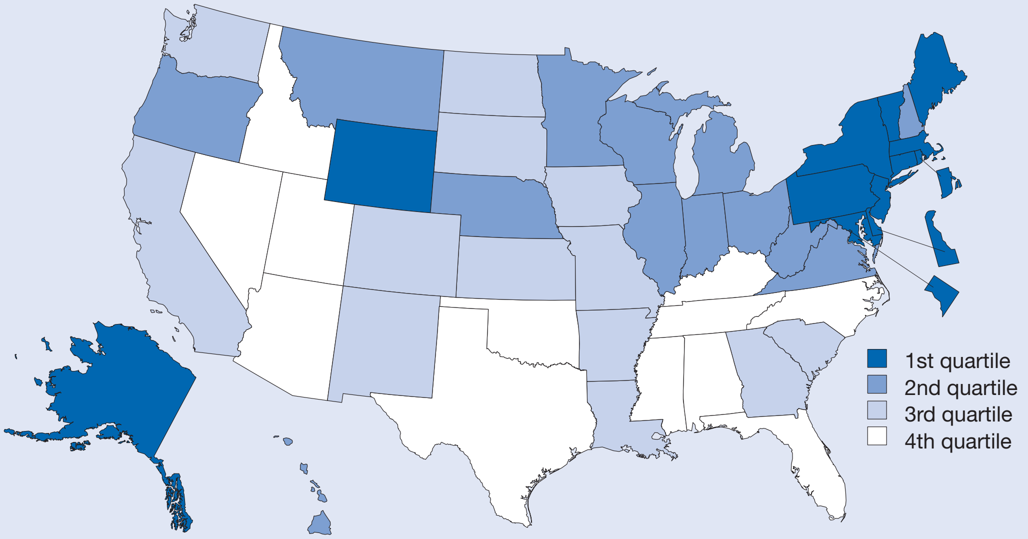
SOURCES: National Center for Education Statistics (NCES), NCES Common Core of Data, National Public Education Financial Survey (various years); Bureau of Economic Analysis, Gross Domestic Product data (various years); and Government of Puerto Rico, Office of the Governor (various years).

Science & Engineering Indicators 2008

Current Expenditures per Pupil for Elementary and Secondary Public Schools

Figure 8-11

Current expenditures per pupil for elementary and secondary public schools: 2005



1st quartile ($14,117–$10,031)	2nd quartile ($9,771–$8,071)	3rd quartile ($8,065–$7,464)	4th quartile ($7,246–$5,216)
Alaska	Hawaii	Arkansas	Alabama
Connecticut	Illinois	California	Arizona
Delaware	Indiana	Colorado	Florida
District of Columbia	Michigan	Georgia	Idaho
Maine	Minnesota	Iowa	Kentucky
Maryland	Montana	Kansas	Mississippi
Massachusetts	Nebraska	Louisiana	Nevada
New Jersey	New Hampshire	Missouri	North Carolina
New York	Ohio	New Mexico	Oklahoma
Pennsylvania	Oregon	North Dakota	Tennessee
Rhode Island	Virginia	South Carolina	Texas
Vermont	West Virginia	South Dakota	Utah
Wyoming	Wisconsin	Washington	

SOURCES: National Center for Education Statistics (NCES), NCES Common Core of Data, State Nonfiscal Survey of Public Elementary/Secondary Education (various years); and National Public Education Financial Survey (various years). See table 8-11.

Findings

- Per-pupil spending on day-to-day operations grew nationwide from $5,529 in 1995 to $8,701 in 2005, an increase of 57% in unadjusted dollars.
- In 2005, all states showed substantial increases in per-pupil spending relative to 1995, and only 1 state failed to exceed the 1995 national average of $5,529 compared with 28 states in 1995.
- Per-pupil spending in individual states varied widely, ranging from a high of $14,117 to a low of $5,216 in 2005.
- There is no direct correlation between spending and academic performance. In fact, several states that ranked in the lower two quartiles of this indicator ranked in the upper quartiles of the National Assessment of Educational Progress indicators.

This indicator measures the investment by local, state, and federal governments in elementary and secondary education, adjusted for the size of the student body. It is calculated by dividing the current expenditures over the entire academic year for prekindergarten through grade 12 by the number of students in those grades in public schools. Current expenditures represent amounts expended for the day-to-day operations of schools and school districts. They include expenditures for instruction and instruction-related costs, student support services, administration, and operations and exclude funds for school construction and other capital outlays, debt services, and programs outside of public elementary and secondary education. During the 2004–05 school year, 65.9% of current expenses were used for instructional costs, 5.2% for student support services, 11.0% for administrative costs, and 17.8% for operational costs.

The number of pupils enrolled in prekindergarten through grade 12 is determined 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. For example, data for 2005 represent costs for the 2004–05 academic year.

Table 8-11

Current expenditures per pupil for elementary and secondary public schools, by state: 1995, 2000, and 2005

State	Public school expenditures ($thousands)			Student enrollment			Per-pupil expenditures ($)		
	1995	2000	2005	1995	2000	2005	1995	2000	2005
United States	243,877,582	323,888,508	424,562,096	44,111,482	46,857,149	48,794,911	5,529	6,912	8,701
Alabama	3,026,287	4,176,082	5,164,406	736,531	740,732	730,140	4,109	5,638	7,073
Alaska	1,020,675	1,183,499	1,442,269	127,057	134,391	132,970	8,033	8,806	10,847
Arizona	3,144,540	4,288,739	6,451,870	737,424	852,612	1,043,298	4,264	5,030	6,184
Arkansas	1,873,595	2,380,331	3,546,999	447,565	451,034	463,115	4,186	5,277	7,659
California	25,949,033	38,129,479	50,918,654	5,407,475	6,038,590	6,441,557	4,799	6,314	7,905
Colorado	3,232,976	4,401,010	5,994,440	640,521	708,109	765,976	5,047	6,215	7,826
Connecticut	4,247,328	5,402,836	7,080,396	506,824	553,993	577,390	8,380	9,753	12,263
Delaware	694,473	937,630	1,299,349	106,813	112,836	119,091	6,502	8,310	10,911
District of Columbia	666,938	780,192	1,023,952	80,450	77,194	76,714	8,290	10,107	13,348
Florida	11,019,735	13,885,988	19,042,877	2,111,188	2,381,396	2,639,336	5,220	5,831	7,215
Georgia	6,136,689	9,158,624	12,528,856	1,270,948	1,422,762	1,553,437	4,828	6,437	8,065
Hawaii	1,028,729	1,213,695	1,648,086	183,795	185,860	183,185	5,597	6,530	8,997
Idaho	951,350	1,302,817	1,618,215	240,448	245,136	256,084	3,957	5,315	6,319
Illinois	10,640,279	14,462,773	18,658,428	1,916,172	2,027,600	2,097,503	5,553	7,133	8,896
Indiana	5,243,761	7,110,930	9,108,931	969,022	988,702	1,021,348	5,411	7,192	8,919
Iowa	2,622,510	3,264,336	3,808,200	500,440	497,301	478,319	5,240	6,564	7,962
Kansas	2,406,580	2,971,814	3,718,153	460,838	472,188	469,136	5,222	6,294	7,926
Kentucky	2,988,892	3,837,794	4,812,591	657,642	648,180	674,796	4,545	5,921	7,132
Louisiana	3,475,926	4,391,189	5,554,766	797,933	756,579	724,281	4,356	5,804	7,669
Maine	1,281,706	1,604,438	2,056,266	212,601	209,253	198,820	6,029	7,667	10,342
Maryland	5,083,380	6,545,135	8,682,586	790,938	846,582	865,561	6,427	7,731	10,031
Massachusetts	6,062,303	8,564,039	11,357,857	893,727	971,425	975,574	6,783	8,816	11,642
Michigan	10,440,206	13,994,294	16,353,921	1,614,784	1,725,639	1,750,919	6,465	8,110	9,340
Minnesota	4,622,930	6,140,442	7,310,284	821,693	854,034	838,503	5,626	7,190	8,718
Mississippi	1,921,480	2,510,376	3,243,888	505,962	500,716	495,376	3,798	5,014	6,548
Missouri	4,275,217	5,655,531	7,115,207	878,541	914,110	905,449	4,866	6,187	7,858
Montana	844,257	994,770	1,193,182	164,341	157,556	146,705	5,137	6,314	8,133
Nebraska	1,594,928	1,926,500	2,512,914	287,100	288,261	285,761	5,555	6,683	8,794
Nevada	1,186,132	1,875,467	2,722,264	250,747	325,610	400,083	4,730	5,760	6,804
New Hampshire	1,053,966	1,418,503	2,021,144	189,319	206,783	206,852	5,567	6,860	9,771
New Jersey	10,776,982	13,327,645	19,669,576	1,174,206	1,289,256	1,393,347	9,178	10,337	14,117
New Mexico	1,441,078	1,890,274	2,554,638	327,248	324,495	326,102	4,404	5,825	7,834
New York	22,989,629	28,433,240	38,866,853	2,766,208	2,887,776	2,836,337	8,311	9,846	13,703
North Carolina	5,440,426	7,713,293	9,567,000	1,156,767	1,275,925	1,385,754	4,703	6,045	6,904
North Dakota	534,632	638,946	786,870	119,288	112,751	100,513	4,482	5,667	7,829
Ohio	10,030,956	12,974,575	17,167,866	1,814,290	1,836,554	1,840,032	5,529	7,065	9,330
Oklahoma	2,763,721	3,382,581	4,161,024	609,718	627,032	629,476	4,533	5,395	6,610
Oregon	2,948,539	3,896,287	4,458,028	521,945	545,033	552,322	5,649	7,149	8,071
Pennsylvania	11,587,027	14,120,112	18,711,100	1,764,946	1,816,716	1,828,089	6,565	7,772	10,235
Rhode Island	1,050,969	1,393,143	1,825,900	147,487	156,454	156,498	7,126	8,904	11,667
South Carolina	2,920,230	4,087,355	5,312,739	648,725	666,780	703,736	4,501	6,130	7,549
South Dakota	612,825	737,998	916,563	143,482	131,037	122,798	4,271	5,632	7,464
Tennessee	3,540,682	4,931,734	6,446,691	881,425	916,202	941,091	4,017	5,383	6,850
Texas	17,572,269	25,098,703	31,919,107	3,677,171	3,991,783	4,405,215	4,779	6,288	7,246
Utah	1,618,047	2,102,655	2,627,022	474,675	480,255	503,607	3,409	4,378	5,216
Vermont	665,559	870,198	1,177,478	104,533	104,559	98,352	6,367	8,323	11,972
Virginia	5,750,318	7,757,598	10,705,162	1,060,809	1,133,994	1,204,739	5,421	6,841	8,886
Washington	5,138,928	6,399,885	7,870,979	938,314	1,003,714	1,020,005	5,477	6,376	7,717
West Virginia	1,758,557	2,086,937	2,527,767	310,511	291,811	280,129	5,663	7,152	9,024
Wisconsin	5,422,264	6,852,178	8,435,359	860,581	877,753	864,757	6,301	7,806	9,755
Wyoming	577,144	683,918	863,423	100,314	92,105	84,733	5,753	7,425	10,190
Puerto Rico	1,501,485	2,086,414	2,865,945	621,121	613,019	575,648	2,417	3,404	4,979

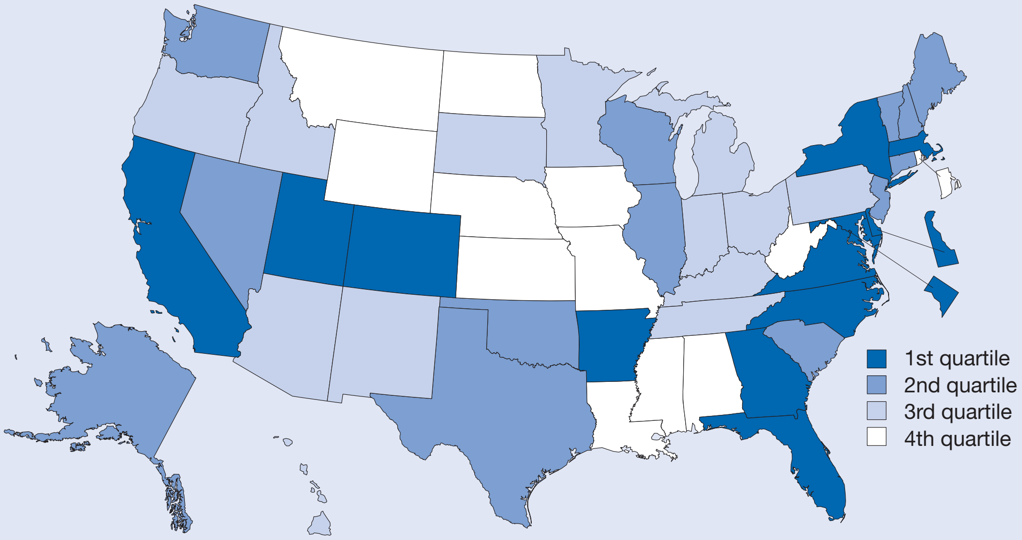
NOTES: Public school expenditures for Missouri, Tennessee, and Washington for 2005 affected by redistribution of reported values to correct for missing data items. Public school expenditures reported in current dollars. 2005 prekindergarten student membership for California was imputed, affecting the total student count and per pupil expenditures calculation.

SOURCES: National Center for Education Statistics (NCES), NCES Common Core of Data, State Nonfiscal Survey of Public Elementary/Secondary Education (various years); and National Public Education Financial Survey (various years).

Science & Engineering Indicators 2008

Share of Public High School Students Taking Advanced Placement Exams

Figure 8-12
Share of public high school students taking Advanced Placement Exams: 2006



1st quartile (36.4%–27.2%)	2nd quartile (27.0%–19.4%)	3rd quartile (19.2%–15.8%)	4th quartile (15.1%–5.1%)
Arkansas	Alaska	Arizona	Alabama
California	Connecticut	Hawaii	Iowa
Colorado	Illinois	Idaho	Kansas
Delaware	Maine	Indiana	Louisiana
District of Columbia	Nevada	Kentucky	Mississippi
Florida	New Hampshire	Michigan	Missouri
Georgia	New Jersey	Minnesota	Montana
Maryland	Oklahoma	New Mexico	Nebraska
Massachusetts	South Carolina	Ohio	North Dakota
New York	Texas	Oregon	Rhode Island
North Carolina	Vermont	Pennsylvania	West Virginia
Utah	Washington	South Dakota	Wyoming
Virginia	Wisconsin	Tennessee	

SOURCE: College Board, Advanced Placement Report to the Nation (various years). See table 8-12.

Findings

- Nationwide, the percent of public school students who took an AP Exam rose from 15.9% of the class of 2000 to 24.2% of the class of 2006.
- The percentage of public school students taking an AP Exam varied greatly among states and ranged from 5.1% to 36.4% of the class of 2006. Thirty-five states and the District of Columbia exceeded the 2000 national average in 2006, compared with 15 states and the District of Columbia that exceeded the national average in 2000.
- AP participation levels were higher for all jurisdictions in 2006 than in 2000. Arkansas and the District of Columbia showed the largest increases; class of 2006 members in these jurisdictions exceeded the participation of the class of 2000 by 22.5 and 16.4 percentage points, respectively.

Participation in the Advanced Placement (AP) program provides a measure of the extent to which a rigorous curriculum is available to and utilized by high school students. This indicator measures the percentage of students in the graduating class who have taken one or more AP Exams. It is calculated by dividing the number of students in the graduating class who have taken at least one AP Exam by the total number of students in the graduating class.

Throughout the United States, more than 660,000 public school students from the class of 2006 took nearly 1.7 million AP Exams during their high school careers. 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, 12,037 public schools participated in the AP program in 2006. This represented over 65% of the public schools in the United States that offer a secondary curriculum. These schools make available an average of eight different AP courses to their students.

Table 8-12

Share of public high school students taking Advanced Placement Exams, by state: 2000, 2004, and 2006

(Percent)

State	2000	2004	2006
United States	15.9	20.9	24.2
Alabama	7.2	8.8	10.2
Alaska	15.4	16.7	20.0
Arizona	11.3	12.9	15.8
Arkansas	8.1	13.0	30.6
California	22.2	28.5	31.3
Colorado	18.6	25.3	28.9
Connecticut	19.1	24.6	26.7
Delaware	13.3	19.6	27.7
District of Columbia	17.3	23.1	33.7
Florida	22.7	33.5	36.4
Georgia	17.2	21.5	27.2
Hawaii	10.6	14.8	15.9
Idaho	9.6	12.5	16.0
Illinois	13.4	18.6	21.7
Indiana	11.9	15.5	18.8
Iowa	6.9	10.0	11.8
Kansas	7.0	9.2	12.2
Kentucky	10.6	15.5	18.9
Louisiana	3.2	5.0	5.1
Maine	14.8	19.9	23.6
Maryland	20.2	29.2	33.5
Massachusetts	19.6	25.3	27.7
Michigan	13.9	16.8	18.7
Minnesota	13.4	16.4	19.2
Mississippi	5.6	7.0	10.6
Missouri	5.5	8.1	9.8
Montana	10.1	13.0	15.1
Nebraska	5.0	6.3	9.3
Nevada	15.1	19.8	23.1
New Hampshire	13.3	16.0	19.4
New Jersey	17.9	21.3	23.5
New Mexico	11.1	17.0	19.1
New York	27.3	32.4	35.4
North Carolina	19.7	26.9	31.7
North Dakota	5.9	8.4	9.6
Ohio	11.3	15.2	17.2
Oklahoma	9.5	17.0	20.4
Oregon	10.5	13.6	17.0
Pennsylvania	12.4	14.9	16.6
Rhode Island	10.7	12.1	13.0
South Carolina	17.7	19.2	22.0
South Dakota	9.6	13.5	15.8
Tennessee	10.4	13.6	16.8
Texas	16.6	23.2	27.0
Utah	24.5	27.6	30.6
Vermont	16.6	21.2	24.8
Virginia	25.0	28.1	32.9
Washington	11.5	18.5	23.5
West Virginia	8.4	13.0	13.6
Wisconsin	15.2	20.0	23.0
Wyoming	6.1	11.2	13.2
Puerto Rico	NA	NA	NA

NA = not available

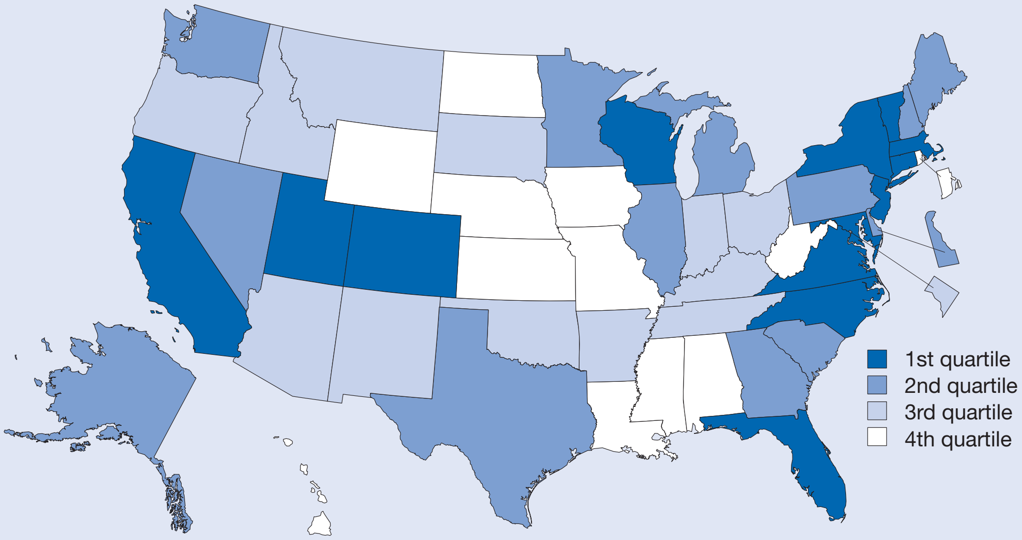
NOTE: National average for United States is reported value in Advanced Placement Report to the Nation.

SOURCE: College Board, Advanced Placement Report to the Nation (various years).

Science & Engineering Indicators 2008

Share of Public High School Students Scoring 3 or Higher on at Least One Advanced Placement Exam

Figure 8-13
Share of public high school students scoring 3 or higher on at least one Advanced Placement Exam: 2006



1st quartile (22.7%–15.8%)	2nd quartile (15.1%–11.1%)	3rd quartile (10.5%–9.0%)	4th quartile (8.4%–2.3%)
California	Alaska	Arizona	Alabama
Colorado	Delaware	Arkansas	Hawaii
Connecticut	Georgia	District of Columbia	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	Rhode Island
Vermont	South Carolina	Oregon	West Virginia
Virginia	Texas	South Dakota	Wyoming
Wisconsin	Washington	Tennessee	

SOURCE: College Board, Advanced Placement Report to the Nation (various years). See table 8-13.

Findings

- Nationally, 14.8% of public school students in the class of 2006 demonstrated the ability to do college-level work by obtaining a score of 3 or higher on at least one AP Exam, a significant increase over the 10.2% achieved by the class of 2000.
- Students from all states demonstrated greater success on AP Exams in 2006 than in 2000, but this success was not uniformly distributed. In 2006, 21 states and the District of Columbia had percentages below the national average of 10.2% compared with 38 jurisdictions in 2000.
- The percentage of students who are successful on AP Exams varies widely among states; state indicator values for public school students in the class of 2006 ranged from a low of 2.3% to a high of 22.7%. This wide range indicates that opportunities for advanced work are more readily available to students in certain states, and that these students are demonstrating college-level skills through successful completion of their AP programs.
- Values of this indicator were higher for all states in 2006 than in 2000. Maryland, Delaware, North Carolina, Washington, and Florida showed the largest increases; class of 2006 members in these states exceeded the performance of class of 2000 participants by more than 6 percentage points.

This indicator provides a measure of the extent to which high school students are successfully demonstrating their mastery of college-level material. It is defined as the percentage of U.S. public high school graduates who have scored 3 or higher on at least one Advanced Placement (AP) Exam. A high value on this indicator shows the extent to which students have been offered access to a rigorous curriculum and successfully mastered these requirements.

A total of 37 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. 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. Many colleges and universities grant college credit or advanced placement for AP Exam grades of 3 or higher.

Table 8-13

Share of public high school students scoring 3 or higher on at least one Advanced Placement Exam, by state: 2000, 2004, and 2006

(Percent)

State	2000	2004	2006
United States	10.2	13.2	14.8
Alabama	3.9	5.0	5.7
Alaska	10.1	10.8	12.6
Arizona	7.2	8.0	9.4
Arkansas	4.3	6.1	9.8
California	15.0	18.7	20.1
Colorado	12.2	16.2	17.9
Connecticut	13.6	17.6	19.4
Delaware	7.6	11.1	14.5
District of Columbia	6.6	8.2	9.6
Florida	13.5	19.2	19.6
Georgia	9.7	12.0	14.8
Hawaii	5.8	7.7	7.6
Idaho	6.5	8.1	9.7
Illinois	9.9	13.3	15.1
Indiana	6.0	7.7	9.2
Iowa	4.9	6.6	7.8
Kansas	4.4	6.3	7.7
Kentucky	5.5	7.7	9.4
Louisiana	1.9	2.5	2.3
Maine	10.1	12.8	14.4
Maryland	14.1	19.4	22.0
Massachusetts	14.5	18.1	19.8
Michigan	8.8	10.9	12.2
Minnesota	8.1	10.6	12.4
Mississippi	2.3	2.9	3.5
Missouri	3.7	5.3	6.3
Montana	6.8	8.8	10.0
Nebraska	3.2	4.0	5.8
Nevada	9.1	12.4	13.3
New Hampshire	9.2	10.9	13.6
New Jersey	12.9	15.5	16.6
New Mexico	6.1	8.1	9.0
New York	17.9	21.2	22.7
North Carolina	11.3	15.8	18.0
North Dakota	4.4	5.7	6.8
Ohio	7.1	9.4	10.5
Oklahoma	5.4	8.3	9.6
Oregon	7.1	8.8	10.4
Pennsylvania	8.3	10.1	11.1
Rhode Island	6.9	7.8	8.4
South Carolina	10.0	11.2	12.5
South Dakota	5.9	8.3	9.4
Tennessee	6.2	7.9	9.5
Texas	9.9	13.1	14.6
Utah	17.4	19.3	20.8
Vermont	11.5	14.0	16.3
Virginia	15.9	17.7	20.7
Washington	7.6	11.6	14.1
West Virginia	4.6	6.4	6.4
Wisconsin	10.5	13.7	15.8
Wyoming	3.8	6.7	6.6
Puerto Rico	NA	NA	NA

NA = not available

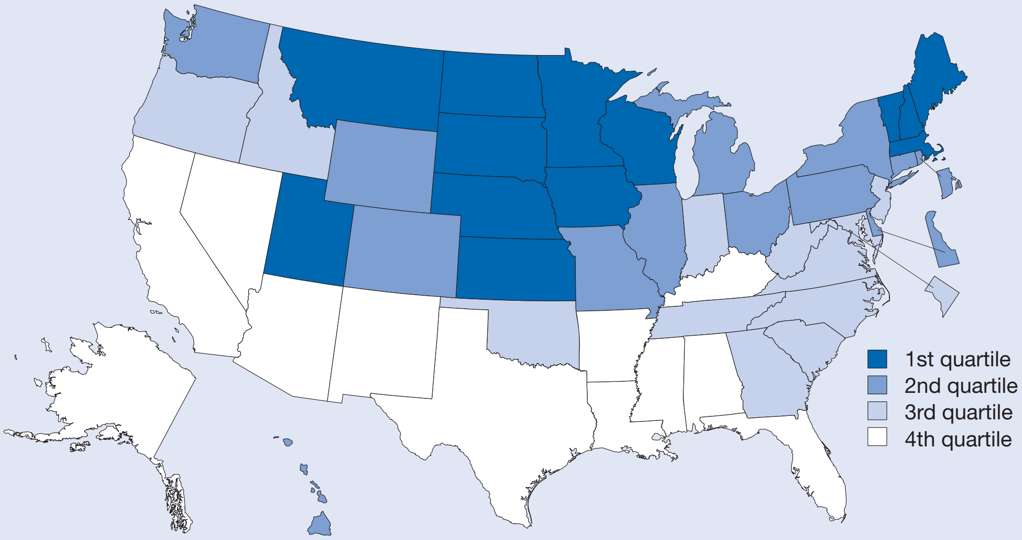
NOTE: National average for United States is reported value in Advanced Placement Report to the Nation.

SOURCE: College Board, Advanced Placement Report to the Nation (various years).

Science & Engineering Indicators 2008

High School Graduates or Higher Among Individuals 25–44 Years Old

Figure 8-14
High school graduates or higher among individuals 25–44 years old: 2005



1st quartile (99.4%–89.6%)	2nd quartile (89.3%–86.8%)	3rd quartile (86.7%–84.6%)	4th quartile (84.4%–77.0%)
Iowa	Colorado	District of Columbia	Alabama
Kansas	Connecticut	Georgia	Alaska
Maine	Delaware	Idaho	Arizona
Massachusetts	Hawaii	Indiana	Arkansas
Minnesota	Illinois	Maryland	California
Montana	Michigan	New Jersey	Florida
Nebraska	Missouri	North Carolina	Kentucky
New Hampshire	New York	Oklahoma	Louisiana
North Dakota	Ohio	Oregon	Mississippi
South Dakota	Pennsylvania	South Carolina	Nevada
Utah	Rhode Island	Tennessee	New Mexico
Vermont	Washington	Virginia	Texas
Wisconsin	Wyoming	West Virginia	

SOURCES: Census Bureau, 2000 Decennial Census; Population Estimates Program (various years); and American Community Survey (various years). See Table 8-14.

Findings

- Nationwide, 84.8% of the early- to mid-career population had at least a high school credential in 2005, which is nearly identical with 85.0% in 2000.
- Only 21 states and the District of Columbia showed an increase in the percentage of their early- to mid-career population with at least a high school credential between 2000 and 2005. Thirteen states had 2005 values below the 2000 national average of 85.0% compared with 17 states and the District of Columbia in 2000.
- In 2005, the early- to mid-career population with at least a high school credential varied greatly among states, ranging from 77.0% to 99.4%. States in close proximity to the southern border tended to rank lowest on this indicator.

This indicator represents the percentage of the early- to mid-career population that has earned at least a high school credential. The indicator represents where high school graduates have chosen to live and work rather than where they were educated. The 25–44-year-old cohort was selected because it is likely to capture both high school diplomas and equivalency degrees. High values indicate a resident population and potential workforce with widespread basic education credentials.

Estimates of educational attainment are developed by the Census Bureau based on the 2000 Decennial Census and the American Community Survey (ACS). The census is conducted every 10 years, but the ACS provides annually updated data on the characteristics of population and housing. In 2005, ACS became the largest household survey in the United States, with an annual sample size of about 3 million addresses. Estimates of population are developed by the Census Bureau through the Population Estimates Program, which is also based on the 2000 Decennial Census. The value of this indicator may be imprecise for jurisdictions with small populations because both its numerator and denominator are based on estimates.

Table 8-14

High school graduates or higher among individuals 25–44 years old, by state: 2000, 2003, and 2005

	Graduates 25–44 years old			Population 25–44 years old			Graduates/population 25–44 years old (%)		
State	2000	2003	2005	2000	2003	2005	2000	2003	2005
United States	72,241,876	71,684,426	71,215,646	85,040,251	84,216,990	84,010,639	85.0	85.1	84.8
Alabama	1,064,945	1,027,964	1,035,193	1,288,527	1,241,184	1,234,729	82.6	82.8	83.8
Alaska	186,160	167,805	162,669	203,522	194,823	194,890	91.5	86.1	83.5
Arizona	1,232,818	1,286,915	1,367,583	1,511,469	1,599,029	1,694,572	81.6	80.5	80.7
Arkansas	622,698	608,116	633,557	750,972	738,579	750,229	82.9	82.3	84.4
California	8,286,071	8,529,909	8,316,850	10,714,403	10,832,873	10,794,860	77.3	78.7	77.0
Colorado	1,242,919	1,239,272	1,240,697	1,400,850	1,417,501	1,421,418	88.7	87.4	87.3
Connecticut	926,614	903,677	852,932	1,032,689	999,800	968,330	89.7	90.4	88.1
Delaware	207,799	204,842	206,583	236,441	233,356	233,683	87.9	87.8	88.4
District of Columbia	157,077	160,782	163,027	189,439	188,758	189,675	82.9	85.2	86.0
Florida	3,840,710	3,924,625	4,000,762	4,569,347	4,676,558	4,812,867	84.1	83.9	83.1
Georgia	2,238,995	2,280,061	2,368,999	2,652,764	2,723,720	2,784,441	84.4	83.7	85.1
Hawaii	333,762	316,491	308,637	362,336	352,806	355,620	92.1	89.7	86.8
Idaho	316,815	323,260	327,870	362,401	370,690	387,620	87.4	87.2	84.6
Illinois	3,265,416	3,267,787	3,200,557	3,795,544	3,727,314	3,672,713	86.0	87.7	87.1
Indiana	1,567,100	1,494,212	1,500,650	1,791,828	1,748,331	1,741,859	87.5	85.5	86.2
Iowa	740,397	709,299	713,525	808,259	775,320	764,399	91.6	91.5	93.3
Kansas	687,268	675,316	656,920	769,204	743,961	732,886	89.3	90.8	89.6
Kentucky	1,009,246	1,013,026	993,094	1,210,773	1,182,970	1,187,091	83.4	85.6	83.7
Louisiana	1,044,255	1,014,054	1,026,229	1,293,128	1,230,819	1,217,481	80.8	82.4	84.3
Maine	339,227	325,208	317,653	370,597	358,691	350,196	91.5	90.7	90.7
Maryland	1,487,216	1,454,663	1,399,879	1,664,677	1,641,907	1,615,367	89.3	88.6	86.7
Massachusetts	1,795,438	1,763,262	1,690,234	1,989,783	1,922,446	1,848,998	90.2	91.7	91.4
Michigan	2,630,713	2,551,652	2,455,339	2,960,544	2,840,435	2,772,896	88.9	89.8	88.5
Minnesota	1,395,170	1,374,938	1,345,742	1,497,320	1,465,370	1,443,493	93.2	93.8	93.2
Mississippi	650,242	645,671	648,458	807,170	782,327	778,254	80.6	82.5	83.3
Missouri	1,426,806	1,399,485	1,378,001	1,626,302	1,587,931	1,585,316	87.7	88.1	86.9
Montana	225,105	213,382	216,509	245,220	232,735	232,383	91.8	91.7	93.2
Nebraska	441,527	432,446	421,008	487,107	471,024	464,556	90.6	91.8	90.6
Nevada	508,173	538,622	585,942	628,572	679,392	729,594	80.8	79.3	80.3
New Hampshire	350,744	340,140	330,926	381,240	373,644	364,731	92.0	91.0	90.7
New Jersey	2,313,820	2,254,281	2,165,296	2,624,146	2,578,072	2,510,115	88.2	87.4	86.3
New Mexico	425,745	400,847	411,608	516,100	506,956	511,007	82.5	79.1	80.5
New York	4,926,064	4,912,059	4,786,794	5,831,622	5,667,484	5,501,929	84.5	86.7	87.0
North Carolina	2,117,289	2,096,022	2,148,501	2,500,535	2,507,025	2,523,658	84.7	83.6	85.1
North Dakota	164,893	157,062	155,297	174,891	160,522	156,178	94.3	97.8	99.4
Ohio	2,965,744	2,840,789	2,759,770	3,325,210	3,172,294	3,105,980	89.2	89.5	88.9
Oklahoma	836,030	796,708	807,209	975,169	946,358	944,171	85.7	84.2	85.5
Oregon	861,602	880,905	872,276	997,269	1,003,698	1,015,644	86.4	87.8	85.9
Pennsylvania	3,136,195	2,966,827	2,908,593	3,508,562	3,343,434	3,255,635	89.4	88.7	89.3
Rhode Island	265,033	262,340	264,154	310,636	306,459	296,717	85.3	85.6	89.0
South Carolina	990,207	1,002,730	999,627	1,185,955	1,167,347	1,171,573	83.5	85.9	85.3
South Dakota	188,052	182,643	180,013	206,399	197,386	195,213	91.1	92.5	92.2
Tennessee	1,439,729	1,446,735	1,459,559	1,718,428	1,684,796	1,698,611	83.8	85.9	85.9
Texas	5,115,457	5,136,496	5,248,281	6,484,321	6,644,003	6,762,605	78.9	77.3	77.6
Utah	555,513	602,199	646,632	626,600	648,111	695,736	88.7	92.9	92.9
Vermont	162,109	153,679	150,073	176,456	168,392	163,707	91.9	91.3	91.7
Virginia	1,962,040	1,911,347	1,896,614	2,237,655	2,227,978	2,228,610	87.7	85.8	85.1
Washington	1,617,766	1,607,576	1,592,550	1,816,217	1,803,610	1,820,192	89.1	89.1	87.5
West Virginia	420,900	400,998	411,155	501,343	479,781	478,383	84.0	83.6	85.9
Wisconsin	1,429,331	1,369,084	1,367,667	1,581,690	1,537,180	1,517,725	90.4	89.1	90.1
Wyoming	126,931	116,217	117,952	138,619	131,810	132,103	91.6	88.2	89.3
Puerto Rico	794,579	NA	868,650	1,049,995	1,069,617	1,077,981	75.7	NA	80.6

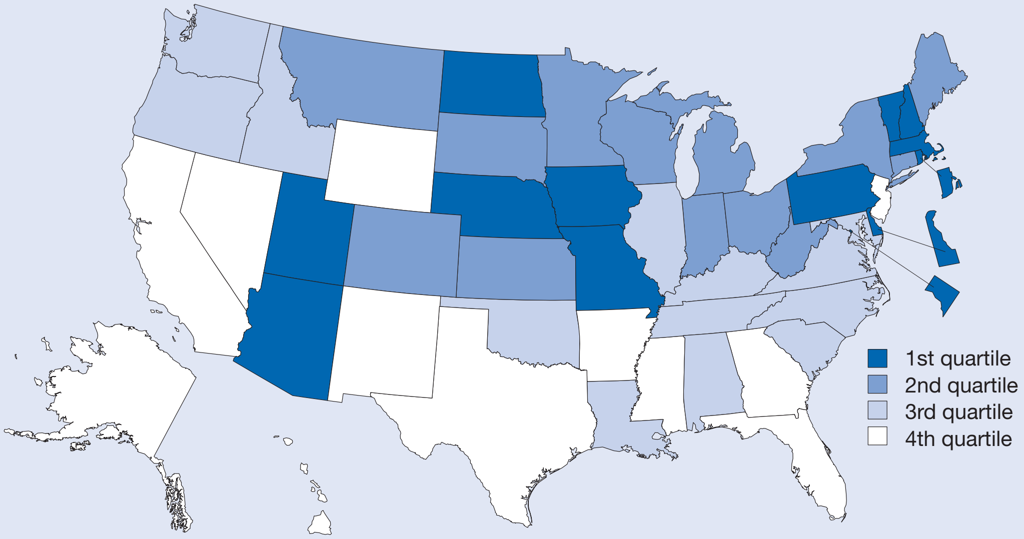
NA = not available

SOURCES: Census Bureau, 2000 Decennial Census; Population Estimates Program (various years); and American Community Survey (various years).

Science & Engineering Indicators 2008

Bachelor's Degrees Conferred per 1,000 Individuals 18–24 Years Old

Figure 8-15
Bachelor's degrees conferred per 1,000 individuals 18–24 years old: 2005



1st quartile (130.5–59.1)	2nd quartile (58.8–51.2)	3rd quartile (49.9–43.2)	4th quartile (42.8–20.3)
Arizona	Colorado	Alabama	Alaska
Delaware	Connecticut	Idaho	Arkansas
District of Columbia	Indiana	Illinois	California
Iowa	Kansas	Kentucky	Florida
Massachusetts	Maine	Louisiana	Georgia
Missouri	Michigan	Maryland	Hawaii
Nebraska	Minnesota	North Carolina	Mississippi
New Hampshire	Montana	Oklahoma	Nevada
North Dakota	New York	Oregon	New Jersey
Pennsylvania	Ohio	South Carolina	New Mexico
Rhode Island	South Dakota	Tennessee	Texas
Utah	West Virginia	Virginia	Wyoming
Vermont	Wisconsin	Washington	

SOURCES: National Center for Education Statistics, Integrated Postsecondary Education Data System (various years); Census Bureau, 2000 Decennial Census; and Population Estimates Program (various years). See Table 8-15.

Findings

- In 2005, 1.42 million bachelor's degrees were conferred nationally in all fields, up from 1.17 million in 1996.
- Over the past decade, the ratio of bachelor's degrees conferred to the 18–24-year-old population has remained essentially constant.
- In 2005, there was great variability among states in undergraduate educational opportunities relative to the size of their youthful population. Across the states, a range of 20.3 to 84.4 bachelor's degrees were conferred per 1,000 18–24-year-olds; the District of Columbia was nearly 131 (an outlier reflecting a large concentration of academic institutions relative to the size of the resident population).
- In 18 states, the number of bachelor's degrees conferred per 1,000 18–24-year-olds decreased between 1996 and 2005.

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 may generate 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.

Although the number of bachelor's degrees awarded is based on an actual count, the population of 18–24-year-olds is an estimate developed by the Census Bureau in the Population Estimates Program, which relies on the Decennial Census. This estimate may make the value of this indicator imprecise for jurisdictions with small populations.

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 8-15
Bachelor's degrees conferred per 1,000 individuals 18–24 years old, by state: 1996, 2001, and 2005

State	Bachelor's degrees			Population 18–24 years old			Degrees/1,000 individuals 18–24 years old		
	1996	2001	2005	1996	2001	2005	1996	2001	2005
United States	1,165,138	1,241,507	1,420,043	24,842,610	27,998,931	29,333,266	46.9	44.3	48.4
Alabama	20,133	20,654	21,388	437,421	448,725	448,894	46.0	46.0	47.6
Alaska	1,497	1,343	1,427	64,682	60,394	70,429	23.1	22.2	20.3
Arizona	18,822	25,509	34,915	417,142	536,708	576,725	45.1	47.5	60.5
Arkansas	9,099	9,628	11,186	247,651	268,747	270,471	36.7	35.8	41.4
California	108,604	118,552	139,417	2,982,515	3,487,649	3,726,736	36.4	34.0	37.4
Colorado	20,043	21,698	24,936	354,247	449,661	459,040	56.6	48.3	54.3
Connecticut	13,814	14,249	16,835	261,580	282,433	313,202	52.8	50.5	53.8
Delaware	4,330	4,466	5,220	65,107	78,501	83,016	66.5	56.9	62.9
District of Columbia	7,787	8,113	9,169	45,801	72,372	70,265	170.0	112.1	130.5
Florida	46,274	49,914	60,434	1,168,986	1,399,219	1,572,959	39.6	35.7	38.4
Georgia	27,322	28,481	35,086	728,478	865,538	903,396	37.5	32.9	38.8
Hawaii	4,696	4,772	5,127	116,166	118,324	123,584	40.4	40.3	41.5
Idaho	4,489	4,646	7,235	130,028	144,632	149,739	34.5	32.1	48.3
Illinois	52,222	55,938	59,611	1,111,306	1,242,578	1,274,718	47.0	45.0	46.8
Indiana	30,571	31,854	36,579	571,520	627,241	623,312	53.5	50.8	58.7
Iowa	17,669	18,577	20,418	269,324	302,946	311,451	65.6	61.3	65.6
Kansas	14,873	15,014	16,565	249,744	281,504	292,984	59.6	53.3	56.5
Kentucky	14,674	15,460	17,905	397,201	409,650	395,618	36.9	37.7	45.3
Louisiana	17,989	19,854	21,199	459,805	484,149	490,354	39.1	41.0	43.2
Maine	5,619	5,429	6,485	110,955	108,029	117,048	50.6	50.3	55.4
Maryland	20,873	22,891	25,685	427,478	473,697	526,277	48.8	48.3	48.8
Massachusetts	40,681	42,717	45,623	511,122	593,001	625,908	79.6	72.0	72.9
Michigan	44,371	45,790	50,565	921,950	957,339	986,126	48.1	47.8	51.3
Minnesota	23,117	23,128	27,869	418,324	486,487	516,133	55.3	47.5	54.0
Mississippi	9,983	11,232	11,681	299,031	316,573	311,137	33.4	35.5	37.5
Missouri	27,251	30,083	33,838	495,615	552,843	572,472	55.0	54.4	59.1
Montana	4,622	5,016	5,177	85,538	88,639	94,488	54.0	56.6	54.8
Nebraska	9,889	10,788	11,993	161,398	178,383	188,583	61.3	60.5	63.6
Nevada	3,417	4,101	5,029	133,106	189,705	207,871	25.7	21.6	24.2
New Hampshire	7,660	7,266	8,111	94,357	108,106	121,124	81.2	67.2	67.0
New Jersey	24,572	26,948	31,987	668,453	696,100	747,332	36.8	38.7	42.8
New Mexico	6,048	5,959	6,580	169,870	186,485	205,017	35.6	32.0	32.1
New York	96,429	100,010	112,475	1,602,205	1,820,985	1,919,224	60.2	54.9	58.6
North Carolina	32,795	34,767	39,289	699,477	816,974	822,150	46.9	42.6	47.8
North Dakota	4,484	4,688	5,161	66,272	74,916	80,276	67.7	62.6	64.3
Ohio	48,865	51,026	56,993	1,052,052	1,081,211	1,112,156	46.4	47.2	51.2
Oklahoma	14,412	15,789	17,922	328,471	367,634	375,095	43.9	42.9	47.8
Oregon	13,159	13,452	16,296	287,641	337,895	341,623	45.7	39.8	47.7
Pennsylvania	61,840	67,041	78,044	1,039,419	1,121,633	1,191,907	59.5	59.8	65.5
Rhode Island	8,788	8,468	9,811	84,855	109,933	116,201	103.6	77.0	84.4
South Carolina	14,998	16,676	19,256	381,672	418,585	420,351	39.3	39.8	45.8
South Dakota	4,603	4,363	4,921	73,421	79,589	83,635	62.7	54.8	58.8
Tennessee	20,659	22,712	25,770	510,638	563,333	557,703	40.5	40.3	46.2
Texas	70,765	76,037	88,000	1,947,117	2,280,525	2,421,692	36.3	33.3	36.3
Utah	15,275	16,775	19,565	265,713	329,723	326,302	57.5	50.9	60.0
Vermont	4,492	4,671	4,841	51,912	58,647	62,424	86.5	79.6	77.6
Virginia	30,914	32,895	36,747	649,086	697,925	737,118	47.6	47.1	49.9
Washington	22,492	23,271	27,571	505,840	581,479	605,063	44.5	40.0	45.6
West Virginia	8,582	8,704	9,572	186,316	174,936	167,236	46.1	49.8	57.2
Wisconsin	26,934	28,415	30,839	483,384	535,174	562,611	55.7	53.1	54.8
Wyoming	1,641	1,677	1,695	51,218	51,476	54,090	32.0	32.6	31.3
Puerto Rico	14,110	15,762	16,669	NA	426,194	411,575	NA	37.0	40.5

NA = not available

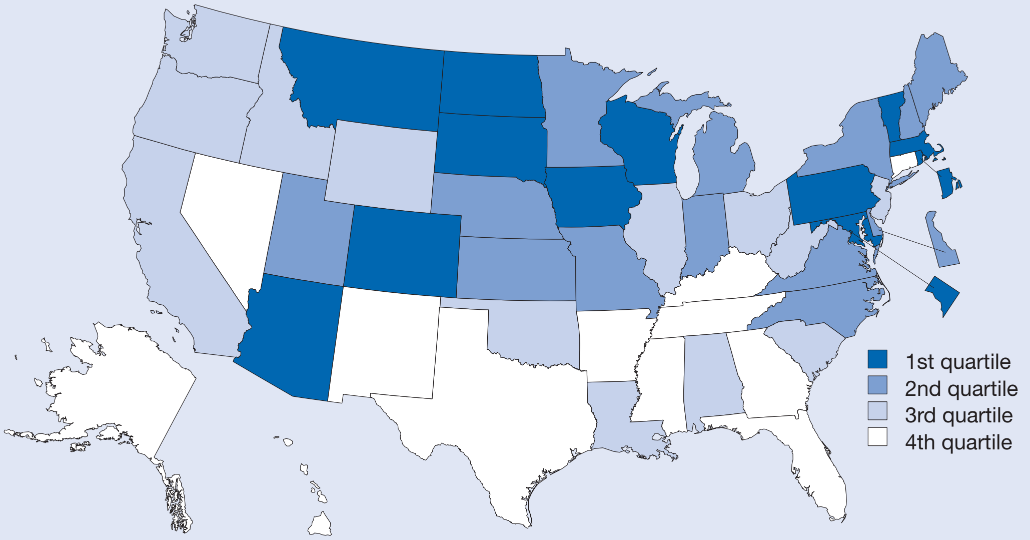
SOURCES: National Center for Education Statistics, Integrated Postsecondary Education Data System (various years); Census Bureau, 2000 Decennial Census; and Population Estimates Program (various years).

Science & Engineering Indicators 2008

Bachelor's Degrees in Natural Sciences and Engineering Conferred per 1,000 Individuals 18–24 Years Old

Figure 8-16

Bachelor's degrees in natural sciences and engineering conferred per 1,000 individuals 18–24 years old: 2005



1st quartile (18.6–9.9)	2nd quartile (9.8–8.2)	3rd quartile (8.1–6.9)	4th quartile (6.8–3.1)
Arizona	Delaware	Alabama	Alaska
Colorado	Indiana	California	Arkansas
District of Columbia	Kansas	Idaho	Connecticut
Iowa	Maine	Illinois	Florida
Maryland	Michigan	Louisiana	Georgia
Massachusetts	Minnesota	New Jersey	Hawaii
Montana	Missouri	Ohio	Kentucky
North Dakota	Nebraska	Oklahoma	Mississippi
Pennsylvania	New Hampshire	Oregon	Nevada
Rhode Island	New York	South Carolina	New Mexico
South Dakota	North Carolina	Washington	Tennessee
Vermont	Utah	West Virginia	Texas
Wisconsin	Virginia	Wyoming	

SOURCES: National Center for Education Statistics, Integrated Postsecondary Education Data System (various years); Census Bureau, 2000 Decennial Census; and Population Estimates Program (various years). See table 8-16.

Findings

- During the past decade, the value of this indicator has remained unchanged at 7.9 NS&E bachelor's degrees conferred per 1,000 18–24-year-olds.
- The percentage of NS&E bachelor's degrees among all bachelor's degrees conferred declined slightly from 16.8% in 1996 to 16.4% in 2005.
- The value of this indicator ranged from 3.1 to 14.9 for individual states. However, the District of Columbia had a value of 18.6, reflecting a large concentration of academic institutions relative to the size of the resident population.
- The value for this indicator has decreased in 21 states and the District of Columbia over the past decade.
- State rankings 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 but exclude social sciences and psychology. The ratio of new NS&E bachelor's degrees to the 18–24-year-old population indicates the extent 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 may generate resources for the state. The 18–24-year-old cohort was chosen to approximate the age range of most students who are pursing an undergraduate degree.

Although the number of NS&E bachelor's degrees awarded is based on an actual count, the population of 18–24-year-olds is an estimate developed by the Census Bureau in the Population Estimates Program, which relies on the Decennial Census. This estimate may make the value of this indicator imprecise for jurisdictions with small populations.

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 8-16

Bachelor's degrees in natural sciences and engineering conferred per 1,000 individuals 18–24 years old, by state: 1996, 2001, and 2005

	NS&E bachelor's degrees			Population 18–24 years old			Degrees/1,000 individuals 18–24 years old		
State	1996	2001	2005	1996	2001	2005	1996	2001	2005
United States	196,433	208,494	232,707	24,842,610	27,998,931	29,333,266	7.9	7.4	7.9
Alabama	3,635	3,596	3,424	437,421	448,725	448,894	8.3	8.0	7.6
Alaska	293	230	248	64,682	60,394	70,429	4.5	3.8	3.5
Arizona	2,846	3,004	6,028	417,142	536,708	576,725	6.8	5.6	10.5
Arkansas	1,408	1,492	1,630	247,651	268,747	270,471	5.7	5.6	6.0
California	20,744	22,180	25,702	2,982,515	3,487,649	3,726,736	7.0	6.4	6.9
Colorado	4,443	4,592	5,107	354,247	449,661	459,040	12.5	10.2	11.1
Connecticut	2,055	1,902	2,116	261,580	282,433	313,202	7.9	6.7	6.8
Delaware	674	682	689	65,107	78,501	83,016	10.4	8.7	8.3
District of Columbia	1,314	1,685	1,304	45,801	72,372	70,265	28.7	23.3	18.6
Florida	6,462	7,422	8,525	1,168,986	1,399,219	1,572,959	5.5	5.3	5.4
Georgia	4,565	5,025	5,943	728,478	865,538	903,396	6.3	5.8	6.6
Hawaii	615	670	724	116,166	118,324	123,584	5.3	5.7	5.9
Idaho	890	900	1,210	130,028	144,632	149,739	6.8	6.2	8.1
Illinois	8,339	9,216	9,667	1,111,306	1,242,578	1,274,718	7.5	7.4	7.6
Indiana	5,095	4,953	5,797	571,520	627,241	623,312	8.9	7.9	9.3
Iowa	2,888	3,055	3,199	269,324	302,946	311,451	10.7	10.1	10.3
Kansas	2,329	2,536	2,596	249,744	281,504	292,984	9.3	9.0	8.9
Kentucky	2,195	2,132	2,290	397,201	409,650	395,618	5.5	5.2	5.8
Louisiana	3,078	3,480	3,539	459,805	484,149	490,354	6.7	7.2	7.2
Maine	970	1,060	1,136	110,955	108,029	117,048	8.7	9.8	9.7
Maryland	4,086	4,737	5,845	427,478	473,697	526,277	9.6	10.0	11.1
Massachusetts	7,207	7,209	7,613	511,122	593,001	625,908	14.1	12.2	12.2
Michigan	8,342	8,344	9,096	921,950	957,339	986,126	9.0	8.7	9.2
Minnesota	3,719	4,009	4,652	418,324	486,487	516,133	8.9	8.2	9.0
Mississippi	1,714	1,755	1,630	299,031	316,573	311,137	5.7	5.5	5.2
Missouri	4,218	4,891	5,238	495,615	552,843	572,472	8.5	8.8	9.1
Montana	1,014	1,171	1,127	85,538	88,639	94,488	11.9	13.2	11.9
Nebraska	1,395	1,495	1,631	161,398	178,383	188,583	8.6	8.4	8.6
Nevada	493	527	653	133,106	189,705	207,871	3.7	2.8	3.1
New Hampshire	1,241	1,198	1,130	94,357	108,106	121,124	13.2	11.1	9.3
New Jersey	4,426	5,199	5,354	668,453	696,100	747,332	6.6	7.5	7.2
New Mexico	1,135	1,140	1,276	169,870	186,485	205,017	6.7	6.1	6.2
New York	14,026	15,153	16,686	1,602,205	1,820,985	1,919,224	8.8	8.3	8.7
North Carolina	6,236	6,183	6,773	699,477	816,974	822,150	8.9	7.6	8.2
North Dakota	821	798	913	66,272	74,916	80,276	12.4	10.7	11.4
Ohio	7,594	7,754	8,086	1,052,052	1,081,211	1,112,156	7.2	7.2	7.3
Oklahoma	2,182	2,491	2,580	328,471	367,634	375,095	6.6	6.8	6.9
Oregon	1,974	2,371	2,753	287,641	337,895	341,623	6.9	7.0	8.1
Pennsylvania	11,281	12,049	13,819	1,039,419	1,121,633	1,191,907	10.9	10.7	11.6
Rhode Island	1,229	1,202	1,730	84,855	109,933	116,201	14.5	10.9	14.9
South Carolina	2,711	2,795	3,062	381,672	418,585	420,351	7.1	6.7	7.3
South Dakota	988	939	1,090	73,421	79,589	83,635	13.5	11.8	13.0
Tennessee	3,511	3,281	3,528	510,638	563,333	557,703	6.9	5.8	6.3
Texas	11,390	11,798	13,681	1,947,117	2,280,525	2,421,692	5.8	5.2	5.6
Utah	2,606	2,797	3,184	265,713	329,723	326,302	9.8	8.5	9.8
Vermont	720	846	865	51,912	58,647	62,424	13.9	14.4	13.9
Virginia	5,564	5,978	6,187	649,086	697,925	737,118	8.6	8.6	8.4
Washington	3,503	3,861	4,426	505,840	581,479	605,063	6.9	6.6	7.3
West Virginia	1,248	1,296	1,288	186,316	174,936	167,236	6.7	7.4	7.7
Wisconsin	4,609	5,004	5,559	483,384	535,174	562,611	9.5	9.4	9.9
Wyoming	412	411	378	51,218	51,476	54,090	8.0	8.0	7.0
Puerto Rico	2,586	3,054	2,848	NA	426,194	411,575	NA	7.2	6.9

NA = not available

NS&E = natural sciences and engineering

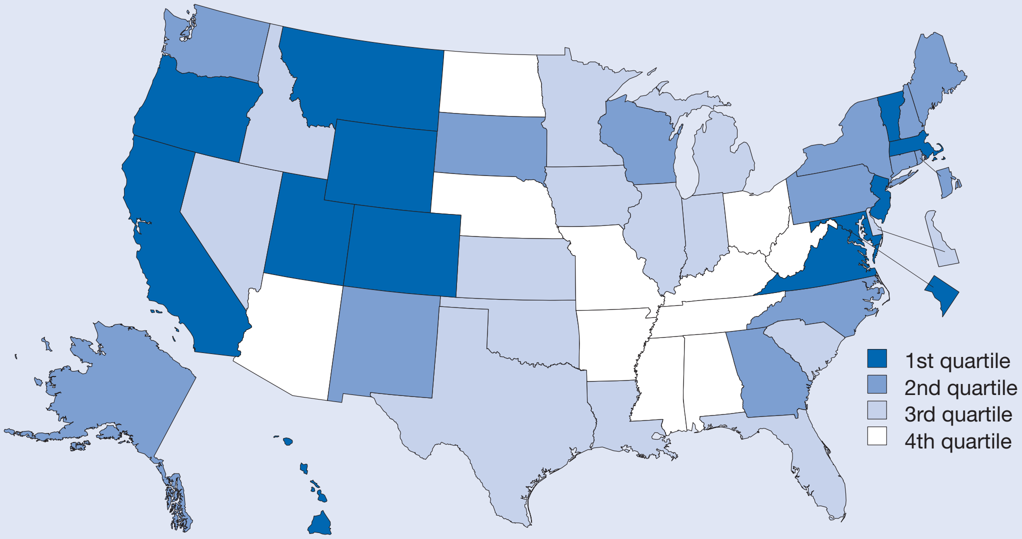
SOURCES: National Center for Education Statistics, Integrated Postsecondary Education Data System (various years); Census Bureau, 2000 Decennial Census; and Population Estimates Program (various years).

Science & Engineering Indicators 2008

S&E Degrees as Share of Higher Education Degrees Conferred

Figure 8-17

S&E degrees as share of higher education degrees conferred: 2005



1st quartile (40.8%–33.3%)	2nd quartile (32.9%–29.2%)	3rd quartile (28.9%–26.3%)	4th quartile (25.8%–18.2%)
California	Alaska	Delaware	Alabama
Colorado	Connecticut	Florida	Arizona
District of Columbia	Georgia	Idaho	Arkansas
Hawaii	Maine	Illinois	Kentucky
Maryland	New Hampshire	Indiana	Mississippi
Massachusetts	New Mexico	Iowa	Missouri
Montana	New York	Kansas	Nebraska
New Jersey	North Carolina	Louisiana	North Dakota
Oregon	Pennsylvania	Michigan	Ohio
Utah	Rhode Island	Minnesota	Tennessee
Vermont	South Dakota	Nevada	West Virginia
Virginia	Washington	Oklahoma	
Wyoming	Wisconsin	South Carolina	
		Texas	

SOURCE: National Center for Education Statistics, Integrated Postsecondary Education Data System (various years). See Table 8-17.

Findings

- In 2005, more than 609,000 S&E bachelor's, master's, and doctoral degrees were conferred nationwide, an increase of 21% during the past decade.
- Overall, there has been a slight decline in the number of S&E degrees as a share of total degrees conferred from 31.0% in 1996 to 29.9% in 2005.
- States place different emphases on technical higher education. In some states, nearly 40% of their degrees are awarded in S&E fields; in others approximately 20% of their degrees are awarded in these fields.
- State emphasis on S&E education remained relatively constant over the decade; notable exceptions are increases in Hawaii and Maryland and decreases in Wyoming and Arizona.
- The District of Columbia has a high value of 41% 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 S&E 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 2005 represent degrees conferred during the 2004–05 academic year.

Table 8-17

S&E degrees as share of higher education degrees conferred, by state: 1996, 2001, and 2005

	S&E degrees			All higher education degrees			S&E/higher education degrees (%)		
State	1996	2001	2005	1996	2001	2005	1996	2001	2005
United States	502,046	519,446	609,114	1,617,096	1,750,369	2,036,215	31.0	29.7	29.9
Alabama	6,975	7,426	7,951	27,139	29,302	31,951	25.7	25.3	24.9
Alaska	670	604	676	1,999	1,776	2,107	33.5	34.0	32.1
Arizona	6,655	6,565	10,968	27,922	40,468	60,188	23.8	16.2	18.2
Arkansas	2,774	2,844	3,306	11,239	12,058	14,303	24.7	23.6	23.1
California	58,551	62,752	75,803	152,162	167,200	197,839	38.5	37.5	38.3
Colorado	11,073	11,696	13,189	27,577	30,390	35,346	40.2	38.5	37.3
Connecticut	6,976	6,929	8,154	21,205	22,479	26,378	32.9	30.8	30.9
Delaware	1,894	1,861	2,158	5,739	6,116	7,455	33.0	30.4	28.9
District of Columbia	6,675	6,856	7,477	15,872	15,939	18,307	42.1	43.0	40.8
Florida	17,289	18,561	23,974	63,271	69,121	84,841	27.3	26.9	28.3
Georgia	10,572	11,489	14,394	37,426	39,537	48,691	28.2	29.1	29.6
Hawaii	1,942	2,131	2,349	6,419	6,461	7,031	30.3	33.0	33.4
Idaho	1,722	1,756	2,360	5,686	5,809	8,969	30.3	30.2	26.3
Illinois	21,551	23,370	25,927	80,126	86,923	95,634	26.9	26.9	27.1
Indiana	11,882	11,187	13,317	39,319	41,484	48,940	30.2	27.0	27.2
Iowa	6,506	6,389	7,328	21,761	22,680	25,393	29.9	28.2	28.9
Kansas	5,332	5,660	6,139	20,246	20,705	22,791	26.3	27.3	26.9
Kentucky	4,933	5,015	6,085	19,566	20,749	25,138	25.2	24.2	24.2
Louisiana	6,781	6,924	7,773	23,737	26,173	28,398	28.6	26.5	27.4
Maine	2,168	2,236	2,550	6,572	6,659	8,173	33.0	33.6	31.2
Maryland	11,479	12,710	15,608	31,688	34,738	39,918	36.2	36.6	39.1
Massachusetts	22,230	22,825	25,232	65,306	70,333	75,589	34.0	32.5	33.4
Michigan	18,796	18,611	21,249	61,625	68,231	74,695	30.5	27.3	28.4
Minnesota	9,289	9,163	11,199	30,672	31,906	40,897	30.3	28.7	27.4
Mississippi	3,473	3,472	3,577	13,108	14,904	15,931	26.5	23.3	22.5
Missouri	10,319	11,353	12,852	38,843	44,278	52,183	26.6	25.6	24.6
Montana	1,891	2,076	2,254	5,535	6,049	6,416	34.2	34.3	35.1
Nebraska	3,119	3,261	3,836	12,542	14,315	16,421	24.9	22.8	23.4
Nevada	1,178	1,277	1,826	4,448	5,366	6,723	26.5	23.8	27.2
New Hampshire	2,893	2,940	3,316	9,857	9,526	10,755	29.3	30.9	30.8
New Jersey	12,560	13,842	15,667	34,043	37,760	45,515	36.9	36.7	34.4
New Mexico	2,864	2,522	2,860	8,865	8,460	9,718	32.3	29.8	29.4
New York	43,392	44,664	51,555	144,398	153,327	176,746	30.1	29.1	29.2
North Carolina	14,516	14,543	16,664	41,615	45,316	52,136	34.9	32.1	32.0
North Dakota	1,462	1,397	1,539	5,268	5,597	6,454	27.8	25.0	23.8
Ohio	19,333	18,661	20,687	68,153	71,266	80,181	28.4	26.2	25.8
Oklahoma	4,982	5,914	6,286	18,626	21,421	23,921	26.7	27.6	26.3
Oregon	6,153	6,427	7,691	17,582	18,646	22,764	35.0	34.5	33.8
Pennsylvania	25,756	26,717	31,632	83,683	91,693	107,302	30.8	29.1	29.5
Rhode Island	3,243	2,872	3,646	11,089	10,633	12,277	29.2	27.0	29.7
South Carolina	5,893	6,131	6,857	19,889	21,781	24,873	29.6	28.1	27.6
South Dakota	1,990	1,801	2,017	5,757	5,445	6,227	34.6	33.1	32.4
Tennessee	7,813	7,787	8,706	27,572	31,505	34,953	28.3	24.7	24.9
Texas	27,252	28,242	34,716	96,227	103,447	123,473	28.3	27.3	28.1
Utah	6,308	6,101	7,840	18,498	20,346	23,521	34.1	30.0	33.3
Vermont	2,128	2,129	2,493	5,844	6,014	6,543	36.4	35.4	38.1
Virginia	15,376	15,782	17,549	42,580	44,738	50,670	36.1	35.3	34.6
Washington	9,523	9,907	12,020	31,320	31,299	36,531	30.4	31.7	32.9
West Virginia	2,761	2,699	2,945	10,885	11,225	12,520	25.4	24.0	23.5
Wisconsin	10,253	10,538	12,160	34,466	36,614	40,287	29.7	28.8	30.2
Wyoming	900	831	757	2,129	2,161	2,202	42.3	38.5	34.4
Puerto Rico	4,113	5,034	5,031	15,736	18,378	20,855	26.1	27.4	24.1

NOTES: S&E degrees include bachelor's, master's, and doctorate. S&E degrees include physical, computer, agricultural, biological, earth, atmospheric, ocean, and social sciences; psychology; mathematics; and engineering. All higher education degrees include bachelor's, master's, and doctorate.

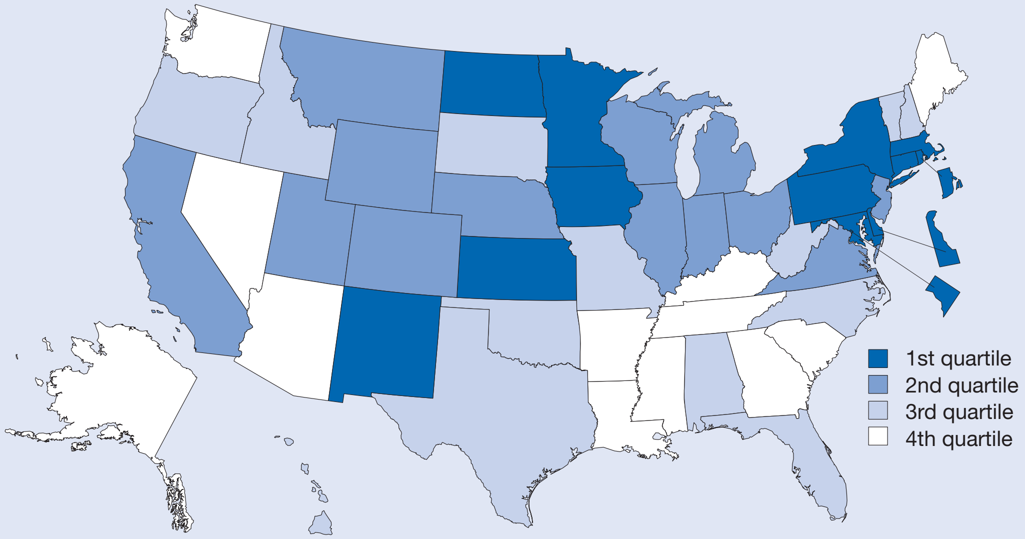
SOURCE: National Center for Education Statistics, Integrated Postsecondary Education Data System (various years).

Science & Engineering Indicators 2008

S&E Graduate Students per 1,000 Individuals 25–34 Years Old

Figure 8-18

S&E graduate students per 1,000 individuals 25–34 years old: 2005



1st quartile (83.1–13.8)	2nd quartile (13.6–10.9)	3rd quartile (10.8–8.5)	4th quartile (8.4–4.5)
Connecticut	California	Alabama	Alaska
Delaware	Colorado	Florida	Arizona
District of Columbia	Illinois	Hawaii	Arkansas
Iowa	Indiana	Idaho	Georgia
Kansas	Michigan	Missouri	Kentucky
Maryland	Montana	New Hampshire	Louisiana
Massachusetts	Nebraska	North Carolina	Maine
Minnesota	New Jersey	Oklahoma	Mississippi
New Mexico	Ohio	Oregon	Nevada
New York	Utah	South Dakota	South Carolina
North Dakota	Virginia	Texas	Tennessee
Pennsylvania	Wisconsin	Vermont	Washington
Rhode Island	Wyoming	West Virginia	

SOURCES: National Science Foundation, Division of Science Resources Statistics, Survey of Graduate Students and Postdoctorates in Science and Engineering; and Census Bureau, Population Estimates Program (various years). See table 8-18.

Findings

- The number of S&E graduate students in the United States grew 15% over the previous decade, rising from approximately 409,000 in 1996 to more than 471,000 in 2005.
- Individual states showed varying levels of graduate level S&E training, with 0.5%–2.7% of their 25–34-year-old population pursuing S&E graduate studies in 2005.
- The District of Columbia is an outlier, with about 8% 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.
- Changes in the value of this indicator over the past decade may reflect shifts in population, changes in S&E graduate education, or a combination of both. Growth in the number of S&E graduate students was highest in California, Texas, and Florida between 1996 and 2005.

Graduate students in S&E fields may become the technical leaders of the future. The ratio of S&E graduate students to a state's 25–34-year-old population is a relative measure of a state's population with graduate training in S&E. The 25–34-year-old cohort was chosen to approximate the age of most graduate students. The cohort includes U.S. citizens and noncitizens as well as graduate students who come from other states. The population cohort includes all state residents ages 25–34 and does not distinguish between citizens and noncitizens.

Data on S&E graduate students were collected by surveying all academic institutions in the United States that offer doctoral 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 8-18
S&E graduate students per 1,000 individuals 25–34 years old, by state: 1996, 2001, and 2005

	S&E graduate students			Population 25–34 years old			S&E graduate students/ 1,000 individuals 25–34 years old		
State	1996	2001	2005	1996	2001	2005	1996	2001	2005
United States	408,754	422,331	471,371	40,245,871	39,701,883	40,144,656	10.2	10.6	11.7
Alabama	5,334	5,257	6,232	630,233	591,099	596,242	8.5	8.9	10.5
Alaska	782	611	795	84,704	88,274	94,149	9.2	6.9	8.4
Arizona	6,381	6,665	6,849	657,074	760,730	864,417	9.7	8.8	7.9
Arkansas	2,040	2,052	2,420	338,213	349,764	370,205	6.0	5.9	6.5
California	51,004	54,249	63,474	5,347,874	5,270,958	5,261,651	9.5	10.3	12.1
Colorado	8,364	8,843	8,835	558,163	681,814	706,360	15.0	13.0	12.5
Connecticut	5,732	6,900	6,943	503,807	438,925	413,537	11.4	15.7	16.8
Delaware	1,459	1,461	1,760	121,415	106,814	107,945	12.0	13.7	16.3
District of Columbia	8,255	7,448	8,662	108,632	102,322	104,177	76.0	72.8	83.1
Florida	14,264	16,345	19,130	2,002,813	2,086,696	2,234,269	7.1	7.8	8.6
Georgia	8,508	9,345	10,675	1,215,294	1,309,335	1,354,947	7.0	7.1	7.9
Hawaii	1,734	1,455	1,892	168,485	169,440	175,190	10.3	8.6	10.8
Idaho	1,343	1,495	1,923	149,784	171,653	196,134	9.0	8.7	9.8
Illinois	22,121	24,173	23,307	1,825,273	1,802,505	1,787,380	12.1	13.4	13.0
Indiana	8,781	8,489	9,695	867,584	822,315	841,485	10.1	10.3	11.5
Iowa	4,722	4,693	5,009	383,395	357,757	358,104	12.3	13.1	14.0
Kansas	5,873	5,846	5,825	368,460	345,539	351,504	15.9	16.9	16.6
Kentucky	3,740	4,017	4,625	565,744	560,393	578,303	6.6	7.2	8.0
Louisiana	5,585	5,703	4,777	614,661	585,687	593,005	9.1	9.7	8.1
Maine	666	605	684	176,186	154,509	151,290	3.8	3.9	4.5
Maryland	9,253	9,181	11,198	838,211	737,209	729,112	11.0	12.5	15.4
Massachusetts	19,537	20,118	22,493	1,036,693	911,871	838,499	18.8	22.1	26.8
Michigan	14,593	15,431	15,224	1,449,151	1,338,131	1,289,703	10.1	11.5	11.8
Minnesota	6,465	6,634	10,674	691,672	669,256	671,628	9.3	9.9	15.9
Mississippi	2,703	2,594	3,138	382,545	375,787	381,834	7.1	6.9	8.2
Missouri	5,895	6,320	7,278	770,644	731,638	757,374	7.6	8.6	9.6
Montana	1,146	1,176	1,371	101,054	101,958	109,731	11.3	11.5	12.5
Nebraska	2,560	2,428	2,811	223,417	221,334	225,120	11.5	11.0	12.5
Nevada	1,439	1,584	1,992	252,663	316,202	363,877	5.7	5.0	5.5
New Hampshire	1,216	1,337	1,448	188,221	158,323	153,457	6.5	8.4	9.4
New Jersey	10,429	11,148	12,093	1,200,054	1,170,282	1,105,168	8.7	9.5	10.9
New Mexico	3,171	3,269	3,762	228,959	231,954	249,745	13.8	14.1	15.1
New York	38,439	38,613	42,039	2,852,788	2,706,393	2,559,820	13.5	14.3	16.4
North Carolina	9,768	10,494	12,019	1,150,418	1,213,053	1,215,149	8.5	8.7	9.9
North Dakota	896	1,078	1,512	87,491	74,406	74,480	10.2	14.5	20.3
Ohio	17,491	16,080	18,885	1,633,740	1,489,708	1,459,108	10.7	10.8	12.9
Oklahoma	3,905	4,166	4,274	442,383	448,235	467,576	8.8	9.3	9.1
Oregon	3,831	3,844	4,310	437,028	476,414	506,932	8.8	8.1	8.5
Pennsylvania	18,814	18,348	20,146	1,705,702	1,520,455	1,460,565	11.0	12.1	13.8
Rhode Island	1,662	1,646	2,018	158,924	137,986	134,088	10.5	11.9	15.0
South Carolina	3,507	3,120	3,234	573,575	553,179	563,274	6.1	5.6	5.7
South Dakota	918	982	930	93,985	89,669	92,998	9.8	11.0	10.0
Tennessee	6,090	5,737	6,448	801,585	804,104	826,126	7.6	7.1	7.8
Texas	26,007	28,224	32,582	2,897,002	3,207,841	3,392,687	9.0	8.8	9.6
Utah	4,107	4,034	4,884	292,112	333,573	390,591	14.1	12.1	12.5
Vermont	599	597	644	87,507	72,773	71,097	6.8	8.2	9.1
Virginia	11,571	12,156	12,408	1,114,265	1,030,917	1,044,709	10.4	11.8	11.9
Washington	5,802	5,834	6,513	828,876	844,924	874,525	7.0	6.9	7.4
West Virginia	1,885	2,013	2,205	230,950	224,034	232,453	8.2	9.0	9.5
Wisconsin	7,606	7,729	8,439	750,352	694,595	697,679	10.1	11.1	12.1
Wyoming	761	764	887	56,110	59,150	65,257	13.6	12.9	13.6
Puerto Rico	2,206	3,062	3,649	NA	537,823	550,887	NA	5.7	6.6

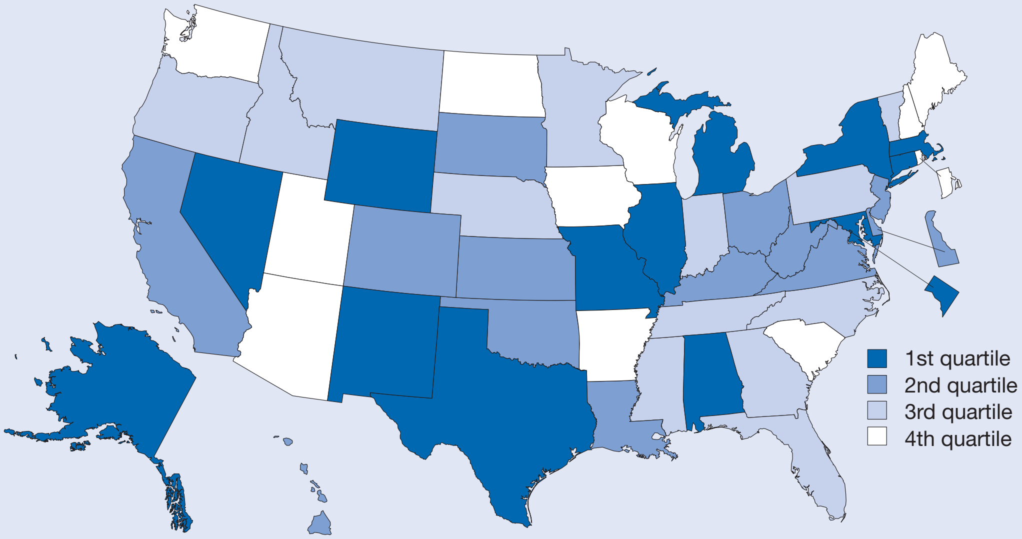
NA = not available

SOURCES: National Science Foundation, Division of Science Resources Statistics, Survey of Graduate Students and Postdoctorates in Science and Engineering; and Census Bureau, Population Estimates Program (various years).

Science & Engineering Indicators 2008

Advanced S&E Degrees as Share of S&E Degrees Conferred

Figure 8-19
Advanced S&E degrees as share of S&E degrees conferred: 2005



1st quartile (44.4%–26.4%)	2nd quartile (25.8%–22.4%)	3rd quartile (22.2%–18.0%)	4th quartile (17.8%–7.7%)
Alabama	California	Florida	Arizona
Alaska	Colorado	Georgia	Arkansas
Connecticut	Delaware	Idaho	Iowa
District of Columbia	Hawaii	Indiana	Maine
Illinois	Kansas	Minnesota	New Hampshire
Maryland	Kentucky	Mississippi	North Dakota
Massachusetts	Louisiana	Montana	Rhode Island
Michigan	New Jersey	Nebraska	South Carolina
Missouri	Ohio	North Carolina	Utah
Nevada	Oklahoma	Oregon	Washington
New Mexico	South Dakota	Pennsylvania	Wisconsin
New York	Virginia	Tennessee	
Texas	West Virginia	Vermont	
Wyoming			

SOURCE: National Center for Education Statistics, Integrated Postsecondary Education Data System (various years). See table 8-19.

Findings

- In 2005, more than 147,000 advanced S&E degrees were awarded nationwide; this total represented approximately 22% more than in 1996, but the share of advanced degrees remained stable at 24% of all S&E degrees conferred.
- Some states specialize in providing graduate-level technical training, with nearly 35% 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%.
- Over the past decade, the largest absolute increases in the production of advanced S&E degree holders have occurred in California, New York, and Texas.
- In states with small S&E graduate programs, the number of advanced S&E degrees conferred varies considerably from year to year. Caution should be used in making annual comparisons for those states with small S&E graduate programs.
- The District of Columbia is an outlier, with 44% reflecting large S&E graduate programs in political science and public administration at several of its academic institutions.

This indicator shows the extent to which a state's higher education programs in S&E 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 S&E degrees include bachelor's, master's, and doctoral degrees but exclude associate's degrees.

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's higher education institutions are emphasizing S&E training at the graduate level.

Table 8-19

Advanced S&E degrees as share of S&E degrees conferred, by state: 1996, 2001, and 2005

	Advanced S&E degrees			All S&E degrees			Advanced/all S&E degrees (%)		
State	1996	2001	2005	1996	2001	2005	1996	2001	2005
United States	121,109	123,561	147,339	502,046	519,446	609,114	24.1	23.8	24.2
Alabama	1,470	1,969	2,271	6,975	7,426	7,951	21.1	26.5	28.6
Alaska	209	184	236	670	604	676	31.2	30.5	34.9
Arizona	1,810	1,632	1,851	6,655	6,565	10,968	27.2	24.9	16.9
Arkansas	439	440	558	2,774	2,844	3,306	15.8	15.5	16.9
California	14,889	15,208	18,894	58,551	62,752	75,803	25.4	24.2	24.9
Colorado	2,919	2,991	3,194	11,073	11,696	13,189	26.4	25.6	24.2
Connecticut	1,767	1,768	2,209	6,976	6,929	8,154	25.3	25.5	27.1
Delaware	434	419	507	1,894	1,861	2,158	22.9	22.5	23.5
District of Columbia	3,194	2,990	3,317	6,675	6,856	7,477	47.9	43.6	44.4
Florida	4,022	4,176	5,253	17,289	18,561	23,974	23.3	22.5	21.9
Georgia	2,403	2,551	3,182	10,572	11,489	14,394	22.7	22.2	22.1
Hawaii	444	529	538	1,942	2,131	2,349	22.9	24.8	22.9
Idaho	389	341	424	1,722	1,756	2,360	22.6	19.4	18.0
Illinois	6,366	7,171	8,280	21,551	23,370	25,927	29.5	30.7	31.9
Indiana	2,629	2,439	2,840	11,882	11,187	13,317	22.1	21.8	21.3
Iowa	1,178	1,014	1,261	6,506	6,389	7,328	18.1	15.9	17.2
Kansas	1,201	1,203	1,394	5,332	5,660	6,139	22.5	21.3	22.7
Kentucky	887	974	1,551	4,933	5,015	6,085	18.0	19.4	25.5
Louisiana	1,481	1,435	1,758	6,781	6,924	7,773	21.8	20.7	22.6
Maine	207	174	196	2,168	2,236	2,550	9.5	7.8	7.7
Maryland	3,458	3,832	4,617	11,479	12,710	15,608	30.1	30.1	29.6
Massachusetts	6,477	6,636	7,653	22,230	22,825	25,232	29.1	29.1	30.3
Michigan	4,734	4,933	5,741	18,796	18,611	21,249	25.2	26.5	27.0
Minnesota	1,843	1,683	2,137	9,289	9,163	11,199	19.8	18.4	19.1
Mississippi	709	636	793	3,473	3,472	3,577	20.4	18.3	22.2
Missouri	2,807	2,939	3,452	10,319	11,353	12,852	27.2	25.9	26.9
Montana	345	358	447	1,891	2,076	2,254	18.2	17.2	19.8
Nebraska	671	697	808	3,119	3,261	3,836	21.5	21.4	21.1
Nevada	297	304	482	1,178	1,277	1,826	25.2	23.8	26.4
New Hampshire	416	463	490	2,893	2,940	3,316	14.4	15.7	14.8
New Jersey	3,023	3,225	3,811	12,560	13,842	15,667	24.1	23.3	24.3
New Mexico	931	729	857	2,864	2,522	2,860	32.5	28.9	30.0
New York	11,219	11,444	13,816	43,392	44,664	51,555	25.9	25.6	26.8
North Carolina	2,502	2,717	3,177	14,516	14,543	16,664	17.2	18.7	19.1
North Dakota	221	183	234	1,462	1,397	1,539	15.1	13.1	15.2
Ohio	5,257	4,650	5,222	19,333	18,661	20,687	27.2	24.9	25.2
Oklahoma	1,285	1,847	1,624	4,982	5,914	6,286	25.8	31.2	25.8
Oregon	1,299	1,296	1,544	6,153	6,427	7,691	21.1	20.2	20.1
Pennsylvania	5,449	5,507	6,753	25,756	26,717	31,632	21.2	20.6	21.3
Rhode Island	662	532	610	3,243	2,872	3,646	20.4	18.5	16.7
South Carolina	1,025	1,114	1,104	5,893	6,131	6,857	17.4	18.2	16.1
South Dakota	417	379	472	1,990	1,801	2,017	21.0	21.0	23.4
Tennessee	1,427	1,506	1,563	7,813	7,787	8,706	18.3	19.3	18.0
Texas	7,072	7,464	9,438	27,252	28,242	34,716	26.0	26.4	27.2
Utah	1,054	1,011	1,283	6,308	6,101	7,840	16.7	16.6	16.4
Vermont	379	295	501	2,128	2,129	2,493	17.8	13.9	20.1
Virginia	3,199	3,238	3,926	15,376	15,782	17,549	20.8	20.5	22.4
Washington	1,970	1,852	2,141	9,523	9,907	12,020	20.7	18.7	17.8
West Virginia	483	523	660	2,761	2,699	2,945	17.5	19.4	22.4
Wisconsin	1,863	1,730	2,069	10,253	10,538	12,160	18.2	16.4	17.0
Wyoming	277	230	200	900	831	757	30.8	27.7	26.4
Puerto Rico	453	791	910	4,113	5,034	5,031	11.0	15.7	18.1

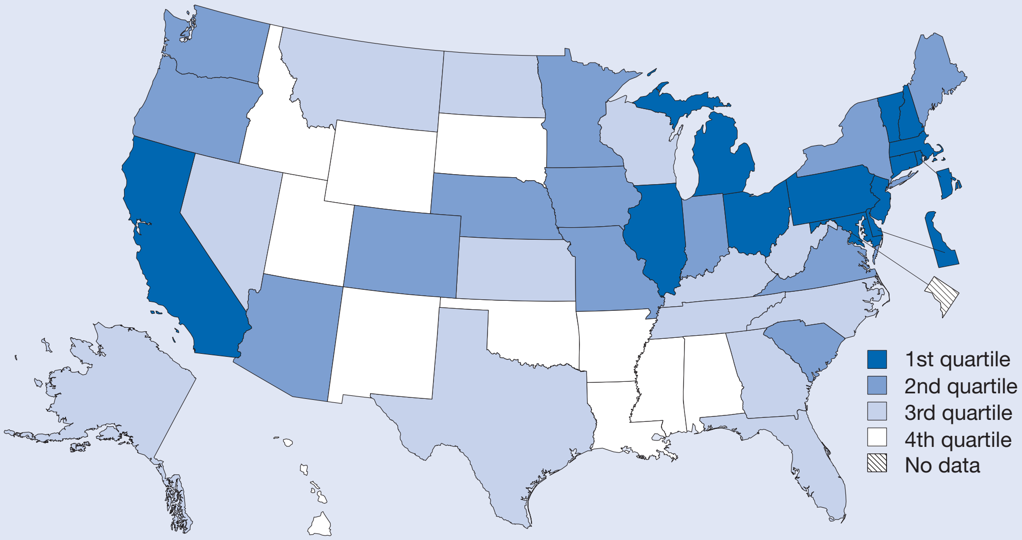
NOTES: All degrees include bachelor's, master's, and doctorate; advanced degrees include only master's and doctorate. S&E degrees include physical, computer, agricultural, biological, earth, atmospheric, ocean, and social sciences; psychology; mathematics; and engineering.

SOURCE: National Center for Education Statistics, Integrated Postsecondary Education Data System (various years).

Science & Engineering Indicators 2008

Average Undergraduate Charge at Public 4-Year Institutions

Figure 8-20
Average undergraduate charge at public 4-year institutions: 2006



1st quartile ($17,708–$13,685)	2nd quartile ($13,275–$11,286)	3rd quartile ($10,973–$9,675)	4th quartile ($9,625–$8,506)	No data
California	Arizona	Alaska	Alabama	District of Columbia
Connecticut	Colorado	Florida	Arkansas	
Delaware	Indiana	Georgia	Hawaii	
Illinois	Iowa	Kansas	Idaho	
Maryland	Maine	Kentucky	Louisiana	
Massachusetts	Minnesota	Montana	Mississippi	
Michigan	Missouri	Nevada	New Mexico	
New Hampshire	Nebraska	North Carolina	Oklahoma	
New Jersey	New York	North Dakota	South Dakota	
Ohio	Oregon	Tennessee	Utah	
Pennsylvania	South Carolina	Texas	Wyoming	
Rhode Island	Virginia	West Virginia		
Vermont	Washington	Wisconsin		

SOURCE: National Center for Education Statistics, Integrated Postsecondary Education Data System (various years). See table 8-20.

Findings

- During 2006, the total annual nominal charge for a full-time undergraduate student to attend a public 4-year institution averaged $12,108 nationally, an increase of 73% during the past decade in current dollars.
- All states showed major increases in undergraduate charges at public institutions in 2006 compared with 1996. In Oklahoma, Iowa, Nebraska, and Texas, undergraduate charges more than doubled during this period.
- In 2006, the state average for a year of undergraduate education at a public 4-year institution ranged from a low of $8,506 to a high of $17,708.
- 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 S&E is to a state's 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 attending each public institution within the state. The total charge for all public 4-year institutions in the state was divided by the total number of full-time undergraduates attending all public 4-year institutions in the state. The year is the latter date of the academic year. For example, data for 2006 represent costs for the 2005–06 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 8-20

Average undergraduate charge at public 4-year institutions, by state: 1996, 2001, and 2006

(Dollars)

State	1996	2001	2006
United States	7,014	8,653	12,108
Alabama	5,735	7,349	9,625
Alaska	6,663	8,390	10,620
Arizona	5,996	7,874	11,480
Arkansas	5,055	6,797	9,192
California	8,209	9,590	13,685
Colorado	7,030	8,362	11,569
Connecticut	8,755	10,521	14,658
Delaware	8,512	10,283	14,326
District of Columbia	NA	NA	NA
Florida	6,251	7,947	10,141
Georgia	5,690	7,463	10,062
Hawaii	NA	8,272	9,042
Idaho	5,306	6,765	8,982
Illinois	7,841	9,532	13,976
Indiana	7,388	9,239	12,388
Iowa	5,945	7,587	12,329
Kansas	5,688	6,654	9,980
Kentucky	5,454	6,923	10,663
Louisiana	5,503	6,329	8,506
Maine	7,899	9,371	12,568
Maryland	8,731	10,834	14,793
Massachusetts	8,770	9,207	14,651
Michigan	8,189	9,825	13,693
Minnesota	6,734	8,127	12,777
Mississippi	5,416	7,195	9,461
Missouri	6,768	8,203	11,861
Montana	7,803	7,615	10,613
Nebraska	5,503	7,355	11,286
Nevada	7,400	8,247	10,865
New Hampshire	8,730	11,720	15,479
New Jersey	9,118	12,007	17,708
New Mexico	5,299	7,086	9,579
New York	8,971	10,260	13,275
North Carolina	5,119	7,076	9,675
North Dakota	5,641	6,418	9,829
Ohio	8,157	10,451	16,032
Oklahoma	4,296	6,022	9,404
Oregon	7,395	9,394	12,720
Pennsylvania	9,138	11,091	15,464
Rhode Island	9,453	11,095	14,315
South Carolina	6,964	9,096	13,145
South Dakota	5,613	6,975	9,493
Tennessee	5,373	7,658	9,956
Texas	5,471	7,614	10,973
Utah	5,389	6,598	8,745
Vermont	10,657	12,847	16,571
Virginia	8,207	8,751	12,279
Washington	7,129	8,909	12,384
West Virginia	6,119	7,290	9,992
Wisconsin	5,839	7,396	10,560
Wyoming	5,429	7,017	8,946
Puerto Rico	NA	NA	NA

NA = not available

NOTES: National average for United States from Digest of Education Statistics data tables. Average charges for entire academic year. Tuition and fees weighted by number of full-time-equivalent undergraduates but not adjusted to reflect student residency. Room and board based on full-time students.

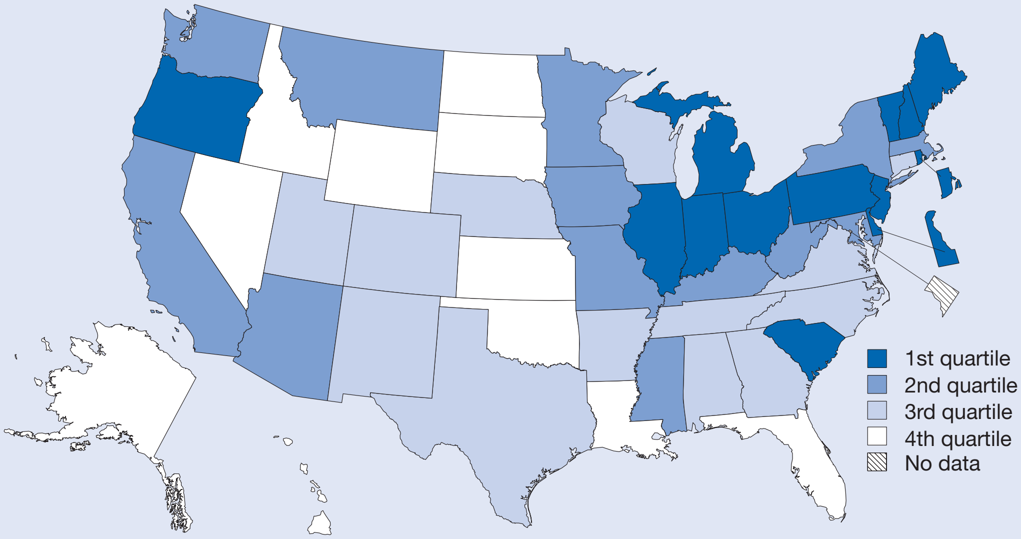
SOURCE: National Center for Education Statistics, Integrated Postsecondary Education Data System (various years).

Science & Engineering Indicators 2008

Average Undergraduate Charge at Public 4-Year Institutions as Share of Disposable Personal Income

Figure 8-21

Average undergraduate charge at public 4-year institutions as share of disposable personal income: 2006



1st quartile (54.9%–41.8%)	2nd quartile (41.4%–37.2%)	3rd quartile (36.8%–33.7%)	4th quartile (33.6%–24.7%)	No data
Delaware	Arizona	Alabama	Alaska	District of Columbia
Illinois	California	Arkansas	Florida	
Indiana	Iowa	Colorado	Hawaii	
Maine	Kentucky	Connecticut	Idaho	
Michigan	Maryland	Georgia	Kansas	
New Hampshire	Massachusetts	Nebraska	Louisiana	
New Jersey	Minnesota	New Mexico	Nevada	
Ohio	Mississippi	North Carolina	North Dakota	
Oregon	Missouri	Tennessee	Oklahoma	
Pennsylvania	Montana	Texas	South Dakota	
Rhode Island	New York	Utah	Wyoming	
South Carolina	Washington	Virginia		
Vermont	West Virginia	Wisconsin		

SOURCES: National Center for Education Statistics, Integrated Postsecondary Education Data System (various years); and Bureau of Economic Analysis, State and Local Personal Income data. See table 8-21.

Findings

- In 2006 throughout the United States, a year of undergraduate education at a state institution would have consumed 38.2% of an average resident's disposable income, an increase from the 33.3% it would have consumed a decade earlier.
- The cost of a year of undergraduate education at a public institution consumed one-quarter to one-half of the per capita disposable income for residents of most states in 2006.
- Although a year of undergraduate education at a public institution became less affordable for residents in most states, affordability improved in six states during the past decade.
- Residents in Ohio, Iowa, South Carolina, and Nebraska experienced the steepest increases in the cost of a year of undergraduate education relative to their purchasing power (in excess of 10% of per capita disposable income) between 1996 and 2006.

This indicator provides a broad measure of the affordability of higher education at a public institution for the average resident. It is calculated by dividing the average undergraduate charge at all public 4-year institutions in the state by the per capita disposable personal income of state residents. The average undergraduate charge includes standard in-state tuition, room, board, and required fees for a student who is a resident of the state. Disposable personal income is the income that is available to state residents for spending or saving. It is calculated as personal income minus personal current taxes paid to federal, state, and local governments. The year is the latter date of the academic year. For example, data for 2006 represent costs for the 2005–06 academic year.

High values indicate that a year of undergraduate education is more costly or less affordable to state residents. However, the data in this indicator do not include any adjustment for financial aid that a student might receive.

Table 8-21

Average undergraduate charge at public 4-year institutions as share of disposable personal income, by state: 1996, 2001, and 2006

	Average undergraduate charge ($)			Per capita disposable personal income ($)			Undergraduate charge/ disposable personal income (%)		
State	1996	2001	2006	1996	2001	2006	1996	2001	2006
United States	7,014	8,653	12,108	21,089	26,228	31,735	33.3	33.0	38.2
Alabama	5,735	7,349	9,625	17,842	21,998	28,185	32.1	33.4	34.1
Alaska	6,663	8,390	10,620	23,003	28,155	33,595	29.0	29.8	31.6
Arizona	5,996	7,874	11,480	18,306	22,932	27,763	32.8	34.3	41.3
Arkansas	5,055	6,797	9,192	16,920	20,443	25,112	29.9	33.2	36.6
California	8,209	9,590	13,685	22,011	27,492	33,373	37.3	34.9	41.0
Colorado	7,030	8,362	11,569	22,174	29,575	34,332	31.7	28.3	33.7
Connecticut	8,755	10,521	14,658	27,105	34,610	40,973	32.3	30.4	35.8
Delaware	8,512	10,283	14,326	22,071	27,266	33,683	38.6	37.7	42.5
District of Columbia	NA	NA	NA	28,275	37,147	47,515	NA	NA	NA
Florida	6,251	7,947	10,141	20,962	25,611	31,635	29.8	31.0	32.1
Georgia	5,690	7,463	10,062	20,029	24,670	28,109	28.4	30.3	35.8
Hawaii	NA	8,272	9,042	22,086	25,136	31,856	NA	32.9	28.4
Idaho	5,306	6,765	8,982	17,898	21,904	26,754	29.6	30.9	33.6
Illinois	7,841	9,532	13,976	22,924	27,852	33,419	34.2	34.2	41.8
Indiana	7,388	9,239	12,388	19,528	23,925	28,979	37.8	38.6	42.7
Iowa	5,945	7,587	12,329	19,962	23,921	29,808	29.8	31.7	41.4
Kansas	5,688	6,654	9,980	20,036	25,045	30,935	28.4	26.6	32.3
Kentucky	5,454	6,923	10,663	17,443	21,766	26,104	31.3	31.8	40.8
Louisiana	5,503	6,329	8,506	17,690	22,047	28,553	31.1	28.7	29.8
Maine	7,899	9,371	12,568	18,801	23,715	28,777	42.0	39.5	43.7
Maryland	8,731	10,834	14,793	23,396	30,061	37,574	37.3	36.0	39.4
Massachusetts	8,770	9,207	14,651	24,439	31,746	38,794	35.9	29.0	37.8
Michigan	8,189	9,825	13,693	21,040	25,998	30,117	38.9	37.8	45.5
Minnesota	6,734	8,127	12,777	21,986	27,825	33,494	30.6	29.2	38.1
Mississippi	5,416	7,195	9,461	16,004	19,849	24,360	33.8	36.2	38.8
Missouri	6,768	8,203	11,861	19,777	24,178	29,066	34.2	33.9	40.8
Montana	7,803	7,615	10,613	16,983	21,889	27,419	45.9	34.8	38.7
Nebraska	5,503	7,355	11,286	20,879	25,117	30,676	26.4	29.3	36.8
Nevada	7,400	8,247	10,865	22,803	26,776	32,290	32.5	30.8	33.6
New Hampshire	8,730	11,720	15,479	23,434	29,223	34,964	37.3	40.1	44.3
New Jersey	9,118	12,007	17,708	26,299	32,816	39,840	34.7	36.6	44.4
New Mexico	5,299	7,086	9,579	17,034	21,491	26,839	31.1	33.0	35.7
New York	8,971	10,260	13,275	24,212	29,154	35,407	37.1	35.2	37.5
North Carolina	5,119	7,076	9,675	19,548	23,834	28,339	26.2	29.7	34.1
North Dakota	5,641	6,418	9,829	19,084	23,199	29,515	29.6	27.7	33.3
Ohio	8,157	10,451	16,032	20,217	24,665	29,223	40.3	42.4	54.9
Oklahoma	4,296	6,022	9,404	17,523	22,999	28,895	24.5	26.2	32.5
Oregon	7,395	9,394	12,720	20,232	24,506	29,310	36.6	38.3	43.4
Pennsylvania	9,138	11,091	15,464	21,258	26,135	32,222	43.0	42.4	48.0
Rhode Island	9,453	11,095	14,315	21,213	26,404	32,734	44.6	42.0	43.7
South Carolina	6,964	9,096	13,145	17,724	22,065	26,406	39.3	41.2	49.8
South Dakota	5,613	6,975	9,493	19,661	24,328	31,116	28.5	28.7	30.5
Tennessee	5,373	7,658	9,956	19,628	24,157	29,456	27.4	31.7	33.8
Texas	5,471	7,614	10,973	19,802	25,691	31,012	27.6	29.6	35.4
Utah	5,389	6,598	8,745	17,085	21,687	25,792	31.5	30.4	33.9
Vermont	10,657	12,847	16,571	19,418	25,221	30,317	54.9	50.9	54.7
Virginia	8,207	8,751	12,279	21,761	27,547	33,628	37.7	31.8	36.5
Washington	7,129	8,909	12,384	22,202	28,169	33,334	32.1	31.6	37.2
West Virginia	6,119	7,290	9,992	16,540	20,776	25,204	37.0	35.1	39.6
Wisconsin	5,839	7,396	10,560	20,091	25,322	30,439	29.1	29.2	34.7
Wyoming	5,429	7,017	8,946	19,159	26,351	36,176	28.3	26.6	24.7
Puerto Rico	NA	NA	NA	NA	NA	NA	NA	NA	NA

NA = not available

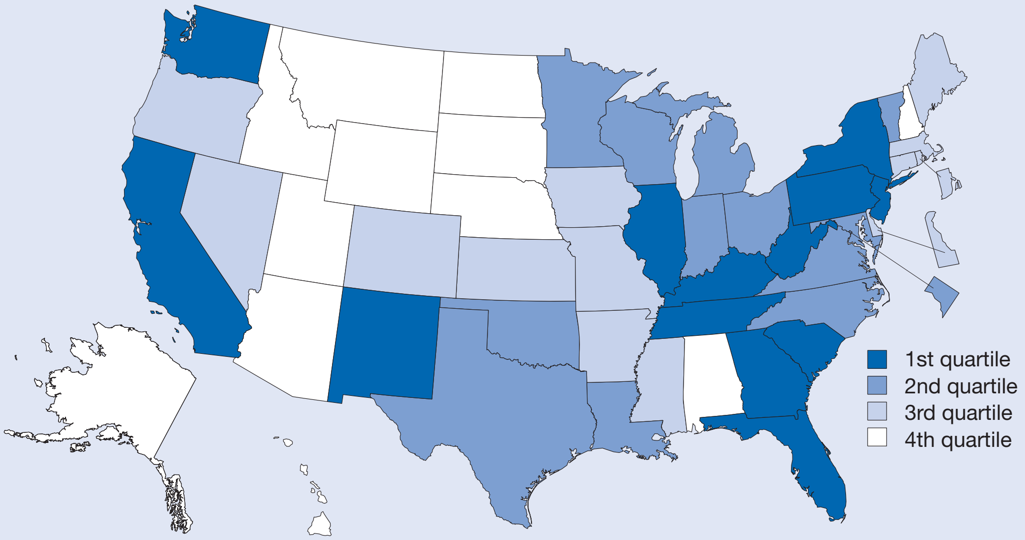
NOTES: National average undergraduate charge for United States from Digest of Education Statistics data tables. Average charges for entire academic year. Tuition and fees weighted by number of full-time-equivalent undergraduates but not adjusted to reflect student residency. Room and board based on full-time students. National value for disposable personal income is value reported by Bureau of Economic Analysis.

SOURCES: National Center for Education Statistics, Integrated Postsecondary Education Data System (various years); and Bureau of Economic Analysis, State and Local Personal Income data.

Science & Engineering Indicators 2008

State Expenditures on Student Aid per Full-Time Undergraduate Student

Figure 8-22
State expenditures on student aid per full-time undergraduate student: 2006



1st quartile ($2,449–$881)	2nd quartile ($860–$505)	3rd quartile ($494–$165)	4th quartile ($158–$12)
California	District of Columbia	Arkansas	Alabama
Florida	Indiana	Colorado	Alaska
Georgia	Louisiana	Connecticut	Arizona
Illinois	Maryland	Delaware	Hawaii
Kentucky	Michigan	Iowa	Idaho
New Jersey	Minnesota	Kansas	Montana
New Mexico	North Carolina	Maine	Nebraska
New York	Ohio	Massachusetts	New Hampshire
Pennsylvania	Oklahoma	Mississippi	North Dakota
South Carolina	Texas	Missouri	South Dakota
Tennessee	Vermont	Nevada	Utah
Washington	Virginia	Oregon	Wyoming
West Virginia	Wisconsin	Rhode Island	

SOURCES: National Association of State Scholarship and Grant Programs, Annual Survey Report (various years); and National Center for Education Statistics, Integrated Postsecondary Education Data System (various years). See Table 8-22.

Findings

- In the United States, the total amount of state financial aid from grants that were provided to undergraduates rose from nearly $2.9 billion in 1996 to nearly $6.8 billion in 2006.
- On a per-student basis, state expenditures for student grants across the United States increased from $427 in 1996 to $802 in 2006 in current dollars.
- The amount of financial assistance provided by the states and the District of Columbia varied greatly in 2006; 10 jurisdictions averaged less than $100 per undergraduate student, while 11 provided more than $1,000 per student, including South Carolina and Georgia with more than $2,000 per student.
- Four states reported spending less in current dollars for student financial aid in 2006 than in 1996 even though the cost of undergraduate education rose rapidly during this time period. All of these states were among the group spending less than $100 per undergraduate student.

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 is not included. The year is the latter date of the academic year. For example, data for 2006 represent costs for the 2005–06 academic year.

Table 8-22

State expenditures on student aid per full-time undergraduate student, by state: 1996, 2001, and 2006

	State expenditures on student aid ($thousands)			Undergraduate enrollment at 4-year institutions			State expenditures on student aid/ undergraduate ($)		
State	1996	2001	2006	1996	2001	2006	1996	2001	2006
United States	2,870,447	4,605,393	6,789,273	6,725,612	7,193,814	8,460,873	427	640	802
Alabama	8,320	7,413	7,626	120,895	130,189	140,142	69	57	54
Alaska	430	0	502	26,641	24,573	26,802	16	0	19
Arizona	2,291	2,990	2,798	88,412	111,429	242,591	26	27	12
Arkansas	11,727	39,151	28,364	63,756	70,538	81,086	184	555	350
California	235,582	461,914	757,809	517,769	599,658	698,811	455	770	1,084
Colorado	36,401	54,151	60,737	119,686	133,500	160,580	304	406	378
Connecticut	20,374	44,763	39,366	79,673	85,143	92,522	256	526	425
Delaware	1,390	1,432	10,240	26,513	25,761	29,225	52	56	350
District of Columbia	939	781	33,856	43,365	40,703	62,888	22	19	538
Florida	100,363	302,633	410,758	235,558	288,143	466,469	426	1,050	881
Georgia	165,220	310,995	461,615	175,093	188,383	222,706	944	1,651	2,073
Hawaii	499	535	410	28,048	26,290	34,336	18	20	12
Idaho	1,027	1,138	5,424	36,169	39,343	57,809	28	29	94
Illinois	282,809	382,566	380,349	259,759	276,559	333,959	1,089	1383	1,139
Indiana	69,599	111,618	182,281	205,747	217,294	241,153	338	514	756
Iowa	39,431	53,100	53,815	93,412	97,241	119,841	422	546	449
Kansas	9,588	12,819	15,168	81,295	84,620	92,127	118	151	165
Kentucky	26,215	66,931	172,866	107,893	109,981	126,074	243	609	1,371
Louisiana	15,053	91,166	116,432	143,810	146,259	135,457	105	623	860
Maine	6,988	11,961	13,387	40,895	42,093	44,100	171	284	304
Maryland	36,066	50,416	76,362	108,231	117,720	130,057	333	428	587
Massachusetts	54,646	116,892	80,093	236,525	235,263	243,742	231	497	329
Michigan	84,154	102,164	197,674	264,454	287,233	318,373	318	356	621
Minnesota	92,099	120,465	131,010	137,830	142,734	167,954	668	844	780
Mississippi	1,235	20,163	22,285	56,733	61,043	65,515	22	330	340
Missouri	24,236	43,882	42,068	166,157	180,799	209,818	146	243	200
Montana	393	3,195	3,760	32,170	32,393	33,784	12	99	111
Nebraska	3,114	5,975	9,918	62,045	58,789	62,753	50	102	158
Nevada	3,063	13,449	39,671	24,519	32,012	80,249	125	420	494
New Hampshire	773	1,497	3,753	40,511	40,367	43,915	19	37	85
New Jersey	141,198	197,619	256,047	146,595	156,867	167,990	963	1,260	1,524
New Mexico	16,988	38,736	61,780	40,438	43,089	50,390	420	899	1,226
New York	630,069	659,394	895,129	560,579	569,260	617,536	1,124	1,158	1,450
North Carolina	43,968	121,153	192,018	182,725	191,117	224,053	241	634	857
North Dakota	2,187	1,152	1,864	28,514	28,462	33,164	77	40	56
Ohio	120,967	173,868	221,411	300,831	302,681	334,964	402	574	661
Oklahoma	20,501	29,035	58,216	90,281	98,512	115,304	227	295	505
Oregon	13,651	19,711	29,429	66,714	76,071	90,742	205	259	324
Pennsylvania	232,020	325,234	403,957	356,314	377,646	415,319	651	861	973
Rhode Island	5,741	6,164	12,883	45,757	49,484	53,930	125	125	239
South Carolina	18,622	98,095	255,744	86,620	92,074	104,430	215	1,065	2,449
South Dakota	562	0	3,367	31,718	32,310	37,183	18	0	91
Tennessee	19,289	30,156	173,907	133,310	139,743	157,956	145	216	1,101
Texas	40,768	108,628	366,873	405,011	432,747	530,410	101	251	692
Utah	1,197	2,511	7,409	102,588	120,151	143,077	12	21	52
Vermont	11,874	14,414	17,560	25,652	25,972	27,968	463	555	628
Virginia	77,386	115,242	132,720	167,392	180,573	210,638	462	638	630
Washington	57,866	98,533	173,835	97,139	105,470	123,879	596	934	1,403
West Virginia	8,132	18,217	70,981	66,079	68,435	66,790	123	266	1,063
Wisconsin	49,528	71,145	93,583	158,986	168,547	180,721	312	422	518
Wyoming	219	0	163	8,805	8,550	9,591	25	0	17
Puerto Rico	23,689	40,231	33,840	138,665	149,699	163,259	171	269	207

NOTES: 2001 and 2006 enrollment data for 4-year degree-granting institutions participating in Title IV federal financial aid programs.

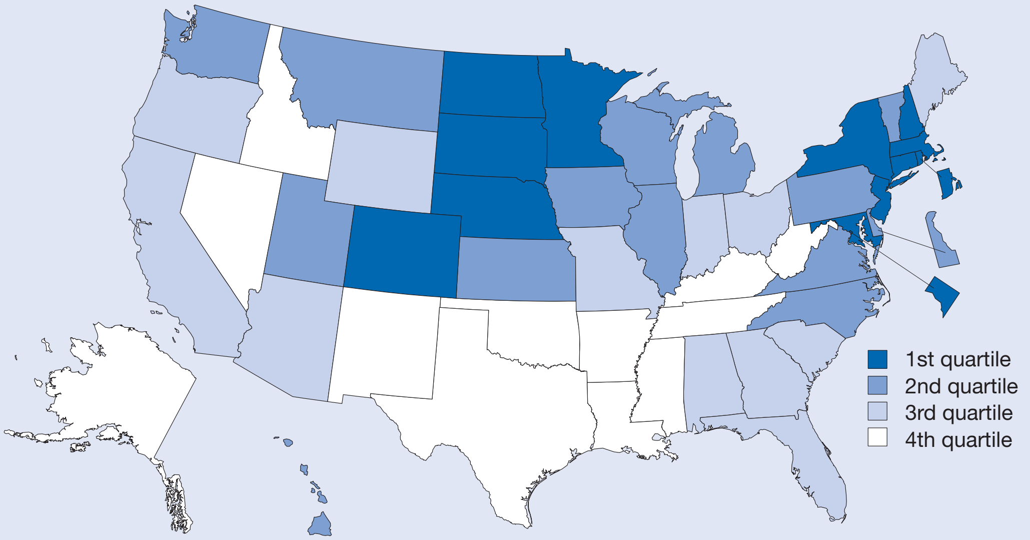
SOURCES: National Association of State Scholarship and Grant Programs, Annual Survey Report (various years); and National Center for Education Statistics, Integrated Postsecondary Education Data System (various years).

Science & Engineering Indicators 2008

Associate's Degree Holders or Higher Among Individuals 25–44 Years Old

Figure 8-23

Associate's degree holders or higher among individuals 25–44 years old: 2005



1st quartile (54.4%–42.3%)	2nd quartile (41.8%–36.5%)	3rd quartile (36.4%–31.5%)	4th quartile (31.4%–26.2%)
Colorado	Delaware	Alabama	Alaska
Connecticut	Hawaii	Arizona	Arkansas
District of Columbia	Illinois	California	Idaho
Maryland	Iowa	Florida	Kentucky
Massachusetts	Kansas	Georgia	Louisiana
Minnesota	Michigan	Indiana	Mississippi
Nebraska	Montana	Maine	Nevada
New Hampshire	North Carolina	Missouri	New Mexico
New Jersey	Pennsylvania	Ohio	Oklahoma
New York	Utah	Oregon	Tennessee
North Dakota	Vermont	South Carolina	Texas
Rhode Island	Virginia	Wyoming	West Virginia
South Dakota	Washington		
	Wisconsin		

SOURCES: Census Bureau, 2000 Decennial Census; Population Estimates Program (various years); and American Community Survey (various years). See table 8-23.

Findings

- The early- to mid-career population with at least an associate's degree was 37.4% nationwide in 2005, which represents an increase from 34.7% in 2000.
- Only Alaska failed to show an increase in the percentage of its early career population with at least an associate's degree between 2000 and 2005. Eighteen states had 2005 values below the 2000 national average of 34.7% compared with 27 states with values below this level in 2000.
- In 2005, the percentage of this cohort with at least an associate's degree varied greatly among states, ranging from 50.4% to 26.2%. States with the lowest cost of living tended to rank lowest on this indicator.

This indicator represents the percentage of the early- to mid-career population that has earned at least a college degree. That degree may be at the associate's through doctoral level. The indicator represents where college degree holders have chosen to live and work rather than where they were educated. The age cohort of 25–44 years represents the group most likely to have completed a college program. High values indicate a resident population or potential workforce with widespread credentials at the community college level or higher.

Estimates of educational attainment are developed by the Census Bureau based on the 2000 Decennial Census and the American Community Survey (ACS). The census is conducted every 10 years, but the ACS provides annually updated data on the characteristics of population and housing. In 2005, ACS became the largest household survey in the United States, with an annual sample size of about 3 million addresses. Estimates of population are taken from the Census Bureau's Population Estimates Program, which is also based on the 2000 Decennial Census.

Table 8-23

Associate's degree holders or higher among individuals 25–44 years old, by state: 2000, 2003, and 2005

State	Associate's degree holders 25–44 years old			Population 25–44 years old			Associate's degree holders/ individuals 25–44 years old (%)		
	2000	2003	2005	2000	2003	2005	2000	2003	2005
United States	29,471,612	30,738,684	31,382,831	85,040,251	84,216,990	84,010,639	34.7	36.5	37.4
Alabama	370,196	381,050	389,490	1,288,527	1,241,184	1,234,729	28.7	30.7	31.5
Alaska	61,646	58,059	58,631	203,522	194,823	194,890	30.3	29.8	30.1
Arizona	472,901	498,703	552,805	1,511,469	1,599,029	1,694,572	31.3	31.2	32.6
Arkansas	177,657	187,589	202,622	750,972	738,579	750,229	23.7	25.4	27.0
California	3,670,622	3,918,228	3,892,099	10,714,403	10,832,873	10,794,860	34.3	36.2	36.1
Colorado	596,036	623,279	636,437	1,400,850	1,417,501	1,421,418	42.5	44.0	44.8
Connecticut	443,608	447,818	432,451	1,032,689	999,800	968,330	43.0	44.8	44.7
Delaware	84,170	90,649	87,994	236,441	233,356	233,683	35.6	38.8	37.7
District of Columbia	90,097	100,283	103,236	189,439	188,758	189,675	47.6	53.1	54.4
Florida	1,513,345	1,616,842	1,694,517	4,569,347	4,676,558	4,812,867	33.1	34.6	35.2
Georgia	884,108	929,979	1,013,471	2,652,764	2,723,720	2,784,441	33.3	34.1	36.4
Hawaii	136,758	132,630	129,858	362,336	352,806	355,620	37.7	37.6	36.5
Idaho	112,690	121,592	121,718	362,401	370,690	387,620	31.1	32.8	31.4
Illinois	1,444,942	1,487,189	1,530,725	3,795,544	3,727,314	3,672,713	38.1	39.9	41.7
Indiana	537,644	543,808	562,483	1,791,828	1,748,331	1,741,859	30.0	31.1	32.3
Iowa	289,740	294,559	317,772	808,259	775,320	764,399	35.8	38.0	41.6
Kansas	282,475	307,608	289,848	769,204	743,961	732,886	36.7	41.3	39.5
Kentucky	317,109	335,263	353,170	1,210,773	1,182,970	1,187,091	26.2	28.3	29.8
Louisiana	316,348	346,949	340,337	1,293,128	1,230,819	1,217,481	24.5	28.2	28.0
Maine	122,958	128,525	123,129	370,597	358,691	350,196	33.2	35.8	35.2
Maryland	672,460	714,825	693,317	1,664,677	1,641,907	1,615,367	40.4	43.5	42.9
Massachusetts	942,748	970,834	932,197	1,989,783	1,922,446	1,848,998	47.4	50.5	50.4
Michigan	982,169	1,026,212	1,013,031	2,960,544	2,840,435	2,772,896	33.2	36.1	36.5
Minnesota	631,677	668,668	684,727	1,497,320	1,465,370	1,443,493	42.2	45.6	47.4
Mississippi	208,866	214,703	231,759	807,170	782,327	778,254	25.9	27.4	29.8
Missouri	517,750	541,597	543,130	1,626,302	1,587,931	1,585,316	31.8	34.1	34.3
Montana	81,428	85,047	85,590	245,220	232,735	232,383	33.2	36.5	36.8
Nebraska	185,090	187,939	202,182	487,107	471,024	464,556	38.0	39.9	43.5
Nevada	152,536	167,370	193,902	628,572	679,392	729,594	24.3	24.6	26.6
New Hampshire	156,434	163,231	161,161	381,240	373,644	364,731	41.0	43.7	44.2
New Jersey	1,076,450	1,105,776	1,114,215	2,624,146	2,578,072	2,510,115	41.0	42.9	44.4
New Mexico	149,398	142,448	153,406	516,100	506,956	511,007	28.9	28.1	30.0
New York	2,359,507	2,432,498	2,499,314	5,831,622	5,667,484	5,501,929	40.5	42.9	45.4
North Carolina	844,019	892,169	933,034	2,500,535	2,507,025	2,523,658	33.8	35.6	37.0
North Dakota	71,509	70,144	73,974	174,891	160,522	156,178	40.9	43.7	47.4
Ohio	1,075,353	1,107,195	1,098,912	3,325,210	3,172,294	3,105,980	32.3	34.9	35.4
Oklahoma	276,525	275,638	296,769	975,169	946,358	944,171	28.4	29.1	31.4
Oregon	333,963	355,143	361,760	997,269	1,003,698	1,015,644	33.5	35.4	35.6
Pennsylvania	1,230,548	1,243,379	1,269,457	3,508,562	3,343,434	3,255,635	35.1	37.2	39.0
Rhode Island	117,758	128,487	127,598	310,636	306,459	296,717	37.9	41.9	43.0
South Carolina	357,570	370,577	389,378	1,185,955	1,167,347	1,171,573	30.2	31.7	33.2
South Dakota	73,128	76,724	82,619	206,399	197,386	195,213	35.4	38.9	42.3
Tennessee	489,940	511,871	521,417	1,718,428	1,684,796	1,698,611	28.5	30.4	30.7
Texas	1,973,279	2,059,427	2,112,582	6,484,321	6,644,003	6,762,605	30.4	31.0	31.2
Utah	222,534	247,337	276,707	626,600	648,111	695,736	35.5	38.2	39.8
Vermont	70,277	68,018	68,447	176,456	168,392	163,707	39.8	40.4	41.8
Virginia	874,239	904,354	925,208	2,237,655	2,227,978	2,228,610	39.1	40.6	41.5
Washington	693,591	721,329	739,976	1,816,217	1,803,610	1,820,192	38.2	40.0	40.7
West Virginia	115,337	123,752	125,231	501,343	479,781	478,383	23.0	25.8	26.2
Wisconsin	566,244	566,942	596,923	1,581,690	1,537,180	1,517,725	35.8	36.9	39.3
Wyoming	44,235	44,448	42,115	138,619	131,810	132,103	31.9	33.7	31.9
Puerto Rico	358,595	NA	424,718	1,049,995	1,069,617	1,077,981	34.2	NA	39.4

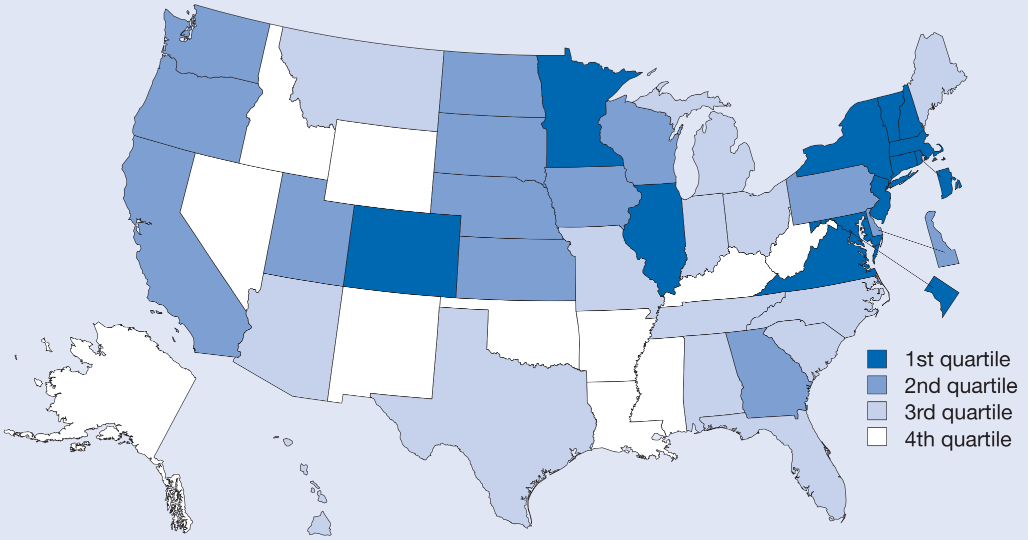
NA = not available

SOURCES: Census Bureau, 2000 Decennial Census; Population Estimates Program (various years); and American Community Survey (various years).

Science & Engineering Indicators 2008

Bachelor's Degree Holders or Higher Among Individuals 25–44 Years Old

Figure 8-24
Bachelor's degree holders or higher among individuals 25–44 years old: 2005



1st quartile (51.0%–32.8%)	2nd quartile (32.1%–28.0%)	3rd quartile (27.6%–23.4%)	4th quartile (23.3%–19.1%)
Colorado	California	Alabama	Alaska
Connecticut	Delaware	Arizona	Arkansas
District of Columbia	Georgia	Florida	Idaho
Illinois	Iowa	Hawaii	Kentucky
Maryland	Kansas	Indiana	Louisiana
Massachusetts	Nebraska	Maine	Mississippi
Minnesota	North Dakota	Michigan	Nevada
New Hampshire	Oregon	Missouri	New Mexico
New Jersey	Pennsylvania	Montana	Oklahoma
New York	South Dakota	North Carolina	West Virginia
Rhode Island	Utah	Ohio	Wyoming
Vermont	Washington	South Carolina	
Virginia	Wisconsin	Tennessee	
		Texas	

SOURCES: Census Bureau, 2000 Decennial Census; Population Estimates Program (various years); and American Community Survey (various years). See table 8-24.

Findings

- The early- to mid-career population with at least a bachelor's degree was 29.0% nationwide in 2005, which represents an increase from 26.8% in 2000.
- Only Hawaii failed to show an increase in the percentage of its early career population with at least a bachelor's degree between 2000 and 2005. Twenty states had 2005 values below the 2000 national average of 26.8% compared with 30 states with values below this level in 2000.
- In 2005, the percentage of the early career population with at least a bachelor's degree varied greatly among states, ranging from 42.2% to 19.1%. States with the lowest cost of living tended to rank lowest on this indicator.

This indicator represents the percentage of the early- to mid-career population that has earned at least a 4-year undergraduate degree. That degree may be at the bachelor's through doctoral level. The indicator represents where college degree holders have chosen to live and work rather than where they were educated. The age cohort of 25–44 years represents the group most likely to have completed a college program. High values indicate a resident population or potential workforce with widespread credentials at the college or university level.

Estimates of educational attainment are developed by the Census Bureau based on the 2000 Decennial Census and the American Community Survey (ACS). The census is conducted every 10 years, but the ACS provides annually updated data on the characteristics of population and housing. In 2005, ACS became the largest household survey in the United States, with an annual sample size of about 3 million addresses. Estimates of population are taken from the Census Bureau's Population Estimates Program, which is also based on the 2000 Decennial Census.

Table 8-24

Bachelor's degree holders or higher among individuals 25–44 years old, by state: 2000, 2003, and 2005

State	Bachelor's degree holders 25–44 years old			Population 25–44 years old			Bachelor's degree holders/individuals 25–44 years old (%)		
	2000	2003	2005	2000	2003	2005	2000	2003	2005
United States	22,781,996	23,984,096	24,353,620	85,040,251	84,216,990	84,010,639	26.8	28.5	29.0
Alabama	275,759	282,805	288,817	1,288,527	1,241,184	1,234,729	21.4	22.8	23.4
Alaska	45,560	44,868	45,315	203,522	194,823	194,890	22.4	23.0	23.3
Arizona	355,836	374,059	408,522	1,511,469	1,599,029	1,694,572	23.5	23.4	24.1
Arkansas	136,883	149,619	152,225	750,972	738,579	750,229	18.2	20.3	20.3
California	2,882,717	3,134,086	3,112,603	10,714,403	10,832,873	10,794,860	26.9	28.9	28.8
Colorado	480,984	513,973	512,178	1,400,850	1,417,501	1,421,418	34.3	36.3	36.0
Connecticut	362,272	380,576	362,929	1,032,689	999,800	968,330	35.1	38.1	37.5
Delaware	65,811	73,052	71,090	236,441	233,356	233,683	27.8	31.3	30.4
District of Columbia	84,836	96,119	96,816	189,439	188,758	189,675	44.8	50.9	51.0
Florida	1,081,551	1,159,165	1,212,200	4,569,347	4,676,558	4,812,867	23.7	24.8	25.2
Georgia	718,591	766,181	820,695	2,652,764	2,723,720	2,784,441	27.1	28.1	29.5
Hawaii	99,378	97,202	95,029	362,336	352,806	355,620	27.4	27.6	26.7
Idaho	80,235	88,937	89,959	362,401	370,690	387,620	22.1	24.0	23.2
Illinois	1,149,688	1,191,554	1,216,933	3,795,544	3,727,314	3,672,713	30.3	32.0	33.1
Indiana	397,050	404,241	408,107	1,791,828	1,748,331	1,741,859	22.2	23.1	23.4
Iowa	202,004	200,579	221,497	808,259	775,320	764,399	25.0	25.9	29.0
Kansas	223,467	243,308	224,946	769,204	743,961	732,886	29.1	32.7	30.7
Kentucky	234,921	247,142	256,209	1,210,773	1,182,970	1,187,091	19.4	20.9	21.6
Louisiana	256,363	283,161	267,429	1,293,128	1,230,819	1,217,481	19.8	23.0	22.0
Maine	86,989	92,827	85,987	370,597	358,691	350,196	23.5	25.9	24.6
Maryland	566,294	600,135	582,280	1,664,677	1,641,907	1,615,367	34.0	36.6	36.0
Massachusetts	773,569	820,821	780,522	1,989,783	1,922,446	1,848,998	38.9	42.7	42.2
Michigan	719,607	764,082	757,970	2,960,544	2,840,435	2,772,896	24.3	26.9	27.3
Minnesota	476,707	506,833	511,402	1,497,320	1,465,370	1,443,493	31.8	34.6	35.4
Mississippi	144,488	149,176	152,606	807,170	782,327	778,254	17.9	19.1	19.6
Missouri	407,449	424,660	429,501	1,626,302	1,587,931	1,585,316	25.1	26.7	27.1
Montana	62,682	63,186	63,693	245,220	232,735	232,383	25.6	27.1	27.4
Nebraska	134,516	138,152	149,233	487,107	471,024	464,556	27.6	29.3	32.1
Nevada	111,517	128,178	143,301	628,572	679,392	729,594	17.7	18.9	19.6
New Hampshire	114,745	121,639	122,682	381,240	373,644	364,731	30.1	32.6	33.6
New Jersey	899,016	932,505	943,939	2,624,146	2,578,072	2,510,115	34.3	36.2	37.6
New Mexico	110,360	106,530	110,562	516,100	506,956	511,007	21.4	21.0	21.6
New York	1,817,661	1,885,493	1,964,870	5,831,622	5,667,484	5,501,929	31.2	33.3	35.7
North Carolina	636,799	682,432	697,740	2,500,535	2,507,025	2,523,658	25.5	27.2	27.6
North Dakota	46,291	49,712	48,381	174,891	160,522	156,178	26.5	31.0	31.0
Ohio	806,803	835,693	833,138	3,325,210	3,172,294	3,105,980	24.3	26.3	26.8
Oklahoma	209,025	211,507	218,272	975,169	946,358	944,171	21.4	22.3	23.1
Oregon	257,875	278,460	284,778	997,269	1,003,698	1,015,644	25.9	27.7	28.0
Pennsylvania	938,930	959,366	979,367	3,508,562	3,343,434	3,255,635	26.8	28.7	30.1
Rhode Island	88,647	101,468	98,477	310,636	306,459	296,717	28.5	33.1	33.2
South Carolina	259,773	279,322	283,280	1,185,955	1,167,347	1,171,573	21.9	23.9	24.2
South Dakota	51,213	52,989	56,951	206,399	197,386	195,213	24.8	26.8	29.2
Tennessee	380,929	393,328	401,027	1,718,428	1,684,796	1,698,611	22.2	23.3	23.6
Texas	1,571,951	1,623,020	1,668,865	6,484,321	6,644,003	6,762,605	24.2	24.4	24.7
Utah	162,495	174,787	197,780	626,600	648,111	695,736	25.9	27.0	28.4
Vermont	52,787	53,121	53,693	176,456	168,392	163,707	29.9	31.5	32.8
Virginia	722,081	750,953	763,865	2,237,655	2,227,978	2,228,610	32.3	33.7	34.3
Washington	520,382	553,669	554,104	1,816,217	1,803,610	1,820,192	28.7	30.7	30.4
West Virginia	83,441	92,148	91,539	501,343	479,781	478,383	16.6	19.2	19.1
Wisconsin	402,965	396,601	430,486	1,581,690	1,537,180	1,517,725	25.5	25.8	28.4
Wyoming	30,103	30,676	29,830	138,619	131,810	132,103	21.7	23.3	22.6
Puerto Rico	245,975	NA	276,934	1,049,995	1,069,617	1,077,981	23.4	NA	25.7

NA = not available

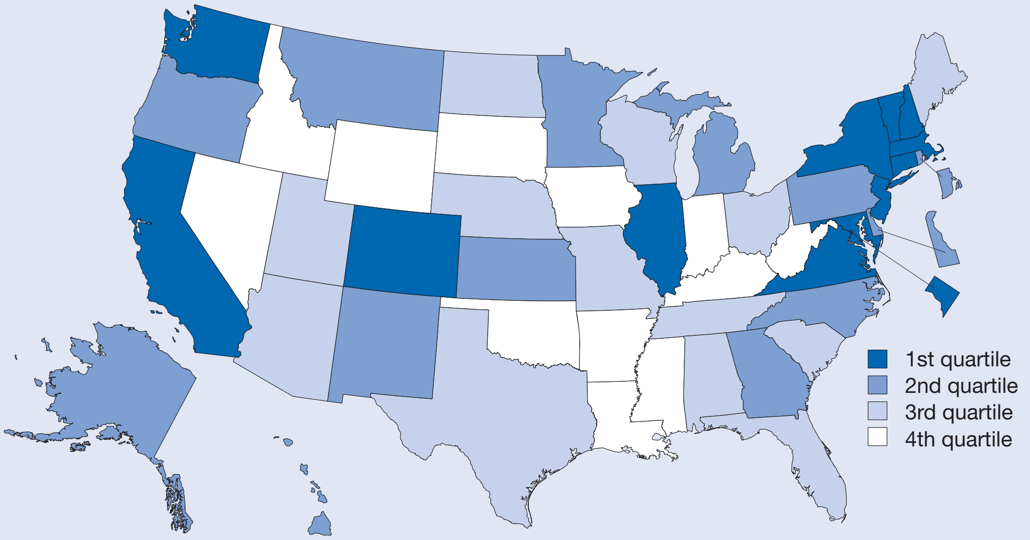
SOURCES: Census Bureau, 2000 Decennial Census; Population Estimates Program (various years); and American Community Survey (various years).

Science & Engineering Indicators 2008

Bachelor's Degree Holders Potentially in the Workforce

Figure 8-25

Bachelor's degree holders potentially in the workforce: 2005



1st quartile (51.2%–34.2%)	2nd quartile (33.6%–29.1%)	3rd quartile (28.9%–26.7%)	4th quartile (26.5%–22.5%)
California	Alaska	Alabama	Arkansas
Colorado	Delaware	Arizona	Idaho
Connecticut	Georgia	Florida	Indiana
District of Columbia	Hawaii	Maine	Iowa
Illinois	Kansas	Missouri	Kentucky
Maryland	Michigan	Nebraska	Louisiana
Massachusetts	Minnesota	North Dakota	Mississippi
New Hampshire	Montana	Ohio	Nevada
New Jersey	New Mexico	South Carolina	Oklahoma
New York	North Carolina	Tennessee	South Dakota
Vermont	Oregon	Texas	West Virginia
Virginia	Pennsylvania	Utah	Wyoming
Washington	Rhode Island	Wisconsin	

SOURCES: Census Bureau, 2000 Decennial Census and American Community Survey (various years); and Bureau of Labor Statistics, Local Area Unemployment Statistics. See table 8-25.

Findings

- In 2005, 45 million individuals between the ages of 25 and 64 held bachelor's degrees in the United States, up from 39 million in 2000. Nationwide, the ratio of bachelor's degree holders to the size of the workforce rose from 28.5% in 2000 to 31.7% in 2005. This ratio varied considerably among the states, ranging from 22.5% to 43.2% in 2005.
- The value of this indicator increased in all states and the District of Columbia between 2000 and 2005. 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 a higher level of education or credentials.
- Between 2000 and 2005, Michigan, Massachusetts, and the District of Columbia showed the largest increases in the ratio of bachelor's degree holders to workforce size.
- The geographic distribution of bachelor's degree holders 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 ratio of bachelor's, graduate, or professional degree holders to the size of a state's workforce is an indicator of a population with undergraduate and/or graduate education skill levels potentially available for its workforce. Workers with at least a bachelor's degree have a clear advantage over less-educated workers in expected lifetime earnings. A high value for this indicator suggests a large percentage of the potential workforce with an undergraduate education. This indicator does not imply that all degree holders are currently employed; rather, it indicates the potential educational level of the workforce if all degree holders were employed. Knowledge-intensive businesses seeking to relocate may be attracted to states with high values on this indicator.

Degree data are based on the U.S. Census Bureau's 2000 Decennial Census and American Community Survey and are limited to individuals who are 25–64 years old because this is the age range of most of the workforce. Individuals younger than age 25 are considered to be in the process of completing their education. Individuals older than 64 are considered to be largely retired, so their educational attainment would have limited applicability to the quality of the workforce. Civilian workforce data are Bureau of Labor Statistics estimates based on Local Area Unemployment Statistics. Estimates for sparsely populated states and the District of Columbia may be imprecise because of their small representation in the survey samples.

Table 8-25

Bachelor's degree holders potentially in the workforce, by state: 2000, 2003, and 2005

	Bachelor's degree holders 25–64 years old			Employed workforce			Bachelor's degree holders/workforce (%)		
State	2000	2003	2005	2000	2003	2005	2000	2003	2005
United States	39,078,598	43,038,717	44,972,214	136,940,378	137,418,377	141,739,774	28.5	31.3	31.7
Alabama	479,734	532,098	549,086	2,067,147	2,000,039	2,056,800	23.2	26.6	26.7
Alaska	87,739	91,931	96,854	299,324	308,523	318,423	29.3	29.8	30.4
Arizona	638,515	689,950	781,932	2,404,916	2,565,030	2,727,003	26.6	26.9	28.7
Arkansas	247,079	276,084	287,058	1,207,352	1,199,379	1,276,851	20.5	23.0	22.5
California	4,960,210	5,611,074	5,732,017	16,024,341	16,226,987	16,782,260	31.0	34.6	34.2
Colorado	819,906	901,534	936,007	2,300,192	2,323,554	2,436,795	35.6	38.8	38.4
Connecticut	633,867	695,356	707,700	1,697,670	1,704,693	1,734,386	37.3	40.8	40.8
Delaware	111,260	126,828	131,287	402,777	403,504	415,687	27.6	31.4	31.6
District of Columbia	133,155	148,230	150,461	291,916	283,736	293,900	45.6	52.2	51.2
Florida	1,968,126	2,266,930	2,398,022	7,569,406	7,811,887	8,375,993	26.0	29.0	28.6
Georgia	1,148,814	1,266,705	1,394,550	4,095,362	4,180,568	4,384,030	28.1	30.3	31.8
Hawaii	184,130	196,970	200,132	584,858	588,880	614,290	31.5	33.4	32.6
Idaho	149,622	172,807	178,690	632,451	652,627	698,466	23.7	26.5	25.6
Illinois	1,876,455	2,032,846	2,113,824	6,176,837	5,942,720	6,112,981	30.4	34.2	34.6
Indiana	672,835	707,713	745,940	3,052,719	3,011,436	3,054,803	22.0	23.5	24.4
Iowa	351,922	366,596	404,729	1,557,081	1,543,507	1,568,561	22.6	23.8	25.8
Kansas	385,924	434,766	425,214	1,351,988	1,364,410	1,389,201	28.5	31.9	30.6
Kentucky	402,094	435,777	467,998	1,866,348	1,851,017	1,879,413	21.5	23.5	24.9
Louisiana	453,353	512,319	496,071	1,930,662	1,899,642	1,938,280	23.5	27.0	25.6
Maine	170,334	193,729	193,647	650,385	655,561	669,250	26.2	29.6	28.9
Maryland	979,588	1,083,343	1,095,665	2,711,382	2,750,040	2,820,526	36.1	39.4	38.8
Massachusetts	1,266,113	1,370,101	1,387,065	3,273,281	3,211,853	3,211,033	38.7	42.7	43.2
Michigan	1,242,388	1,378,696	1,407,669	4,953,421	4,681,180	4,726,204	25.1	29.5	29.8
Minnesota	783,613	891,852	906,335	2,720,492	2,765,997	2,796,622	28.8	32.2	32.4
Mississippi	256,581	279,111	293,533	1,239,859	1,228,526	1,226,492	20.7	22.7	23.9
Missouri	695,491	776,798	792,737	2,875,336	2,819,935	2,847,758	24.2	27.5	27.8
Montana	124,462	130,542	139,593	446,552	447,679	463,929	27.9	29.2	30.1
Nebraska	230,857	244,248	267,867	923,198	932,870	940,040	25.0	26.2	28.5
Nevada	206,361	241,719	272,492	1,015,221	1,092,651	1,178,072	20.3	22.1	23.1
New Hampshire	207,431	226,741	243,698	675,541	684,348	703,175	30.7	33.1	34.7
New Jersey	1,510,429	1,639,510	1,734,942	4,130,310	4,126,674	4,255,813	36.6	39.7	40.8
New Mexico	226,334	232,196	252,804	810,024	832,639	867,317	27.9	27.9	29.1
New York	3,031,927	3,275,249	3,460,430	8,751,441	8,713,529	8,959,845	34.6	37.6	38.6
North Carolina	1,044,025	1,155,486	1,229,917	3,969,235	3,965,695	4,112,828	26.3	29.1	29.9
North Dakota	80,545	91,105	95,520	335,780	335,453	341,847	24.0	27.2	27.9
Ohio	1,375,311	1,480,377	1,521,816	5,573,154	5,502,110	5,546,537	24.7	26.9	27.4
Oklahoma	383,381	414,535	431,778	1,609,522	1,597,338	1,629,217	23.8	26.0	26.5
Oregon	488,862	533,853	564,786	1,716,954	1,704,397	1,754,715	28.5	31.3	32.2
Pennsylvania	1,618,658	1,736,241	1,842,351	5,830,902	5,818,296	5,966,226	27.8	29.8	30.9
Rhode Island	156,862	185,148	181,553	520,758	535,458	539,709	30.1	34.6	33.6
South Carolina	454,656	521,905	534,821	1,902,029	1,868,309	1,939,646	23.9	27.9	27.6
South Dakota	89,855	95,907	104,555	397,678	405,840	411,551	22.6	23.6	25.4
Tennessee	649,844	719,592	750,100	2,756,498	2,720,676	2,758,184	23.6	26.4	27.2
Texas	2,646,909	2,892,917	3,062,665	9,896,002	10,260,318	10,677,171	26.7	28.2	28.7
Utah	276,360	292,932	339,337	1,097,915	1,132,948	1,211,803	25.2	25.9	28.0
Vermont	103,476	113,291	118,184	326,742	333,788	341,442	31.7	33.9	34.6
Virginia	1,232,454	1,361,804	1,438,181	3,502,524	3,646,114	3,785,583	35.2	37.3	38.0
Washington	932,352	1,037,358	1,069,031	2,898,677	2,916,045	3,089,953	32.2	35.6	34.6
West Virginia	157,883	179,117	181,476	764,649	742,990	754,060	20.6	24.1	24.1
Wisconsin	690,065	732,493	791,966	2,894,884	2,866,994	2,887,434	23.8	25.5	27.4
Wyoming	60,451	64,307	68,128	256,685	259,987	267,669	23.6	24.7	25.5
Puerto Rico	378,586	NA	454,714	1,162,153	1,200,322	1,250,335	32.6	NA	36.4

NA = not available

NOTES: Bachelor's degree holders include those completing a bachelor's or higher degree. Workforce represents employed component of civilian labor force and reported as annual data not seasonally adjusted.

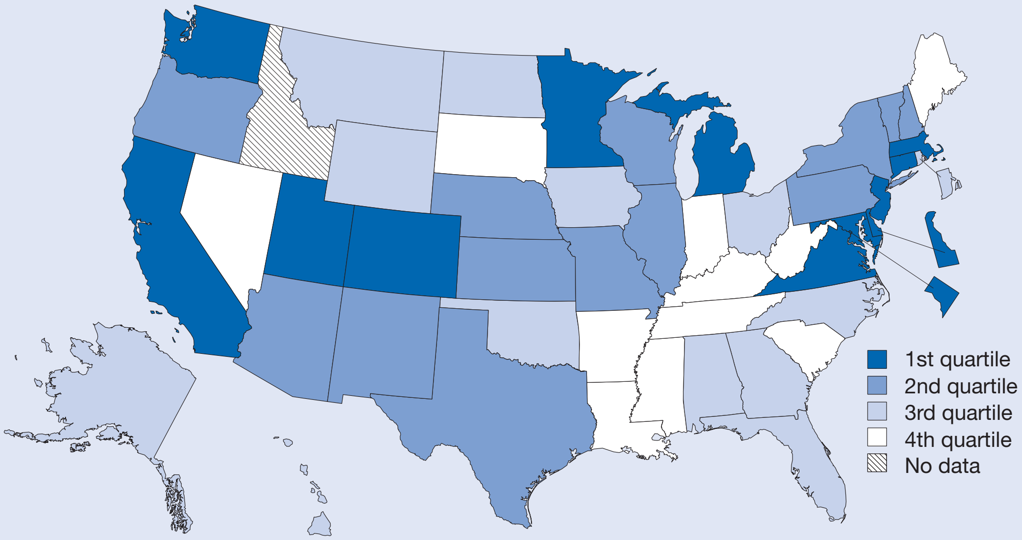
SOURCES: Census Bureau, 2000 Decennial Census and American Community Survey (various years); and Bureau of Labor Statistics, Local Area Unemployment Statistics.

Science & Engineering Indicators 2008

Individuals in S&E Occupations as Share of Workforce

Figure 8-26

Individuals in S&E occupations as share of workforce: 2006



1st quartile (21.59%–3.90%)	2nd quartile (3.89%–3.32%)	3rd quartile (3.31%–2.70%)	4th quartile (2.68%–1.92%)	No data
California	Arizona	Alabama	Arkansas	Idaho
Colorado	Illinois	Alaska	Indiana	
Connecticut	Kansas	Florida	Kentucky	
Delaware	Missouri	Georgia	Louisiana	
District of Columbia	Nebraska	Hawaii	Maine	
Maryland	New Hampshire	Iowa	Mississippi	
Massachusetts	New Mexico	Montana	Nevada	
Michigan	New York	North Carolina	South Carolina	
Minnesota	Oregon	North Dakota	South Dakota	
New Jersey	Pennsylvania	Ohio	Tennessee	
Utah	Texas	Oklahoma	West Virginia	
Virginia	Vermont	Rhode Island		
Washington	Wisconsin	Wyoming		

SOURCES: Bureau of Labor Statistics, Occupational Employment and Wage Estimates; and Local Area Unemployment Statistics. See table 8-26.

Findings

- In 2006, 3.7% of the U.S. workforce, or about 5.4 million people, worked in occupations classified as S&E.
- The percentage of the workforce engaged in S&E occupations ranged from 1.9% to 6.5% in individual states in 2006.
- The highest percentage of S&E occupations was found in the District of Columbia and the adjacent states of Maryland and Virginia as well as in Massachusetts, Washington, and Colorado.
- Between 2004 and 2006, the percentage of S&E occupations increased in 29 states and the District of Columbia, and it decreased in 18 states.

This indicator shows the extent to which a state's workforce is employed in S&E 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 standard occupational codes that encompass mathematical, computer, life, physical, and social scientists; engineers; and postsecondary teachers in any of these S&E fields. Managers, technicians, elementary and secondary schoolteachers, and medical personnel 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 8-26

Individuals in S&E occupations as share of workforce, by state: 2004 and 2006

	S&E occupations		Employed workforce		Workforce in S&E occupations (%)	
State	2004	2006	2004	2006	2004	2006
United States	5,065,330	5,383,860	139,213,523	144,581,912	3.64	3.72
Alabama	57,560	66,100	2,014,678	2,120,573	2.86	3.12
Alaska	10,660	10,720	312,922	323,531	3.41	3.31
Arizona	95,380	98,110	2,649,243	2,854,381	3.60	3.44
Arkansas	22,150	24,860	1,228,163	1,292,886	1.80	1.92
California	693,670	730,010	16,444,457	17,029,307	4.22	4.29
Colorado	126,280	133,730	2,384,562	2,537,037	5.30	5.27
Connecticut	82,820	79,380	1,714,758	1,765,075	4.83	4.50
Delaware	17,980	21,550	408,022	424,506	4.41	5.08
District of Columbia	57,750	64,120	285,567	296,957	20.22	21.59
Florida	229,950	246,190	8,056,259	8,692,761	2.85	2.83
Georgia	141,710	136,470	4,257,465	4,522,025	3.33	3.02
Hawaii	16,360	18,940	597,147	628,277	2.74	3.01
Idaho	22,310	NA	670,746	723,621	3.33	NA
Illinois	219,530	222,470	6,012,320	6,315,715	3.65	3.52
Indiana	79,120	80,110	3,017,271	3,108,806	2.62	2.58
Iowa	39,280	43,670	1,542,342	1,602,849	2.55	2.72
Kansas	52,020	48,620	1,378,713	1,400,169	3.77	3.47
Kentucky	44,350	44,680	1,859,902	1,922,163	2.38	2.32
Louisiana	42,230	40,180	1,926,594	1,910,348	2.19	2.10
Maine	15,160	15,950	661,163	678,843	2.29	2.35
Maryland	154,310	159,470	2,766,653	2,892,620	5.58	5.51
Massachusetts	186,260	198,670	3,204,653	3,234,860	5.81	6.14
Michigan	183,140	208,520	4,694,981	4,730,291	3.90	4.41
Minnesota	119,380	125,930	2,781,744	2,822,297	4.29	4.46
Mississippi	23,190	24,910	1,234,167	1,218,664	1.88	2.04
Missouri	87,200	96,420	2,821,802	2,885,857	3.09	3.34
Montana	11,390	13,010	456,624	478,162	2.49	2.72
Nebraska	31,720	32,500	940,047	945,270	3.37	3.44
Nevada	23,980	26,930	1,134,550	1,240,868	2.11	2.17
New Hampshire	24,350	27,680	693,648	711,512	3.51	3.89
New Jersey	165,150	176,460	4,177,841	4,309,021	3.95	4.10
New Mexico	33,500	30,800	850,164	895,623	3.94	3.44
New York	272,930	306,810	8,810,155	9,072,733	3.10	3.38
North Carolina	135,380	138,790	4,028,598	4,250,619	3.36	3.27
North Dakota	8,420	9,360	338,221	346,359	2.49	2.70
Ohio	180,360	185,190	5,507,404	5,609,056	3.27	3.30
Oklahoma	NA	50,770	1,608,849	1,650,877	NA	3.08
Oregon	62,570	64,520	1,722,058	1,796,165	3.63	3.59
Pennsylvania	195,730	214,910	5,889,957	6,009,858	3.32	3.58
Rhode Island	19,660	18,060	531,121	547,618	3.70	3.30
South Carolina	51,030	53,230	1,900,122	1,988,378	2.69	2.68
South Dakota	9,420	10,120	409,263	417,100	2.30	2.43
Tennessee	65,120	67,040	2,733,793	2,835,530	2.38	2.36
Texas	383,180	408,710	10,456,224	10,921,673	3.66	3.74
Utah	43,030	49,690	1,169,163	1,272,801	3.68	3.90
Vermont	11,770	12,780	337,709	348,026	3.49	3.67
Virginia	220,180	251,720	3,704,593	3,878,988	5.94	6.49
Washington	154,610	171,780	3,008,352	3,160,350	5.14	5.44
West Virginia	16,100	17,150	744,034	767,134	2.16	2.24
Wisconsin	95,230	96,860	2,871,034	2,918,155	3.32	3.32
Wyoming	6,760	7,640	263,705	275,617	2.56	2.77
Puerto Rico	20,410	23,850	1,226,251	1,260,703	1.66	1.89

NOTE: Workforce represents employed component of civilian labor force and reported as annual data not seasonally adjusted.

SOURCES: Bureau of Labor Statistics, Occupational Employment and Wage Estimates; and Local Area Unemployment Statistics.

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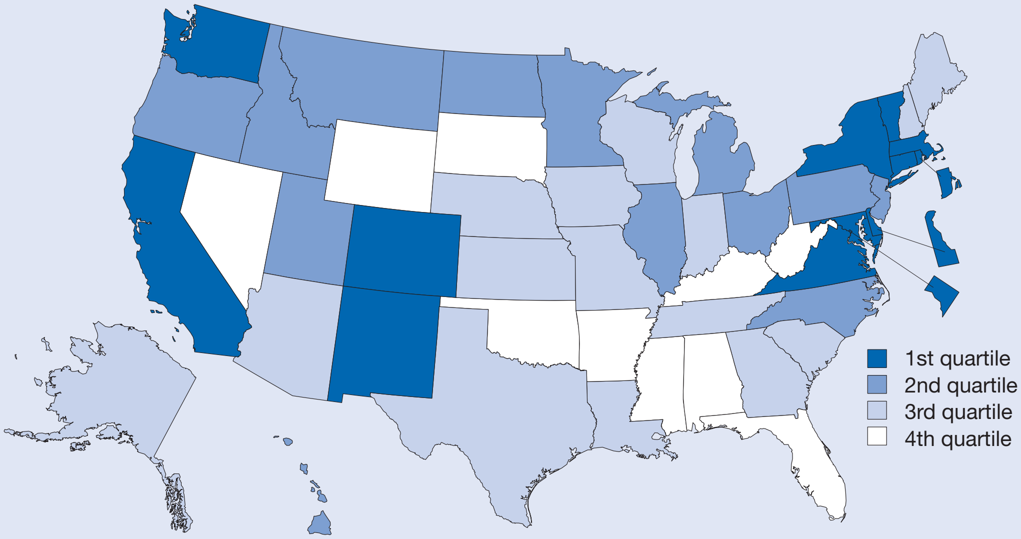
Employed S&E Doctorate Holders as Share of Workforce

Figure 8-27
Employed S&E doctorate holders as share of workforce: 2006



1st quartile (4.49%–0.49%)	2nd quartile (0.48%–0.37%)	3rd quartile (0.35%–0.29%)	4th quartile (0.28%–0.20%)
California	Hawaii	Alaska	Alabama
Colorado	Idaho	Arizona	Arkansas
Connecticut	Illinois	Georgia	Florida
Delaware	Michigan	Indiana	Kentucky
District of Columbia	Minnesota	Iowa	Mississippi
Maryland	Montana	Kansas	Nevada
Massachusetts	New Jersey	Louisiana	Oklahoma
New Mexico	North Carolina	Maine	South Dakota
New York	North Dakota	Missouri	West Virginia
Rhode Island	Ohio	Nebraska	Wyoming
Vermont	Oregon	New Hampshire	
Virginia	Pennsylvania	South Carolina	
Washington	Utah	Tennessee	
		Texas	
		Wisconsin	

SOURCES: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients; and Bureau of Labor Statistics, Local Area Unemployment Statistics. See table 8-27.

Findings

- The number of employed S&E doctorate holders in the United States rose from 517,000 in 1997 to 618,000 in 2006, an increase of 20%.
- For the United States, the value of this indicator rose from 0.39% to 0.43% of the workforce because the number of employed S&E doctorate holders increased more rapidly than the size of the workforce during this period.
- In 2006, the values for this indicator in individual states ranged from 0.20% to 1.00% of the state's workforce; the District of Columbia was an outlier at 4.49%, reflecting the fact that there are many government offices, colleges and universities, and government contractors in the area that employ scientists and engineers.
- 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 ability to attract and retain highly trained scientists and engineers. These individuals often conduct R&D, 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 S&E.

S&E fields include physical, life, earth, ocean, atmospheric, computer, and social sciences; mathematics; engineering; and psychology. S&E doctorate data derive from NSF's Survey of Doctorate Recipients, which excludes those with doctorates from foreign institutions. The location of the employed doctorate holders primarily reflects the state in which the individuals work. Civilian workforce data are Bureau of Labor Statistics' estimates from the Local Area Unemployment Statistics, 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 8-27
Employed S&E doctorate holders as share of workforce, by state: 1997, 2001, and 2006

	Employed S&E doctorate holders			Employed workforce			S&E doctorate holders in workforce (%)		
State	1997	2001	2006	1997	2001	2006	1997	2001	2006
United States	516,560	572,800	618,370	130,988,267	137,115,199	144,581,912	0.39	0.42	0.43
Alabama	6,610	5,330	5,900	2,035,156	2,034,909	2,120,573	0.32	0.26	0.28
Alaska[a]	1,110	1,200	1,110	289,963	301,694	323,531	0.38	0.40	0.34
Arizona	6,280	7,070	8,410	2,196,901	2,453,453	2,854,381	0.29	0.29	0.29
Arkansas	2,320	2,560	2,840	1,177,143	1,194,024	1,292,886	0.20	0.21	0.22
California	70,490	80,870	87,370	14,780,791	16,220,033	17,029,307	0.48	0.50	0.51
Colorado	10,740	11,780	13,150	2,154,294	2,303,494	2,537,037	0.50	0.51	0.52
Connecticut	8,770	9,490	10,330	1,674,937	1,700,046	1,765,075	0.52	0.56	0.59
Delaware	3,710	3,540	3,110	378,117	404,135	424,506	0.98	0.88	0.73
District of Columbia	11,800	14,200	13,330	262,789	286,649	296,957	4.49	4.95	4.49
Florida	13,330	15,740	17,630	7,040,660	7,624,718	8,692,761	0.19	0.21	0.20
Georgia	9,880	11,990	12,940	3,751,699	4,112,868	4,522,025	0.26	0.29	0.29
Hawaii	2,550	2,580	2,850	566,766	589,216	628,277	0.45	0.44	0.45
Idaho[a]	2,030	2,230	2,840	598,004	644,816	723,621	0.34	0.35	0.39
Illinois	21,260	22,110	24,110	5,988,296	6,113,536	6,315,715	0.36	0.36	0.38
Indiana	7,570	9,580	9,870	3,014,499	3,020,985	3,108,806	0.25	0.32	0.32
Iowa	4,120	4,390	4,890	1,555,837	1,568,638	1,602,849	0.26	0.28	0.31
Kansas	3,770	3,970	4,250	1,329,797	1,347,715	1,400,169	0.28	0.29	0.30
Kentucky	4,110	4,590	4,990	1,809,785	1,852,056	1,922,163	0.23	0.25	0.26
Louisiana	5,360	5,290	5,470	1,890,102	1,922,110	1,910,348	0.28	0.28	0.29
Maine[a]	2,150	1,990	2,350	624,410	650,699	678,843	0.34	0.31	0.35
Maryland	21,020	22,730	26,220	2,646,200	2,712,268	2,892,620	0.79	0.84	0.91
Massachusetts	23,330	29,100	32,360	3,158,851	3,275,343	3,234,860	0.74	0.89	1.00
Michigan	15,050	17,380	17,900	4,748,691	4,876,338	4,730,291	0.32	0.36	0.38
Minnesota	9,810	11,410	11,850	2,605,673	2,755,808	2,822,297	0.38	0.41	0.42
Mississippi	3,000	3,170	3,310	1,200,845	1,229,884	1,218,664	0.25	0.26	0.27
Missouri	9,490	9,280	9,230	2,780,185	2,867,853	2,885,857	0.34	0.32	0.32
Montana[a]	1,690	1,440	1,990	427,504	447,827	478,162	0.40	0.32	0.42
Nebraska	3,010	2,890	2,970	904,492	925,783	945,270	0.33	0.31	0.31
Nevada	1,620	2,030	2,620	895,258	1,042,182	1,240,868	0.18	0.19	0.21
New Hampshire[a]	2,230	2,470	2,440	635,469	680,706	711,512	0.35	0.36	0.34
New Jersey	20,440	22,740	20,840	4,031,022	4,117,543	4,309,021	0.51	0.55	0.48
New Mexico	7,480	7,750	8,330	768,596	821,003	895,623	0.97	0.94	0.93
New York	40,080	43,980	45,840	8,416,544	8,743,924	9,072,733	0.48	0.50	0.51
North Carolina	13,730	16,760	18,880	3,809,601	3,929,977	4,250,619	0.36	0.43	0.44
North Dakota[a]	1,350	1,080	1,380	335,854	336,228	346,359	0.40	0.32	0.40
Ohio	18,700	20,070	20,540	5,448,161	5,566,735	5,609,056	0.34	0.36	0.37
Oklahoma	4,580	4,360	4,420	1,543,105	1,614,627	1,650,877	0.30	0.27	0.27
Oregon	6,210	7,040	8,280	1,652,997	1,711,041	1,796,165	0.38	0.41	0.46
Pennsylvania	23,940	26,140	29,090	5,775,178	5,874,153	6,009,858	0.41	0.45	0.48
Rhode Island	2,450	2,640	3,020	504,147	520,677	547,618	0.49	0.51	0.55
South Carolina	4,780	5,130	5,920	1,819,508	1,842,291	1,988,378	0.26	0.28	0.30
South Dakota[a]	1,060	1,000	1,050	383,216	400,352	417,100	0.28	0.25	0.25
Tennessee	8,520	8,980	9,980	2,640,005	2,728,523	2,835,530	0.32	0.33	0.35
Texas	28,570	32,490	35,970	9,395,279	9,991,920	10,921,673	0.30	0.33	0.33
Utah	4,800	4,820	5,540	1,034,429	1,108,547	1,272,801	0.46	0.43	0.44
Vermont[a]	1,750	1,750	1,700	315,806	330,099	348,026	0.55	0.53	0.49
Virginia	15,250	17,460	19,790	3,323,266	3,537,719	3,878,988	0.46	0.49	0.51
Washington	13,360	14,760	16,920	2,822,223	2,863,705	3,160,350	0.47	0.52	0.54
West Virginia[a]	1,980	1,890	2,020	746,442	758,904	767,134	0.27	0.25	0.26
Wisconsin	8,460	8,720	9,500	2,855,830	2,897,937	2,918,155	0.30	0.30	0.33
Wyoming[a]	860	840	730	243,944	259,508	275,617	0.35	0.32	0.26
Puerto Rico	660	1,410	1,690	1,132,658	1,133,988	1,260,703	0.06	0.12	0.13

[a] Estimates for S&E doctorate holders may vary between 10% and 25% because geography is not part of the sample design.

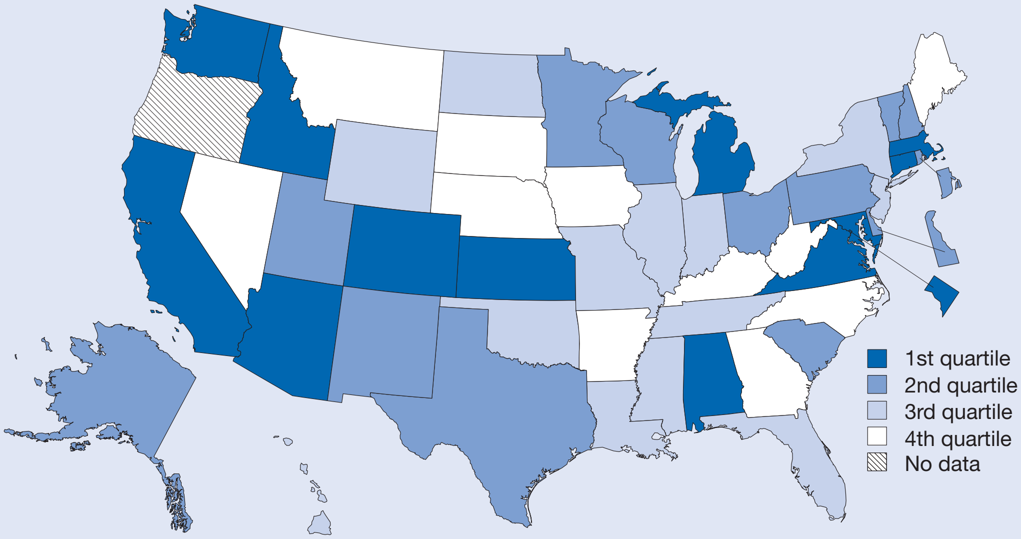
NOTES: Data on S&E doctorate holders classified by employer location, and workforce data based on respondents' residence. Data on 2006 employed S&E doctorate holders are preliminary. Workforce represents employed component of civilian labor force and reported as annual data not seasonally adjusted.

SOURCES: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients; and Bureau of Labor Statistics, Local Area Unemployment Statistics.

Science & Engineering Indicators 2008

Engineers as Share of Workforce

Figure 8-28
Engineers as share of workforce, by state: 2006



1st quartile (3.00%–1.24%)	2nd quartile (1.21%–0.99%)	3rd quartile (0.94%–0.73%)	4th quartile (0.71%–0.53%)	No data
Alabama	Alaska	Florida	Arkansas	Oregon
Arizona	Delaware	Hawaii	Georgia	
California	Minnesota	Illinois	Iowa	
Colorado	New Hampshire	Indiana	Kentucky	
Connecticut	New Mexico	Louisiana	Maine	
District of Columbia	Ohio	Mississippi	Montana	
Idaho	Pennsylvania	Missouri	Nebraska	
Kansas	Rhode Island	New Jersey	Nevada	
Maryland	South Carolina	New York	North Carolina	
Massachusetts	Texas	North Dakota	South Dakota	
Michigan	Utah	Oklahoma	West Virginia	
Virginia	Vermont	Tennessee		
Washington	Wisconsin	Wyoming		

SOURCES: Bureau of Labor Statistics, Occupational Employment and Wage Estimates; and Local Area Unemployment Statistics. See table 8-28.

Findings

- In the United States, 1.54 million individuals were employed in engineering occupations in 2006, an increase over the 1.48 million engineers employed in 2004. During this period, the percentage of the workforce employed in engineering occupations remained unchanged at 1.06%.
- The concentration of engineers in individual states ranged from 0.53% to 2.11% in 2006.
- The District of Columbia was an outlier at 3.00%, reflecting the fact that there are many government offices, colleges and universities, and government contractors in the area that employ scientists and engineers.
- Between 2004 and 2006, the percentage of engineers in the workforce increased in 28 states and decreased in 17 states and the District of Columbia.
- 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 the 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 8-28
Engineers as share of workforce, by state: 2004 and 2006

	Engineers		Employed workforce		Engineers in workforce (%)	
State	2004	2006	2004	2006	2004	2006
United States	1,480,520	1,535,620	139,213,523	144,581,912	1.06	1.06
Alabama	22,170	26,210	2,014,678	2,120,573	1.10	1.24
Alaska	3,480	3,330	312,922	323,531	1.11	1.03
Arizona	36,180	35,630	2,649,243	2,854,381	1.37	1.25
Arkansas	5,900	7,210	1,228,163	1,292,886	0.48	0.56
California	220,120	231,480	16,444,457	17,029,307	1.34	1.36
Colorado	34,370	37,040	2,384,562	2,537,037	1.44	1.46
Connecticut	26,160	24,070	1,714,758	1,765,075	1.53	1.36
Delaware	3,810	4,810	408,022	424,506	0.93	1.13
District of Columbia	10,490	8,920	285,567	296,957	3.67	3.00
Florida	59,070	67,810	8,056,259	8,692,761	0.73	0.78
Georgia	30,550	30,170	4,257,465	4,522,025	0.72	0.67
Hawaii	4,560	5,380	597,147	628,277	0.76	0.86
Idaho	8,250	9,270	670,746	723,621	1.23	1.28
Illinois	59,010	57,270	6,012,320	6,315,715	0.98	0.91
Indiana	30,380	28,380	3,017,271	3,108,806	1.01	0.91
Iowa	9,900	10,420	1,542,342	1,602,849	0.64	0.65
Kansas	19,020	17,480	1,378,713	1,400,169	1.38	1.25
Kentucky	12,870	12,950	1,859,902	1,922,163	0.69	0.67
Louisiana	15,790	15,250	1,926,594	1,910,348	0.82	0.80
Maine	4,830	4,230	661,163	678,843	0.73	0.62
Maryland	33,190	36,880	2,766,653	2,892,620	1.20	1.27
Massachusetts	50,370	51,750	3,204,653	3,234,860	1.57	1.60
Michigan	91,600	99,680	4,694,981	4,730,291	1.95	2.11
Minnesota	30,370	28,280	2,781,744	2,822,297	1.09	1.00
Mississippi	8,140	9,830	1,234,167	1,218,664	0.66	0.81
Missouri	21,070	22,870	2,821,802	2,885,857	0.75	0.79
Montana	2,580	2,840	456,624	478,162	0.57	0.59
Nebraska	5,810	5,820	940,047	945,270	0.62	0.62
Nevada	7,190	7,960	1,134,550	1,240,868	0.63	0.64
New Hampshire	7,890	8,090	693,648	711,512	1.14	1.14
New Jersey	37,850	38,130	4,177,841	4,309,021	0.91	0.88
New Mexico	12,170	10,870	850,164	895,623	1.43	1.21
New York	64,920	68,540	8,810,155	9,072,733	0.74	0.76
North Carolina	31,400	30,040	4,028,598	4,250,619	0.78	0.71
North Dakota	2,230	2,520	338,221	346,359	0.66	0.73
Ohio	62,560	57,810	5,507,404	5,609,056	1.14	1.03
Oklahoma	12,520	13,840	1,608,849	1,650,877	0.78	0.84
Oregon	18,500	NA	1,722,058	1,796,165	1.07	NA
Pennsylvania	NA	61,620	5,889,957	6,009,858	NA	1.03
Rhode Island	5,270	5,430	531,121	547,618	0.99	0.99
South Carolina	21,260	22,460	1,900,122	1,988,378	1.12	1.13
South Dakota	2,050	2,210	409,263	417,100	0.50	0.53
Tennessee	21,100	21,230	2,733,793	2,835,530	0.77	0.75
Texas	120,810	123,990	10,456,224	10,921,673	1.16	1.14
Utah	11,560	13,090	1,169,163	1,272,801	0.99	1.03
Vermont	3,440	3,780	337,709	348,026	1.02	1.09
Virginia	47,180	50,780	3,704,593	3,878,988	1.27	1.31
Washington	45,140	49,840	3,008,352	3,160,350	1.50	1.58
West Virginia	4,920	5,230	744,034	767,134	0.66	0.68
Wisconsin	29,590	30,990	2,871,034	2,918,155	1.03	1.06
Wyoming	2,290	2,570	263,705	275,617	0.87	0.93
Puerto Rico	7,290	8,280	1,226,251	1,260,703	0.59	0.66

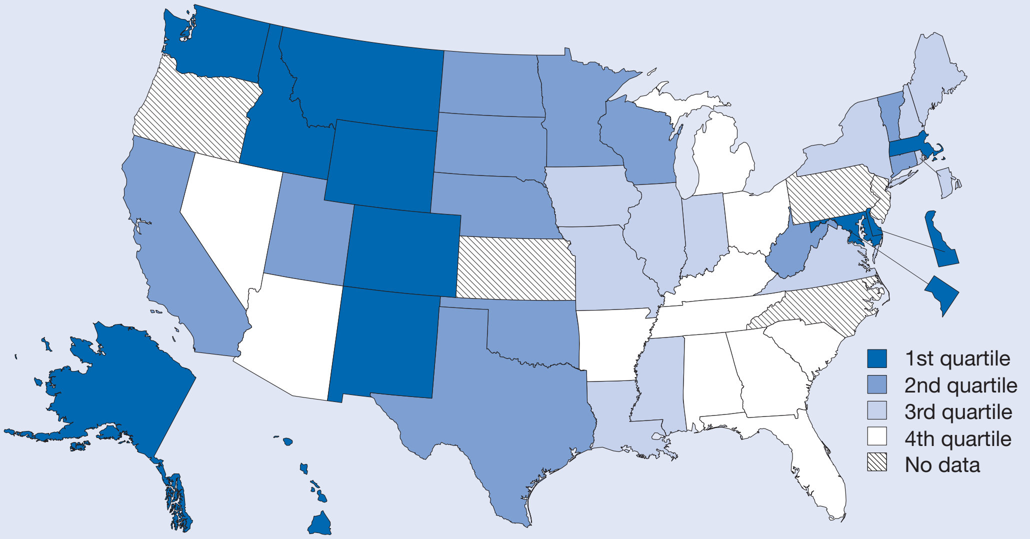
NOTE: Workforce represents employed component of civilian labor force and reported as annual data not seasonally adjusted.

SOURCES: Bureau of Labor Statistics, Occupational Employment and Wage Estimates; and Local Area Unemployment Statistics.

Science & Engineering Indicators 2008

Life and Physical Scientists as Share of Workforce

Figure 8-29
Life and physical scientists as share of workforce: 2006



1st quartile (2.15%–0.52%)	2nd quartile (0.50%–0.42%)	3rd quartile (0.40%–0.32%)	4th quartile (0.31%–0.22%)	No data
Alaska	California	Illinois	Alabama	Kansas
Colorado	Connecticut	Indiana	Arizona	New Jersey
Delaware	Minnesota	Iowa	Arkansas	North Carolina
District of Columbia	Nebraska	Louisiana	Florida	Oregon
Hawaii	North Dakota	Maine	Georgia	Pennsylvania
Idaho	Oklahoma	Mississippi	Kentucky	
Maryland	South Dakota	Missouri	Michigan	
Massachusetts	Texas	New Hampshire	Nevada	
Montana	Utah	New York	Ohio	
New Mexico	Vermont	Rhode Island	South Carolina	
Washington	West Virginia	Virginia	Tennessee	
Wyoming	Wisconsin			

SOURCES: Bureau of Labor Statistics, Occupational Employment and Wage Estimates; and Local Area Unemployment Statistics. See Table 8-29.

Findings

- Nearly 578,000 individuals, or 0.40% of the workforce, were employed as life and physical scientists in the United States in 2006, an increase over the 546,000 life and physical scientists employed in 2004, which was 0.39% of the workforce.
- In 2006, individual states had indicator values ranging from 0.22% to 0.93%, which showed major differences in the concentration of jobs in the life and physical sciences.
- The District of Columbia was an outlier at 2.15%, reflecting the fact that there are many government offices, colleges and universities, and government contractors in the area that employ scientists and engineers.
- Between 2004 and 2006, the percentage of life and physical scientists in the workforce increased in 18 states and the District of Columbia and decreased in 11 states.

This indicator shows a state's ability to attract and retain life and physical scientists. Life scientists are identified from standard occupational codes that include agricultural and food scientists, biological scientists, conservation scientists and foresters, and medical scientists. Physical scientists are identified from standard occupational codes that include astronomers, physicists, atmospheric and space scientists, chemists, materials scientists, environmental scientists, and 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 sciences 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 8-29

Life and physical scientists as share of workforce, by state: 2004 and 2006

	Life and physical scientists		Employed workforce		Life and physical scientists in workforce (%)	
State	2004	2006	2004	2006	2004	2006
United States	546,160	577,890	139,213,523	144,581,912	0.39	0.40
Alabama	5,630	5,690	2,014,678	2,120,573	0.28	0.27
Alaska	3,090	3,010	312,922	323,531	0.99	0.93
Arizona	6,940	6,460	2,649,243	2,854,381	0.26	0.23
Arkansas	2,890	2,880	1,228,163	1,292,886	0.24	0.22
California	68,020	72,590	16,444,457	17,029,307	0.41	0.43
Colorado	NA	14,130	2,384,562	2,537,037	NA	0.56
Connecticut	8,460	7,750	1,714,758	1,765,075	0.49	0.44
Delaware	3,100	2,940	408,022	424,506	0.76	0.69
District of Columbia	5,860	6,370	285,567	296,957	2.05	2.15
Florida	20,490	22,100	8,056,259	8,692,761	0.25	0.25
Georgia	13,090	9,820	4,257,465	4,522,025	0.31	0.22
Hawaii	2,400	3,390	597,147	628,277	0.40	0.54
Idaho	9,930	3,860	670,746	723,621	1.48	0.53
Illinois	19,390	22,650	6,012,320	6,315,715	0.32	0.36
Indiana	NA	10,350	3,017,271	3,108,806	NA	0.33
Iowa	NA	5,390	1,542,342	1,602,849	NA	0.34
Kansas	4,640	NA	1,378,713	1,400,169	0.34	NA
Kentucky	5,300	4,990	1,859,902	1,922,163	0.28	0.26
Louisiana	6,130	6,090	1,926,594	1,910,348	0.32	0.32
Maine	2,430	2,650	661,163	678,843	0.37	0.39
Maryland	18,150	19,930	2,766,653	2,892,620	0.66	0.69
Massachusetts	20,700	23,260	3,204,653	3,234,860	0.65	0.72
Michigan	10,340	12,940	4,694,981	4,730,291	0.22	0.27
Minnesota	11,700	13,450	2,781,744	2,822,297	0.42	0.48
Mississippi	4,540	4,490	1,234,167	1,218,664	0.37	0.37
Missouri	9,920	10,190	2,821,802	2,885,857	0.35	0.35
Montana	3,050	3,450	456,624	478,162	0.67	0.72
Nebraska	4,280	4,350	940,047	945,270	0.46	0.46
Nevada	3,210	3,460	1,134,550	1,240,868	0.28	0.28
New Hampshire	1,870	2,250	693,648	711,512	0.27	0.32
New Jersey	19,710	NA	4,177,841	4,309,021	0.47	NA
New Mexico	7,550	5,380	850,164	895,623	0.89	0.60
New York	NA	31,280	8,810,155	9,072,733	NA	0.34
North Carolina	19,190	NA	4,028,598	4,250,619	0.48	NA
North Dakota	1,570	1,610	338,221	346,359	0.46	0.46
Ohio	15,020	17,320	5,507,404	5,609,056	0.27	0.31
Oklahoma	NA	7,010	1,608,849	1,650,877	NA	0.42
Oregon	7,990	NA	1,722,058	1,796,165	0.46	NA
Pennsylvania	25,460	NA	5,889,957	6,009,858	0.43	NA
Rhode Island	2,790	2,120	531,121	547,618	0.53	0.39
South Carolina	5,190	5,680	1,900,122	1,988,378	0.27	0.29
South Dakota	1,770	1,900	409,263	417,100	0.43	0.46
Tennessee	7,380	7,680	2,733,793	2,835,530	0.27	0.27
Texas	47,540	50,040	10,456,224	10,921,673	0.45	0.46
Utah	5,820	6,330	1,169,163	1,272,801	0.50	0.50
Vermont	1,250	1,480	337,709	348,026	0.37	0.43
Virginia	NA	15,370	3,704,593	3,878,988	NA	0.40
Washington	NA	20,590	3,008,352	3,160,350	NA	0.65
West Virginia	2,850	3,230	744,034	767,134	0.38	0.42
Wisconsin	11,660	13,000	2,871,034	2,918,155	0.41	0.45
Wyoming	1,840	2,070	263,705	275,617	0.70	0.75
Puerto Rico	4,840	5,470	1,226,251	1,260,703	0.39	0.43

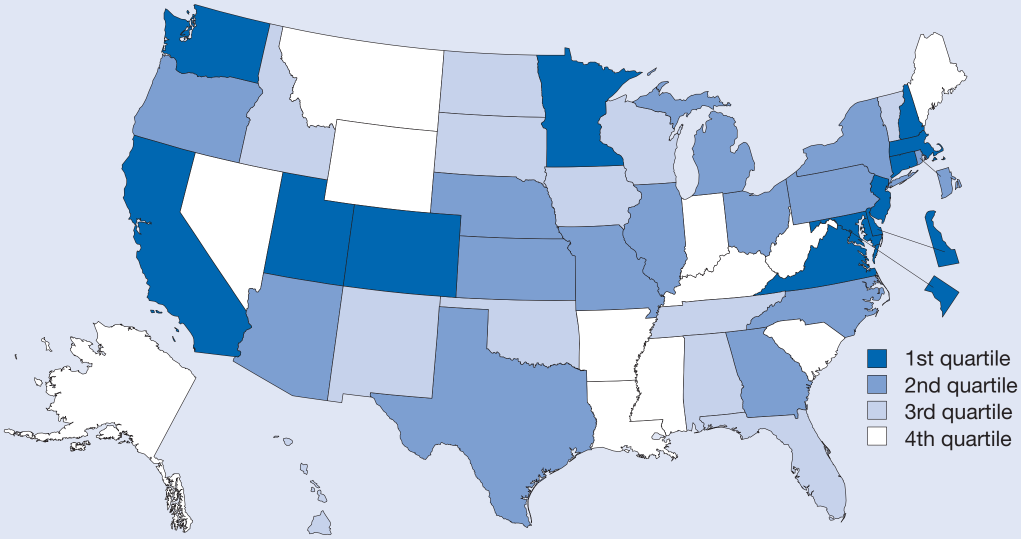
NOTE: Workforce represents employed component of civilian labor force and reported as annual data not seasonally adjusted.

SOURCES: Bureau of Labor Statistics, Occupational Employment and Wage Estimates; and Local Area Unemployment Statistics.

Science & Engineering Indicators 2008

Computer Specialists as Share of Workforce

Figure 8-30
Computer specialists as share of workforce: 2006



1st quartile (10.71%–2.23%)	2nd quartile (2.12%–1.72%)	3rd quartile (1.70%–1.23%)	4th quartile (1.22%–0.70%)
California	Arizona	Alabama	Alaska
Colorado	Georgia	Florida	Arkansas
Connecticut	Illinois	Hawaii	Indiana
Delaware	Kansas	Idaho	Kentucky
District of Columbia	Michigan	Iowa	Louisiana
Maryland	Missouri	New Mexico	Maine
Massachusetts	Nebraska	North Dakota	Mississippi
Minnesota	New York	Oklahoma	Montana
New Hampshire	North Carolina	South Dakota	Nevada
New Jersey	Ohio	Tennessee	South Carolina
Utah	Oregon	Vermont	West Virginia
Virginia	Pennsylvania	Wisconsin	Wyoming
Washington	Rhode Island		
	Texas		

SOURCES: BLS, Occupational Employment and Wage Estimates; and Local Area Unemployment Statistics. See Table 8-30.

Findings

- In the United States, 2.96 million individuals, or 2.05% of the workforce, were employed as computer specialists in 2006, an increase over the 2.80 million computer specialists employed in 2004, which was 2.02% of the workforce.
- Individual states showed considerable differences in the intensity of computer-related operations in their economies, with 0.70% to 4.38% of their workforce employed in computer-related occupations in 2006.
- There was a concentration of computer-intensive occupations in the District of Columbia and the adjacent states of Maryland and Virginia. This may be due to the fact that there are many government offices, colleges and universities, and government contractors in the area that employ scientists and engineers, especially computer scientists.
- Between 2004 and 2006, the percentage of computer specialists in the workforce increased in 31 states and the District of Columbia and decreased in 18 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 8-30

Computer specialists as share of workforce, by state: 2004 and 2006

State	Computer specialists		Employed workforce		Computer specialists in workforce (%)	
	2004	2006	2004	2006	2004	2006
United States	2,806,910	2,960,460	139,213,523	144,581,912	2.02	2.05
Alabama	28,320	32,720	2,014,678	2,120,573	1.41	1.54
Alaska	3,320	3,810	312,922	323,531	1.06	1.18
Arizona	45,930	49,180	2,649,243	2,854,381	1.73	1.72
Arkansas	12,470	13,360	1,228,163	1,292,886	1.02	1.03
California	370,180	380,040	16,444,457	17,029,307	2.25	2.23
Colorado	74,940	76,200	2,384,562	2,537,037	3.14	3.00
Connecticut	44,120	44,160	1,714,758	1,765,075	2.57	2.50
Delaware	8,730	11,930	408,022	424,506	2.14	2.81
District of Columbia	28,040	31,810	285,567	296,957	9.82	10.71
Florida	137,740	143,450	8,056,259	8,692,761	1.71	1.65
Georgia	94,080	89,390	4,257,465	4,522,025	2.21	1.98
Hawaii	7,440	8,140	597,147	628,277	1.25	1.30
Idaho	8,710	10,180	670,746	723,621	1.30	1.41
Illinois	114,860	129,880	6,012,320	6,315,715	1.91	2.06
Indiana	37,540	37,230	3,017,271	3,108,806	1.24	1.20
Iowa	22,650	24,940	1,542,342	1,602,849	1.47	1.56
Kansas	20,850	24,110	1,378,713	1,400,169	1.51	1.72
Kentucky	23,800	23,510	1,859,902	1,922,163	1.28	1.22
Louisiana	18,500	17,090	1,926,594	1,910,348	0.96	0.89
Maine	6,860	7,640	661,163	678,843	1.04	1.13
Maryland	92,450	91,040	2,766,653	2,892,620	3.34	3.15
Massachusetts	103,280	109,430	3,204,653	3,234,860	3.22	3.38
Michigan	74,600	89,280	4,694,981	4,730,291	1.59	1.89
Minnesota	67,600	71,930	2,781,744	2,822,297	2.43	2.55
Mississippi	8,770	8,510	1,234,167	1,218,664	0.71	0.70
Missouri	56,460	61,120	2,821,802	2,885,857	2.00	2.12
Montana	4,500	5,790	456,624	478,162	0.99	1.21
Nebraska	15,890	20,030	940,047	945,270	1.69	2.12
Nevada	11,540	12,940	1,134,550	1,240,868	1.02	1.04
New Hampshire	13,180	16,390	693,648	711,512	1.90	2.30
New Jersey	114,370	116,290	4,177,841	4,309,021	2.74	2.70
New Mexico	9,720	11,060	850,164	895,623	1.14	1.23
New York	170,140	188,620	8,810,155	9,072,733	1.93	2.08
North Carolina	77,240	80,150	4,028,598	4,250,619	1.92	1.89
North Dakota	4,250	4,650	338,221	346,359	1.26	1.34
Ohio	93,300	99,960	5,507,404	5,609,056	1.69	1.78
Oklahoma	21,600	26,200	1,608,849	1,650,877	1.34	1.59
Oregon	29,120	33,960	1,722,058	1,796,165	1.69	1.89
Pennsylvania	102,590	110,090	5,889,957	6,009,858	1.74	1.83
Rhode Island	7,150	9,490	531,121	547,618	1.35	1.73
South Carolina	20,730	23,070	1,900,122	1,988,378	1.09	1.16
South Dakota	5,090	5,160	409,263	417,100	1.24	1.24
Tennessee	36,870	36,570	2,733,793	2,835,530	1.35	1.29
Texas	209,360	224,330	10,456,224	10,921,673	2.00	2.05
Utah	25,340	30,060	1,169,163	1,272,801	2.17	2.36
Vermont	5,810	5,920	337,709	348,026	1.72	1.70
Virginia	151,810	169,830	3,704,593	3,878,988	4.10	4.38
Washington	83,480	80,140	3,008,352	3,160,350	2.77	2.54
West Virginia	7,230	7,250	744,034	767,134	0.97	0.95
Wisconsin	46,380	46,400	2,871,034	2,918,155	1.62	1.59
Wyoming	1,750	2,040	263,705	275,617	0.66	0.74
Puerto Rico	7,380	9,050	1,226,251	1,260,703	0.60	0.72

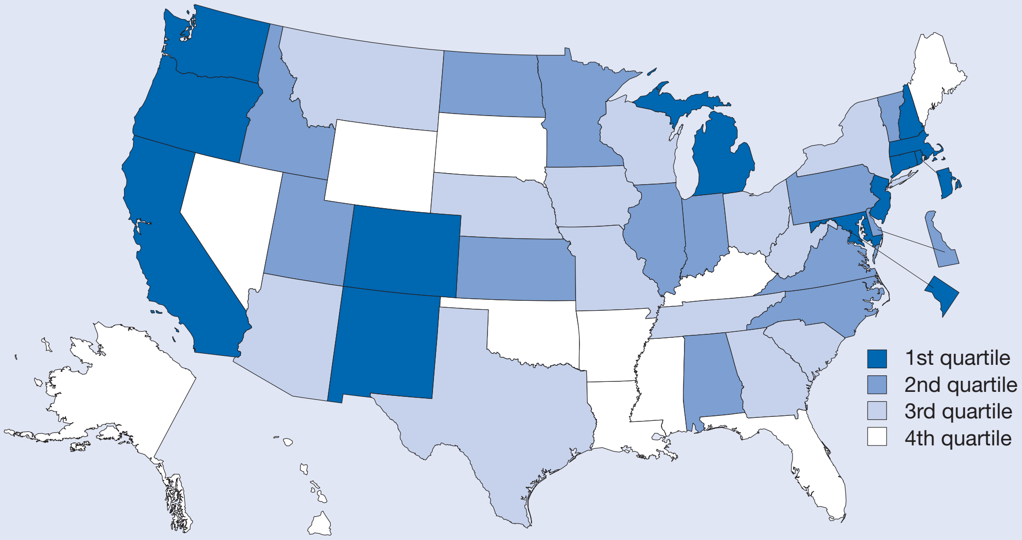
NOTES: For a small number of states, data for selected computer occupations suppressed by state or Bureau of Labor Statistics (BLS) and not reported at state level. Workforce represents employed component of civilian labor force and reported as annual data not seasonally adjusted.

SOURCES: BLS, Occupational Employment and Wage Estimates; and Local Area Unemployment Statistics.

Science & Engineering Indicators 2008

R&D as Share of Gross Domestic Product

Figure 8-31
R&D as share of gross domestic product: 2004



1st quartile (8.01%–2.71%)	2nd quartile (2.69%–1.95%)	3rd quartile (1.84%–1.05%)	4th quartile (0.96%–0.41%)
California	Alabama	Arizona	Alaska
Colorado	Delaware	Georgia	Arkansas
Connecticut	Idaho	Iowa	Florida
District of Columbia	Illinois	Missouri	Hawaii
Maryland	Indiana	Montana	Kentucky
Massachusetts	Kansas	Nebraska	Louisiana
Michigan	Minnesota	New York	Maine
New Hampshire	North Carolina	Ohio	Mississippi
New Jersey	North Dakota	South Carolina	Nevada
New Mexico	Pennsylvania	Tennessee	Oklahoma
Oregon	Utah	Texas	South Dakota
Rhode Island	Vermont	West Virginia	Wyoming
Washington	Virginia	Wisconsin	

SOURCES: National Science Foundation, Division of Science Resources Statistics, National Patterns of R&D Resources (various years); and Bureau of Economic Analysis, Gross Domestic Product data. See Table 8-31.

Findings

- The national value of R&D expenditures as a share of GDP has varied from 2.47% in 1998 to 2.44% in 2004.
- In 2004, state values for this indicator ranged from 0.41% to 8.01%, 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 GDP.
- Between 1998 and 2004, the value of this indicator increased in 31 states and declined in 18 states and the District of Columbia.
- 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 R&D 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 2004, industry performed roughly 71% of total R&D, followed by colleges and universities at 15%; government facilities, including federally funded R&D centers, at 12%; and nonprofit institutions at 2%. Data for the value of gross domestic product (GDP) 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 8-31

R&D as share of gross domestic product, by state: 1998, 2001, and 2004

	R&D performed ($millions)			State GDP ($millions)			R&D performed/GDP (%)		
State	1998	2001	2004	1998	2001	2004	1998	2001	2004
United States	214,752	255,897	283,439	8,679,660	10,058,169	11,633,573	2.47	2.54	2.44
Alabama	1,926	2,251	2,760	106,656	118,682	141,702	1.81	1.90	1.95
Alaska	NA	297	271	23,165	26,609	34,729	NA	1.11	0.78
Arizona	2,318	3,048	3,544	137,581	165,358	194,134	1.68	1.84	1.83
Arkansas	283	451	514	61,861	68,927	81,752	0.46	0.65	0.63
California	43,919	50,959	59,607	1,085,884	1,301,050	1,515,453	4.04	3.92	3.93
Colorado	4,565	4,313	5,497	143,160	178,078	198,407	3.19	2.42	2.77
Connecticut	3,559	5,311	7,881	145,373	165,025	183,873	2.45	3.22	4.29
Delaware	2,556	1,316	1,182	36,831	44,206	52,454	6.94	2.98	2.25
District of Columbia	2,606	2,543	2,383	51,682	63,730	77,782	5.04	3.99	3.06
Florida	4,773	5,642	5,409	417,169	497,423	607,201	1.14	1.13	0.89
Georgia	2,492	3,236	3,655	255,612	299,442	337,622	0.97	1.08	1.08
Hawaii	242	358	490	37,549	41,822	50,781	0.64	0.86	0.96
Idaho	1,127	1,259	1,006	29,800	35,631	42,697	3.78	3.53	2.36
Illinois	8,830	10,472	11,300	423,855	476,461	534,364	2.08	2.20	2.11
Indiana	3,089	4,235	5,130	178,909	195,196	229,618	1.73	2.17	2.23
Iowa	1,054	1,324	1,625	83,665	91,920	111,626	1.26	1.44	1.46
Kansas	1,518	1,597	2,169	76,005	86,430	99,125	2.00	1.85	2.19
Kentucky	645	951	1,006	108,813	115,113	131,839	0.59	0.83	0.76
Louisiana	542	827	972	118,085	133,689	162,646	0.46	0.62	0.60
Maine	159	389	384	31,731	37,129	43,131	0.50	1.05	0.89
Maryland	8,019	11,379	14,341	161,954	192,659	229,158	4.95	5.91	6.26
Massachusetts	13,382	14,665	15,987	236,079	280,509	309,483	5.67	5.23	5.17
Michigan	13,655	15,533	16,722	309,431	334,419	363,380	4.41	4.64	4.60
Minnesota	3,818	5,010	5,992	164,897	190,231	222,628	2.32	2.63	2.69
Mississippi	366	650	651	60,513	65,961	76,534	0.61	0.99	0.85
Missouri	1,868	2,550	3,038	164,267	182,362	204,733	1.14	1.40	1.48
Montana	191	239	295	19,884	22,471	27,790	0.96	1.06	1.06
Nebraska	315	580	740	52,076	57,438	67,976	0.60	1.01	1.09
Nevada	571	444	623	63,635	77,291	99,342	0.90	0.57	0.63
New Hampshire	1,340	1,587	1,665	39,102	44,279	51,656	3.43	3.58	3.22
New Jersey	11,368	11,392	12,460	314,117	362,987	409,156	3.62	3.14	3.05
New Mexico	3,032	3,947	5,114	45,918	51,359	63,861	6.60	7.69	8.01
New York	13,731	14,422	13,113	686,906	808,537	908,308	2.00	1.78	1.44
North Carolina	4,560	5,825	6,491	242,904	285,651	324,622	1.88	2.04	2.00
North Dakota	119	461	558	16,936	18,527	22,715	0.71	2.49	2.46
Ohio	6,970	8,790	7,816	348,723	374,719	424,562	2.00	2.35	1.84
Oklahoma	513	872	814	79,341	94,329	111,400	0.65	0.92	0.73
Oregon	1,910	5,447	3,664	100,951	110,916	135,014	1.89	4.91	2.71
Pennsylvania	8,762	11,156	10,813	361,800	406,713	464,467	2.42	2.74	2.33
Rhode Island	1,677	1,579	1,840	29,537	35,149	42,213	5.68	4.49	4.36
South Carolina	989	1,447	1,599	102,945	117,296	132,348	0.96	1.23	1.21
South Dakota	60	141	149	20,771	23,910	29,519	0.29	0.59	0.50
Tennessee	2,503	2,651	3,180	160,872	180,582	214,400	1.56	1.47	1.48
Texas	10,774	12,722	14,266	629,209	762,247	904,412	1.71	1.67	1.58
Utah	1,495	1,495	1,602	60,168	70,109	81,059	2.48	2.13	1.98
Vermont	175	423	546	15,935	18,828	22,002	1.10	2.24	2.48
Virginia	4,934	5,544	7,345	226,569	276,762	325,467	2.18	2.00	2.26
Washington	8,466	10,372	10,936	195,794	225,765	252,384	4.32	4.59	4.33
West Virginia	421	466	523	39,500	43,365	49,903	1.07	1.07	1.05
Wisconsin	2,501	3,249	3,675	160,681	181,936	208,269	1.56	1.79	1.76
Wyoming	65	82	98	14,859	18,941	23,876	0.44	0.44	0.41
Puerto Rico	NA	NA	NA	54,086	69,208	79,209	NA	NA	NA

NA = not available

GDP = gross domestic product

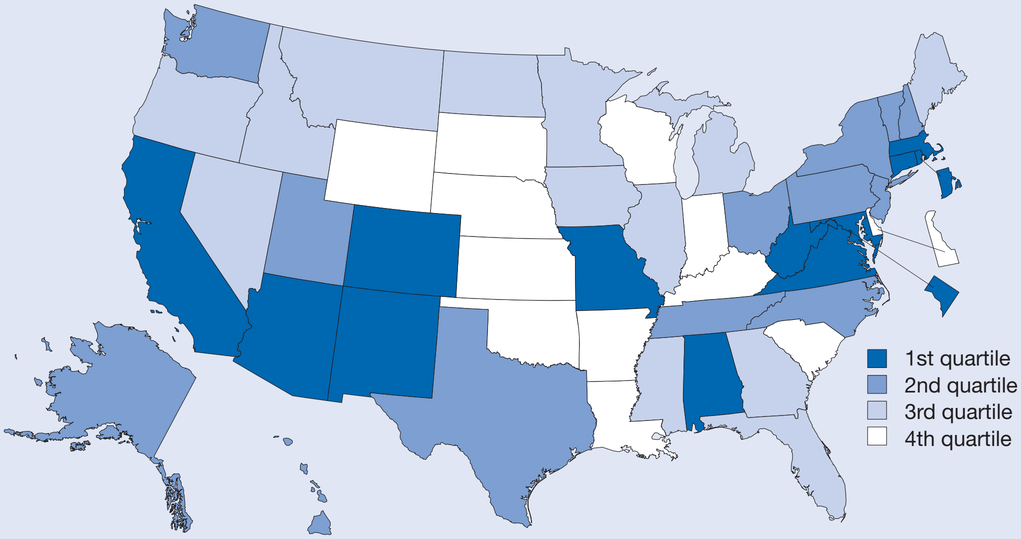
NOTES: R&D includes R&D performed by federal agencies, industry, universities, and other nonprofit organizations. R&D and GDP reported in current dollars.

SOURCES: National Science Foundation, Division of Science Resources Statistics, National Patterns of R&D Resources (various years); Bureau of Economic Analysis, Gross Domestic Product data; and Government of Puerto Rico, Office of the Governor.

Science & Engineering Indicators 2008

Federal R&D Obligations per Civilian Worker

Figure 8-32
Federal R&D obligations per civilian worker: 2005



1st quartile ($13,588–$836)	2nd quartile ($773–$427)	3rd quartile ($391–$234)	4th quartile ($226–$121)
Alabama	Alaska	Florida	Arkansas
Arizona	Hawaii	Georgia	Delaware
California	New Hampshire	Idaho	Indiana
Colorado	New Jersey	Illinois	Kansas
Connecticut	New York	Iowa	Kentucky
District of Columbia	North Carolina	Maine	Louisiana
Maryland	Ohio	Michigan	Nebraska
Massachusetts	Pennsylvania	Minnesota	Oklahoma
Missouri	Tennessee	Mississippi	South Carolina
New Mexico	Texas	Montana	South Dakota
Rhode Island	Utah	Nevada	Wisconsin
Virginia	Vermont	North Dakota	Wyoming
West Virginia	Washington	Oregon	

SOURCES: National Science Foundation, Division of Science Resources Statistics, Federal Funds for Research and Development (various years); and Bureau of Labor Statistics, Local Area Unemployment Statistics. See Table 8-32.

Findings

- Federal R&D obligations rose from $67 billion in 1995 to nearly $107 billion in 2005, an increase of 59% in current dollars.
- The increase in federal R&D obligations (in current dollars) was greater than the increase in the civilian workforce causing the value of this indicator to rise from $532 per worker in 1995 to $753 per worker in 2005.
- Federal R&D obligations in 2005 varied greatly among the states, ranging from $121 to $4,329 per worker. Higher values were found in the states surrounding the District of Columbia and in sparsely populated states with national laboratories or federal facilities.
- The District of Columbia was an outlier with $13,588 per worker in 2005, possibly because many federal employees work there but live in neighboring states.
- Between 1995 and 2005, the value of R&D obligations per worker increased in 44 states and the District of Columbia and decreased in 6 states.

This indicator shows how federal R&D 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 8-32

Federal R&D obligations per civilian worker, by state: 1995, 2000, and 2005

	Federal R&D obligations ($thousands)			Civilian workers			Federal R&D obligations/ civilian worker ($)		
State	1995	2000	2005	1995	2000	2005	1995	2000	2005
United States	67,033,110	71,034,535	106,743,406	126,063,353	136,940,378	141,739,774	532	519	753
Alabama	2,016,252	1,614,901	2,800,183	1,955,846	2,067,147	2,056,800	1,031	781	1,361
Alaska	96,915	146,777	233,543	282,098	299,324	318,423	344	490	733
Arizona	915,087	1,121,701	2,674,487	2,095,749	2,404,916	2,727,003	437	466	981
Arkansas	97,724	116,333	154,255	1,170,593	1,207,352	1,276,851	83	96	121
California	12,703,572	14,082,960	19,379,567	14,062,361	16,024,341	16,782,260	903	879	1,155
Colorado	965,060	1,369,733	2,036,617	2,041,652	2,300,192	2,436,795	473	595	836
Connecticut	902,334	806,228	2,153,517	1,657,732	1,697,670	1,734,386	544	475	1,242
Delaware	56,381	69,867	94,151	366,200	402,777	415,687	154	173	226
District of Columbia	2,805,093	2,374,647	3,993,434	273,764	291,916	293,900	10,246	8,135	13,588
Florida	2,403,899	2,216,206	2,197,889	6,655,500	7,569,406	8,375,993	361	293	262
Georgia	4,365,770	2,632,186	1,707,465	3,522,905	4,095,362	4,384,030	1,239	643	389
Hawaii	480,428	209,737	384,401	557,042	584,858	614,290	862	359	626
Idaho	211,063	216,928	273,093	567,558	632,451	698,466	372	343	391
Illinois	1,116,137	1,404,613	1,982,619	5,857,677	6,176,837	6,112,981	191	227	324
Indiana	426,192	506,326	553,616	2,977,440	3,052,719	3,054,803	143	166	181
Iowa	214,316	267,038	447,661	1,527,972	1,557,081	1,568,561	140	171	285
Kansas	120,846	223,493	198,017	1,296,202	1,351,988	1,389,201	93	165	143
Kentucky	75,670	203,851	262,780	1,757,111	1,866,348	1,879,413	43	109	140
Louisiana	176,253	249,045	402,068	1,820,359	1,930,662	1,938,280	97	129	207
Maine	54,476	249,812	239,831	601,565	650,385	669,250	91	384	358
Maryland	7,039,183	8,684,796	12,211,434	2,572,708	2,711,382	2,820,526	2,736	3,203	4,329
Massachusetts	3,339,532	4,145,472	5,701,829	3,029,360	3,273,281	3,211,033	1,102	1,266	1,776
Michigan	688,376	975,052	1,105,199	4,576,521	4,953,421	4,726,204	150	197	234
Minnesota	571,128	781,132	758,267	2,529,464	2,720,492	2,796,622	226	287	271
Mississippi	212,739	394,585	424,101	1,175,278	1,239,859	1,226,492	181	318	346
Missouri	1,613,322	890,597	4,040,346	2,690,210	2,875,336	2,847,758	600	310	1,419
Montana	64,821	95,025	176,841	417,770	446,552	463,929	155	213	381
Nebraska	86,762	98,491	145,135	882,603	923,198	940,040	98	107	154
Nevada	372,570	263,897	382,463	805,286	1,015,221	1,178,072	463	260	325
New Hampshire	213,647	356,873	364,332	605,929	675,541	703,175	353	528	518
New Jersey	1,325,902	1,937,769	2,344,121	3,846,322	4,130,310	4,255,813	345	469	551
New Mexico	1,987,076	2,130,504	3,279,285	744,557	810,024	867,317	2,669	2,630	3,781
New York	2,581,383	2,927,523	4,955,670	8,125,798	8,751,441	8,959,845	318	335	553
North Carolina	825,433	1,062,536	1,791,495	3,582,647	3,969,235	4,112,828	230	268	436
North Dakota	47,313	64,051	105,109	331,252	335,780	341,847	143	191	307
Ohio	1,811,413	1,799,136	2,369,822	5,330,591	5,573,154	5,546,537	340	323	427
Oklahoma	159,395	185,121	253,602	1,490,602	1,609,522	1,629,217	107	115	156
Oregon	277,229	468,167	557,481	1,583,153	1,716,954	1,754,715	175	273	318
Pennsylvania	2,414,250	2,357,552	3,234,522	5,554,303	5,830,902	5,966,226	435	404	542
Rhode Island	515,425	418,037	572,251	477,409	520,758	539,709	1,080	803	1,060
South Carolina	177,962	248,988	408,407	1,754,633	1,902,029	1,939,646	101	131	211
South Dakota	26,492	38,803	69,982	373,515	397,678	411,551	71	98	170
Tennessee	581,956	734,406	1,292,888	2,574,000	2,756,498	2,758,184	226	266	469
Texas	4,062,175	2,671,790	4,988,545	8,985,635	9,896,002	10,677,171	452	270	467
Utah	371,208	285,968	813,912	979,367	1,097,915	1,211,803	379	260	672
Vermont	53,590	72,030	170,743	305,279	326,742	341,442	176	220	500
Virginia	3,603,023	4,842,811	8,214,449	3,317,434	3,502,524	3,785,583	1,086	1,383	2,170
Washington	1,127,750	1,329,466	2,387,686	2,636,011	2,898,677	3,089,953	428	459	773
West Virginia	296,347	235,677	772,528	723,904	764,649	754,060	409	308	1,024
Wisconsin	347,089	420,839	648,219	2,773,640	2,894,884	2,887,434	125	145	224
Wyoming	35,151	35,059	33,548	240,846	256,685	267,669	146	137	125
Puerto Rico	46,657	81,016	101,433	1,076,473	1,162,153	1,250,335	43	70	81

NOTES: Only 11 agencies required to report federal R&D obligations: Departments of Agriculture, Commerce, Defense, Energy, Health and Human Services, Homeland Security (not established in 1995 and 2000), 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 1995, 2000, and 2005. Civilian workers represent employed component of civilian labor force and reported as annual data not seasonally adjusted.

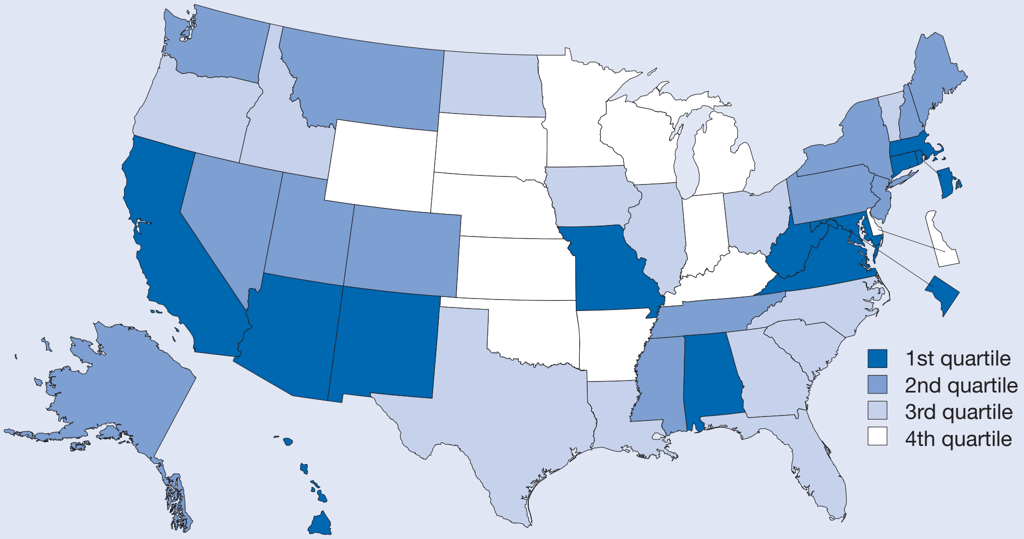
SOURCES: National Science Foundation, Division of Science Resources Statistics, Federal Funds for Research and Development (various years); and Bureau of Labor Statistics, Local Area Unemployment Statistics.

Science & Engineering Indicators 2008

Federal R&D Obligations per Individual in S&E Occupation

Figure 8-33

Federal R&D obligations per individual in S&E occupation: 2005



1st quartile ($100,808–$22,016)	2nd quartile ($20,796–$13,451)	3rd quartile ($13,371–$8,094)	4th quartile ($7,398–$3,835)
Alabama	Alaska	Florida	Arkansas
Arizona	Colorado	Georgia	Delaware
California	Maine	Idaho	Indiana
Connecticut	Mississippi	Illinois	Kansas
District of Columbia	Montana	Iowa	Kentucky
Hawaii	Nevada	Louisiana	Michigan
Maryland	New Hampshire	North Carolina	Minnesota
Massachusetts	New Jersey	North Dakota	Nebraska
Missouri	New York	Ohio	Oklahoma
New Mexico	Pennsylvania	Oregon	South Dakota
Rhode Island	Tennessee	South Carolina	Wisconsin
Virginia	Utah	Texas	Wyoming
West Virginia	Washington	Vermont	

SOURCES: National Science Foundation, Division of Science Resources Statistics, Federal Funds for Research and Development (various years); and Bureau of Labor Statistics, Occupational Employment and Wage Estimates. See Table 8-33.

Findings

- The federal government obligated nearly $107 billion for R&D in 2005, more than $20,000 for each person employed in an S&E occupation.
- The distribution for this indicator was highly skewed in 2005, with only 13 states and the District of Columbia above the national average. High values were reported in the District of Columbia and adjoining states and also in states where federal facilities or major defense contractors are located.
- The state distribution of federal R&D obligations per person employed in an S&E occupation ranged from $3,835 to $100,808 in 2005.
- Between 2003 and 2005, the value of this indicator increased in 25 states and the District of Columbia and decreased in 25 states. The largest increases in indicator value occurred in Missouri, West Virginia, and Maryland, and the largest decreases in Mississippi.

This indicator demonstrates how federal R&D obligations are distributed geographically based on individuals with a bachelor's or higher degree who work in S&E 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.

Table 8-33
Federal R&D obligations per individual in S&E occupation, by state: 2003 and 2005

	Federal R&D obligations ($millions)		Individuals in S&E occupations		Federal R&D obligations/ individual in S&E occupation ($)	
State	2003	2005	2003	2005	2003	2005
United States	91,247	106,743	4,961,550	5,233,510	18,391	20,396
Alabama	2,933	2,800	56,380	62,790	52,020	44,596
Alaska	246	234	10,600	11,230	23,210	20,796
Arizona	1,857	2,674	92,120	96,410	20,156	27,741
Arkansas	140	154	21,340	24,660	6,547	6,255
California	17,410	19,380	676,180	716,530	25,748	27,046
Colorado	1,612	2,037	124,140	126,110	12,985	16,150
Connecticut	2,068	2,154	81,380	83,930	25,411	25,658
Delaware	91	94	17,370	18,010	5,261	5,228
District of Columbia	2,916	3,993	54,890	63,410	53,127	62,978
Florida	2,522	2,198	221,070	241,000	11,408	9,120
Georgia	1,514	1,707	144,170	137,580	10,503	12,411
Hawaii	350	384	16,090	17,460	21,731	22,016
Idaho	216	273	22,150	23,880	9,757	11,436
Illinois	1,900	1,983	211,230	221,630	8,996	8,946
Indiana	561	554	78,410	79,910	7,158	6,928
Iowa	465	448	37,320	40,300	12,466	11,108
Kansas	190	198	51,970	51,630	3,656	3,835
Kentucky	232	263	45,230	44,530	5,131	5,901
Louisiana	442	402	41,900	41,030	10,547	9,799
Maine	145	240	15,020	15,500	9,650	15,473
Maryland	7,804	12,211	149,250	160,120	52,291	76,264
Massachusetts	5,157	5,702	184,690	193,180	27,920	29,516
Michigan	1,673	1,105	182,940	192,150	9,146	5,752
Minnesota	861	758	117,120	120,930	7,354	6,270
Mississippi	1,174	424	22,190	23,480	52,900	18,062
Missouri	1,270	4,040	84,150	92,260	15,091	43,793
Montana	130	177	11,450	11,940	11,314	14,811
Nebraska	146	145	30,710	31,530	4,765	4,603
Nevada	409	382	22,330	24,400	18,330	15,675
New Hampshire	363	364	23,430	26,840	15,498	13,574
New Jersey	1,786	2,344	161,420	174,270	11,063	13,451
New Mexico	2,850	3,279	33,600	32,530	84,823	100,808
New York	3,973	4,956	272,440	289,010	14,583	17,147
North Carolina	1,611	1,791	132,440	134,290	12,163	13,340
North Dakota	102	105	8,430	9,070	12,070	11,589
Ohio	2,396	2,370	177,100	180,900	13,529	13,100
Oklahoma	274	254	44,360	46,370	6,185	5,469
Oregon	480	557	61,230	62,030	7,843	8,987
Pennsylvania	3,788	3,235	185,560	204,270	20,413	15,835
Rhode Island	523	572	18,740	18,080	27,927	31,651
South Carolina	412	408	48,740	50,460	8,447	8,094
South Dakota	55	70	9,150	9,460	5,988	7,398
Tennessee	1,039	1,293	63,680	66,390	16,320	19,474
Texas	4,757	4,989	365,270	389,550	13,023	12,806
Utah	650	814	45,570	45,110	14,268	18,043
Vermont	182	171	11,420	12,770	15,926	13,371
Virginia	6,213	8,214	209,280	236,650	29,687	34,711
Washington	2,292	2,388	150,230	160,960	15,257	14,834
West Virginia	367	773	16,220	16,040	22,651	48,163
Wisconsin	657	648	93,320	93,590	7,042	6,926
Wyoming	41	34	6,130	7,350	6,704	4,564
Puerto Rico	112	101	19,940	20,950	5,628	4,842

NOTES: Only 11 agencies required to report federal R&D obligations: Departments of Agriculture, Commerce, Defense, Energy, Health and Human Services, Homeland Security (2005 only), 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 2003 and 2005.

SOURCES: National Science Foundation, Division of Science Resources Statistics, Federal Funds for Research and Development (various years); and Bureau of Labor Statistics, Occupational Employment and Wage Estimates.

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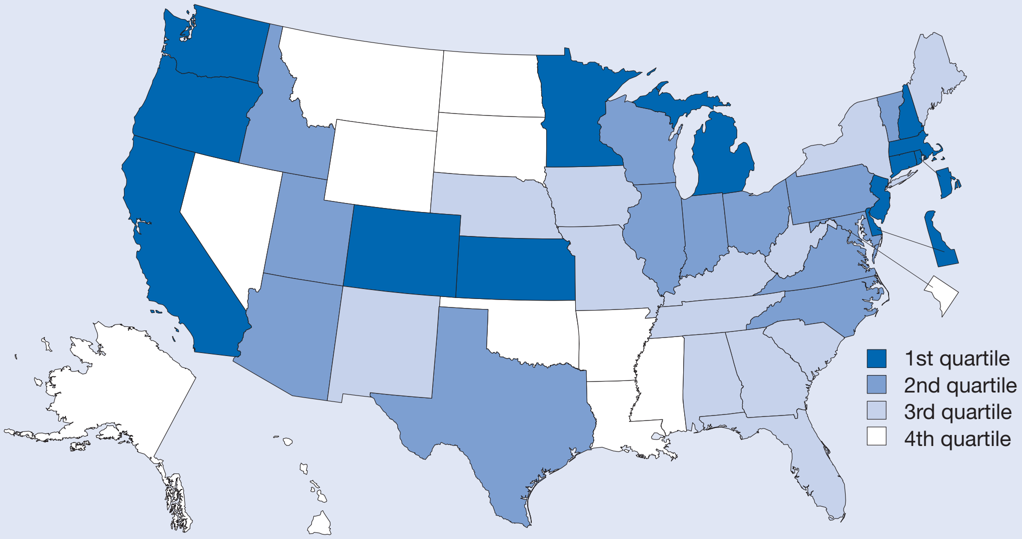
Industry-Performed R&D as Share of Private-Industry Output

Figure 8-34
Industry-performed R&D as share of private-industry output: 2005



1st quartile (5.04%–2.23%)	2nd quartile (2.17%–1.41%)	3rd quartile (1.37%–0.55%)	4th quartile (0.49%–0.10%)
California	Arizona	Alabama	Alaska
Colorado	Idaho	Florida	Arkansas
Connecticut	Illinois	Georgia	District of Columbia
Delaware	Indiana	Iowa	Hawaii
Kansas	Maryland	Kentucky	Louisiana
Massachusetts	North Carolina	Maine	Mississippi
Michigan	Ohio	Missouri	Montana
Minnesota	Pennsylvania	Nebraska	Nevada
New Hampshire	Texas	New Mexico	North Dakota
New Jersey	Utah	New York	Oklahoma
Oregon	Vermont	South Carolina	South Dakota
Rhode Island	Virginia	Tennessee	Wyoming
Washington	Wisconsin	West Virginia	

SOURCES: National Science Foundation, Division of Science Resources Statistics, Survey of Industrial Research and Development (various years); and Bureau of Economic Analysis, Gross Domestic Product data. See Table 8-34.

Findings

- The amount of R&D performed by industry rose from $164 billion in 1998 to $222 billion in 2005, an increase of 36% (unadjusted for inflation).
- The value of this indicator for the United States has shown a downward trend over the past 7 years; starting at 2.14% in 1998, it declined to 2.03% in 2002 and has held steady through 2005.
- Industrial R&D is concentrated in a few states—only 14 states had indicator values exceeding the national average in 2005.
- 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 R&D. 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 major investments 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 years before 1998 are not comparable.

Table 8-34

Industry-performed R&D as share of private-industry output, by state: 1998, 2002, and 2005

	Industry-performed R&D ($millions)			Private-industry output ($millions)			Industry-performed R&D/ private-industry output (%)		
State	1998	2002	2005	1998	2002	2005	1998	2002	2005
United States	163,658	185,505	222,427	7,652,500	9,131,170	10,892,216	2.14	2.03	2.04
Alabama	845	846	1,417	89,994	104,211	128,397	0.94	0.81	1.10
Alaska	37	51	32	18,175	23,302	32,416	0.20	0.22	0.10
Arizona	1,801	3,201	2,980	120,484	150,429	185,757	1.49	2.13	1.60
Arkansas	213	225	271	54,258	62,883	75,322	0.39	0.36	0.36
California	32,856	42,177	50,683	965,937	1,184,559	1,435,610	3.40	3.56	3.53
Colorado	3,180	2,823	4,299	126,013	160,289	188,879	2.52	1.76	2.28
Connecticut	3,346	6,077	7,885	132,955	150,755	176,328	2.52	4.03	4.47
Delaware	1,356	1,219	1,511	33,652	41,196	52,017	4.03	2.96	2.90
District of Columbia	598	194	166	32,710	43,937	54,453	1.83	0.44	0.30
Florida	3,265	3,707	4,164	365,813	459,933	590,516	0.89	0.81	0.71
Georgia	1,617	2,107	2,282	224,870	267,441	311,917	0.72	0.79	0.73
Hawaii	55	103	168	29,201	33,619	42,515	0.19	0.31	0.40
Idaho	1,103	992	642	25,510	31,197	39,542	4.32	3.18	1.62
Illinois	7,318	7,616	9,712	384,342	438,363	500,730	1.90	1.74	1.94
Indiana	2,922	3,572	4,610	161,797	184,923	212,463	1.81	1.93	2.17
Iowa	750	753	1,039	73,908	85,652	104,033	1.01	0.88	1.00
Kansas	1,384	1,427	1,993	65,697	77,183	89,350	2.11	1.85	2.23
Kentucky	606	656	660	94,081	103,514	118,016	0.64	0.63	0.56
Louisiana	377	248	300	103,343	116,505	159,901	0.36	0.21	0.19
Maine	137	250	350	27,363	33,121	38,543	0.50	0.75	0.91
Maryland	1,905	3,800	3,706	133,482	168,770	203,772	1.43	2.25	1.82
Massachusetts	10,367	10,609	13,342	214,890	258,688	291,776	4.82	4.10	4.57
Michigan	12,554	13,565	16,752	278,874	313,384	332,057	4.50	4.33	5.04
Minnesota	3,367	4,460	6,340	148,057	177,427	207,306	2.27	2.51	3.06
Mississippi	183	224	194	50,894	56,215	65,879	0.36	0.40	0.29
Missouri	1,505	1,592	2,602	146,453	166,436	190,015	1.03	0.96	1.37
Montana	63	66	77	16,607	19,565	25,066	0.38	0.34	0.31
Nebraska	195	342	407	44,485	50,901	62,166	0.44	0.67	0.65
Nevada	476	339	382	56,995	72,826	99,213	0.84	0.47	0.39
New Hampshire	1,138	1,153	1,435	35,812	41,991	49,161	3.18	2.75	2.92
New Jersey	11,107	11,566	13,214	282,938	335,111	383,478	3.93	3.45	3.45
New Mexico	1,450	331	405	37,455	41,702	56,803	3.87	0.79	0.71
New York	10,283	9,234	9,474	614,396	736,066	861,618	1.67	1.25	1.10
North Carolina	3,483	3,704	5,158	212,790	259,825	305,739	1.64	1.43	1.69
North Dakota	46	154	104	14,277	16,671	21,012	0.32	0.92	0.49
Ohio	5,742	6,230	5,900	312,647	346,524	393,696	1.84	1.80	1.50
Oklahoma	369	412	422	65,997	80,492	102,166	0.56	0.51	0.41
Oregon	1,345	2,320	3,252	88,532	100,222	122,121	1.52	2.31	2.66
Pennsylvania	7,393	7,064	8,846	324,847	381,405	437,693	2.28	1.85	2.02
Rhode Island	1,332	1,121	1,387	25,892	32,294	38,160	5.14	3.47	3.63
South Carolina	996	1,054	1,402	87,771	102,565	117,441	1.13	1.03	1.19
South Dakota	40	53	68	17,932	23,084	26,493	0.22	0.23	0.26
Tennessee	2,440	1,289	1,246	142,438	169,564	200,821	1.71	0.76	0.62
Texas	8,984	10,744	12,438	558,165	691,968	882,277	1.61	1.55	1.41
Utah	1,119	1,116	1,234	51,610	61,934	75,777	2.17	1.80	1.63
Vermont	114	286	360	13,976	16,974	19,963	0.82	1.68	1.80
Virginia	2,540	2,920	4,379	186,444	235,685	290,120	1.36	1.24	1.51
Washington	7,072	8,579	9,736	168,427	198,461	233,449	4.20	4.32	4.17
West Virginia	335	264	242	33,440	37,308	43,913	1.00	0.71	0.55
Wisconsin	1,929	2,649	2,729	143,368	167,489	192,732	1.35	1.58	1.42
Wyoming	20	21	30	12,506	16,611	23,628	0.16	0.13	0.13
Puerto Rico	NA	NA	NA	NA	NA	NA	NA	NA	NA

NA = not available

NOTES: In 1998, >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, >50% of industrial R&D value imputed for Delaware, District of Columbia, Idaho, Kansas, New Mexico, Rhode Island, and Washington. In 2002, >50% of industrial R&D value imputed because of raking of state data for Alaska, Arkansas, Louisiana, and Wisconsin. In 2002, >50% of industrial R&D value imputed for Kansas, Maine, Oregon, and Vermont. In 2005, >50% of industrial R&D value imputed because of raking of state data for Alaska. In 2005, >50% of industrial R&D value imputed for Indiana, Kansas, Montana, and Rhode Island. Private-industry output reported in current dollars.

SOURCES: National Science Foundation, Division of Science Resources Statistics, Survey of Industrial Research and Development (various years); and Bureau of Economic Analysis, Gross Domestic Product data.

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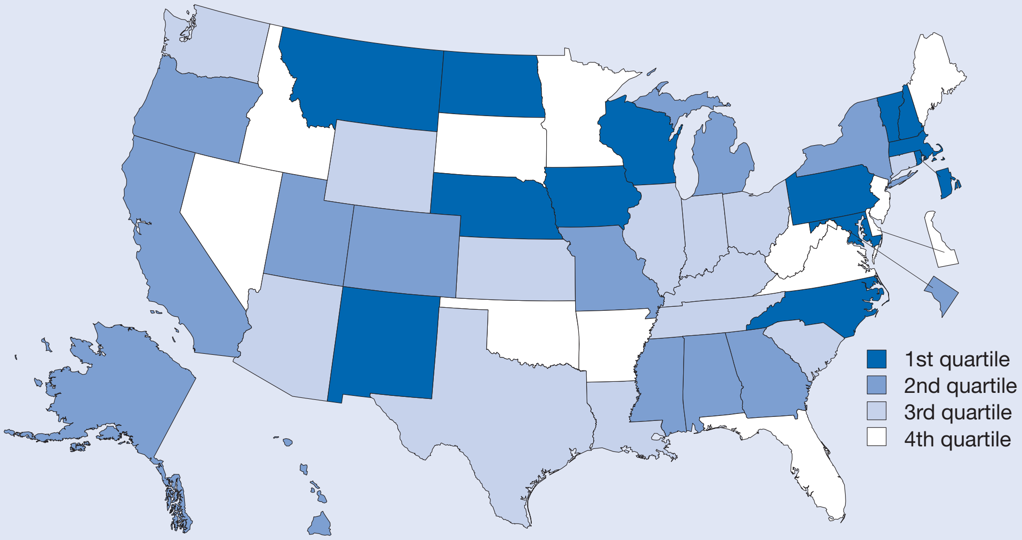
Academic R&D per $1,000 of Gross Domestic Product

Figure 8-35
Academic R&D per $1,000 of gross domestic product: 2005



1st quartile ($6.87–$4.58)	2nd quartile ($4.53–$3.56)	3rd quartile ($3.47–$3.06)	4th quartile ($2.73–$1.62)
Iowa	Alabama	Arizona	Arkansas
Maryland	Alaska	Connecticut	Delaware
Massachusetts	California	Illinois	Florida
Montana	Colorado	Indiana	Idaho
Nebraska	District of Columbia	Kansas	Maine
New Hampshire	Georgia	Kentucky	Minnesota
New Mexico	Hawaii	Louisiana	Nevada
North Carolina	Michigan	Ohio	New Jersey
North Dakota	Mississippi	South Carolina	Oklahoma
Pennsylvania	Missouri	Tennessee	South Dakota
Rhode Island	New York	Texas	Virginia
Vermont	Oregon	Washington	West Virginia
Wisconsin	Utah	Wyoming	

SOURCES: National Science Foundation, Division of Science Resources Statistics, Academic Research and Development Expenditures (various years); and Bureau of Economic Analysis, Gross Domestic Product data. See table 8-35.

Findings

- Expenditures for research performed in academic institutions have doubled in a decade, rising from $21.6 billion in 1995 to $44.9 billion in 2005 (unadjusted for inflation).
- In the United States, academic research increased more rapidly than GDP, causing the value of this indicator to increase by 21% between 1995 and 2005. During this period, 45 states reported increases in the value of this indicator and 5 states and the District of Columbia showed decreases.
- The largest percentage increases in academic R&D as a share of GDP occurred in Hawaii and Mississippi, where the value of this indicator approximately doubled between 1995 and 2005.
- 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 R&D 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 the 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 domestic product (GDP) by state and for R&D expenditures are shown in current dollars.

Table 8-35

Academic R&D per $1,000 of gross domestic product, by state: 1995, 2000, and 2005

State	Academic R&D ($thousands)			State GDP ($millions)			Academic R&D/ $1,000 GDP		
	1995	2000	2005	1995	2000	2005	1995	2000	2005
United States	21,649,053	29,551,103	44,945,923	7,232,723	9,749,104	12,372,847	2.99	3.03	3.63
Alabama	336,644	428,122	589,860	94,021	114,576	151,342	3.58	3.74	3.90
Alaska	72,453	108,099	153,721	24,805	27,034	39,394	2.92	4.00	3.90
Arizona	380,216	465,777	720,184	104,036	158,533	212,312	3.65	2.94	3.39
Arkansas	94,257	131,868	209,518	53,303	66,801	87,004	1.77	1.97	2.41
California	2,666,631	4,065,130	6,272,890	908,963	1,287,145	1,616,351	2.93	3.16	3.88
Colorado	399,315	544,584	825,984	108,043	171,862	214,337	3.70	3.17	3.85
Connecticut	380,511	468,435	669,199	120,800	160,436	193,496	3.15	2.92	3.46
Delaware	54,197	78,126	115,751	27,507	41,472	56,731	1.97	1.88	2.04
District of Columbia	187,695	245,828	302,921	47,123	58,699	82,628	3.98	4.19	3.67
Florida	608,896	851,932	1,448,634	340,501	471,316	666,639	1.79	1.81	2.17
Georgia	684,492	926,749	1,274,410	199,138	290,887	358,365	3.44	3.19	3.56
Hawaii	78,429	161,300	240,247	36,572	40,202	54,773	2.14	4.01	4.39
Idaho	61,906	73,726	119,871	27,099	34,989	45,891	2.28	2.11	2.61
Illinois	831,644	1,170,743	1,770,938	359,723	464,194	555,599	2.31	2.52	3.19
Indiana	377,034	509,141	759,419	147,984	194,419	236,357	2.55	2.62	3.21
Iowa	323,535	418,263	548,237	71,905	90,186	117,635	4.50	4.64	4.66
Kansas	181,777	258,336	348,751	63,699	82,812	105,228	2.85	3.12	3.31
Kentucky	155,345	276,986	452,265	90,459	111,900	138,616	1.72	2.48	3.26
Louisiana	329,534	409,143	579,734	109,153	131,520	180,336	3.02	3.11	3.21
Maine	33,512	57,753	81,624	27,648	35,542	44,906	1.21	1.62	1.82
Maryland	762,306	1,070,630	1,678,649	137,391	180,367	244,447	5.55	5.94	6.87
Massachusetts	1,164,614	1,486,174	2,079,463	195,277	274,949	320,050	5.96	5.41	6.50
Michigan	779,483	1,007,582	1,455,849	251,017	337,235	372,148	3.11	2.99	3.91
Minnesota	342,003	418,029	559,585	131,357	185,093	231,437	2.60	2.26	2.42
Mississippi	118,436	217,064	353,445	53,816	64,266	79,786	2.20	3.38	4.43
Missouri	403,589	614,028	893,013	137,528	176,708	215,073	2.93	3.47	4.15
Montana	69,975	99,069	170,791	17,393	21,366	29,915	4.02	4.64	5.71
Nebraska	158,717	208,480	360,148	44,505	55,478	72,242	3.57	3.76	4.99
Nevada	86,902	106,154	178,492	48,974	73,719	110,158	1.77	1.44	1.62
New Hampshire	93,073	150,982	287,472	32,149	43,518	54,119	2.90	3.47	5.31
New Jersey	441,835	567,666	867,121	266,724	344,824	427,654	1.66	1.65	2.03
New Mexico	232,428	243,822	345,844	41,459	50,725	69,692	5.61	4.81	4.96
New York	1,780,233	2,291,749	3,604,414	594,444	777,157	961,385	2.99	2.95	3.75
North Carolina	720,413	1,039,812	1,652,049	191,579	273,698	350,700	3.76	3.80	4.71
North Dakota	59,617	67,406	149,994	14,515	17,752	24,935	4.11	3.80	6.02
Ohio	646,498	918,241	1,530,915	293,260	372,006	442,243	2.20	2.47	3.46
Oklahoma	189,722	252,419	291,697	69,580	89,757	121,558	2.73	2.81	2.40
Oregon	260,059	346,149	536,228	80,099	112,438	141,831	3.25	3.08	3.78
Pennsylvania	1,150,888	1,552,417	2,353,640	314,504	389,619	486,139	3.66	3.98	4.84
Rhode Island	99,408	129,697	199,709	25,666	33,609	43,623	3.87	3.86	4.58
South Carolina	227,727	294,274	486,399	86,053	112,514	140,088	2.65	2.62	3.47
South Dakota	21,747	27,589	67,012	17,807	23,099	30,541	1.22	1.19	2.19
Tennessee	310,766	405,291	726,078	135,655	174,851	224,995	2.29	2.32	3.23
Texas	1,510,543	2,037,681	3,073,724	507,441	727,233	989,333	2.98	2.80	3.11
Utah	202,212	308,059	400,276	46,303	67,568	88,364	4.37	4.56	4.53
Vermont	54,839	64,762	117,442	13,892	17,782	23,056	3.95	3.64	5.09
Virginia	452,717	553,924	914,166	185,490	260,743	350,692	2.44	2.12	2.61
Washington	494,333	643,757	901,102	151,338	221,961	271,381	3.27	2.90	3.32
West Virginia	53,510	73,420	145,150	36,362	41,476	53,091	1.47	1.77	2.73
Wisconsin	481,967	661,641	998,449	134,096	175,737	216,985	3.59	3.76	4.60
Wyoming	40,470	43,094	83,449	14,567	17,331	27,246	2.78	2.49	3.06
Puerto Rico	69,636	74,529	100,235	42,647	61,702	82,650	1.63	1.21	1.21

GDP = gross domestic product

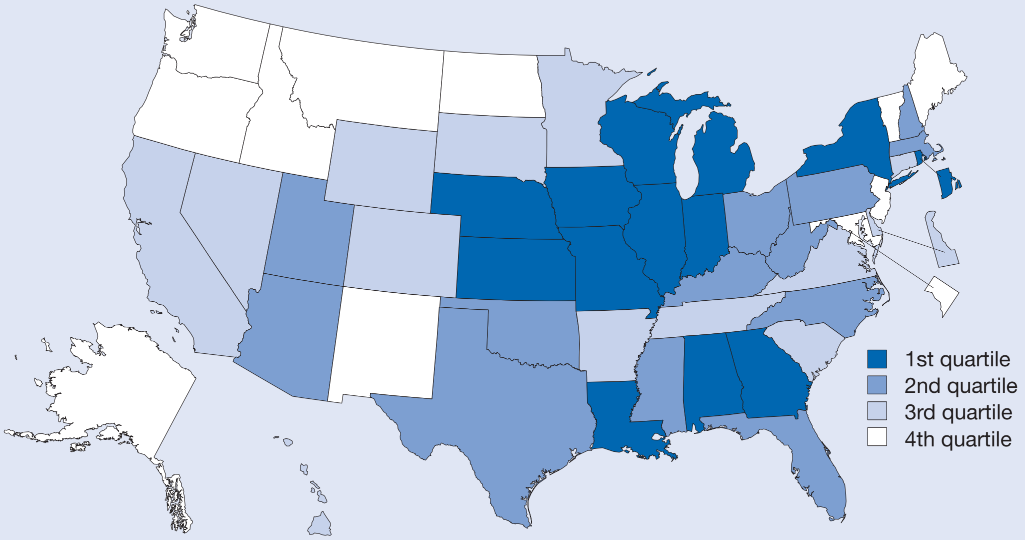
NOTES: In 2000 and 2005, academic R&D reported for all institutions; in 1995, reported for doctorate-granting institutions only. For Maryland, academic R&D excludes R&D performed by Applied Physics Laboratory at Johns Hopkins University. GDP reported in current dollars.

SOURCES: National Science Foundation, Division of Science Resources Statistics, Academic Research and Development Expenditures (various years); Bureau of Economic Analysis, Gross Domestic Product data; and Government of Puerto Rico, Office of the Governor.

Science & Engineering Indicators 2008

S&E Doctorates Conferred per 1,000 S&E Doctorate Holders

Figure 8-36
S&E Doctorates Conferred per 1,000 S&E Doctorate Holders: 2005 and 2006



1st quartile (61.8–47.3)	2nd quartile (47.1–39.8)	3rd quartile (38.1–30.5)	4th quartile (29.0–8.2)
Alabama	Arizona	Arkansas	Alaska
Georgia	Florida	California	District of Columbia
Illinois	Kentucky	Colorado	Idaho
Indiana	Massachusetts	Connecticut	Maine
Iowa	Mississippi	Delaware	Maryland
Kansas	New Hampshire	Hawaii	Montana
Louisiana	North Carolina	Minnesota	New Jersey
Michigan	Ohio	Nevada	New Mexico
Missouri	Oklahoma	South Carolina	North Dakota
Nebraska	Pennsylvania	South Dakota	Oregon
New York	Texas	Tennessee	Vermont
Rhode Island	Utah	Virginia	Washington
Wisconsin	West Virginia	Wyoming	

SOURCES: National Science Foundation, Division of Science Resources Statistics, Survey of Earned Doctorates and Survey of Doctorate Recipients. See table 8-36.

Findings

- In 2005, nearly 28,000 S&E doctorates were awarded by U.S. academic institutions, approximately 10% more than in 2001 and 3% more than in 1997.
- Nationwide, the value of this indicator declined between 1997 and 2003, reflecting 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 S&E 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 8-36
S&E doctorates conferred per 1,000 S&E doctorate holders, by state: 1997, 2001, 2005, and 2006

	S&E doctorates conferred			S&E doctorate holders			S&E doctorates/1,000 doctorate holders		
State	1997	2001	2005	1997	2001	2006	1997	2001	2005/2006
United States	27,145	25,404	27,930	579,610	654,180	708,080	46.8	38.8	39.4
Alabama	332	300	338	7,450	6,380	7,090	44.6	47.0	47.7
Alaska[a]	20	26	25	1,320	1,430	1,330	15.2	18.2	18.8
Arizona	480	403	473	7,450	8,720	10,050	64.4	46.2	47.1
Arkansas	67	62	116	2,630	3,040	3,250	25.5	20.4	35.7
California	3,493	3,345	3,600	78,910	91,690	99,110	44.3	36.5	36.3
Colorado	566	491	522	12,280	14,220	16,080	46.1	34.5	32.5
Connecticut	398	371	428	9,930	11,030	11,830	40.1	33.6	36.2
Delaware	131	128	128	4,400	4,370	3,880	29.8	29.3	33.0
District of Columbia	319	291	307	12,220	14,560	13,750	26.1	20.0	22.3
Florida	825	782	977	16,320	19,410	22,020	50.6	40.3	44.4
Georgia	544	612	742	11,030	13,640	14,890	49.3	44.9	49.8
Hawaii	130	107	99	2,810	2,860	3,230	46.3	37.4	30.7
Idaho	57	51	56	2,400	2,660	3,190	23.8	19.2	17.6
Illinois	1,370	1,325	1,332	23,630	24,610	26,800	58.0	53.8	49.7
Indiana	691	668	686	8,320	10,870	11,380	83.1	61.5	60.3
Iowa	404	376	355	4,720	5,060	5,740	85.6	74.3	61.8
Kansas	285	264	246	4,340	4,720	4,830	65.7	55.9	50.9
Kentucky	214	172	242	4,540	5,400	5,760	47.1	31.9	42.0
Louisiana	317	333	338	6,110	6,140	6,290	51.9	54.2	53.7
Maine[a]	41	30	24	2,740	2,400	2,930	15.0	12.5	8.2
Maryland	682	663	744	23,760	25,590	29,870	28.7	25.9	24.9
Massachusetts	1,500	1,454	1,632	25,310	31,860	35,440	59.3	45.6	46.0
Michigan	973	909	1,075	16,750	19,210	19,790	58.1	47.3	54.3
Minnesota	472	457	504	10,980	12,640	13,220	43.0	36.2	38.1
Mississippi	153	131	168	3,300	3,580	3,910	46.4	36.6	43.0
Missouri	482	438	489	10,330	10,290	10,340	46.7	42.6	47.3
Montana	59	42	59	2,120	1,820	2,480	27.8	23.1	23.8
Nebraska	179	164	166	3,210	3,150	3,320	55.8	52.1	50.0
Nevada	48	52	90	1,930	2,320	2,940	24.9	22.4	30.6
New Hampshire	94	76	117	2,590	3,000	2,760	36.3	25.3	42.4
New Jersey	623	620	628	22,420	25,350	23,610	27.8	24.5	26.6
New Mexico	162	147	176	8,570	9,140	9,960	18.9	16.1	17.7
New York	2,360	2,140	2,419	43,880	49,100	50,760	53.8	43.6	47.7
North Carolina	729	726	863	15,480	19,120	21,670	47.1	38.0	39.8
North Dakota[a]	51	43	45	1,580	1,270	1,550	32.3	33.9	29.0
Ohio	1,229	1,061	1,041	20,990	23,370	23,630	58.6	45.4	44.1
Oklahoma	241	237	232	5,310	5,160	5,290	45.4	45.9	43.9
Oregon	295	262	260	7,600	8,720	10,900	38.8	30.0	23.9
Pennsylvania	1,376	1,235	1,397	26,710	29,280	32,780	51.5	42.2	42.6
Rhode Island	160	161	175	2,700	2,880	3,290	59.3	55.9	53.2
South Carolina	222	216	227	5,560	6,010	6,920	39.9	35.9	32.8
South Dakota[a]	37	34	38	1,170	1,250	1,220	31.6	27.2	31.1
Tennessee	394	377	377	9,570	10,350	11,380	41.2	36.4	33.1
Texas	1,653	1,613	1,781	31,600	37,510	41,420	52.3	43.0	43.0
Utah	279	236	290	5,350	5,920	6,730	52.1	39.9	43.1
Vermont[a]	34	52	37	1,960	2,040	2,070	17.3	25.5	17.9
Virginia	669	628	695	17,340	20,360	22,800	38.6	30.8	30.5
Washington	482	458	495	15,390	17,150	19,900	31.3	26.7	24.9
West Virginia[a]	77	67	108	2,330	2,360	2,510	33.0	28.4	43.0
Wisconsin	681	530	532	9,310	10,130	11,200	73.1	52.3	47.5
Wyoming[a]	65	38	36	960	1,040	990	67.7	36.5	36.4
Puerto Rico	84	92	44	770	1,530	1,860	109.1	60.1	23.7

[a] Estimates for S&E doctorate holders may vary between 10% and 25% because geography is not part of the sample design.

NOTES: Data on U.S. S&E doctorate holders classified by employer location. Data on 2006 S&E doctorate holders are preliminary.

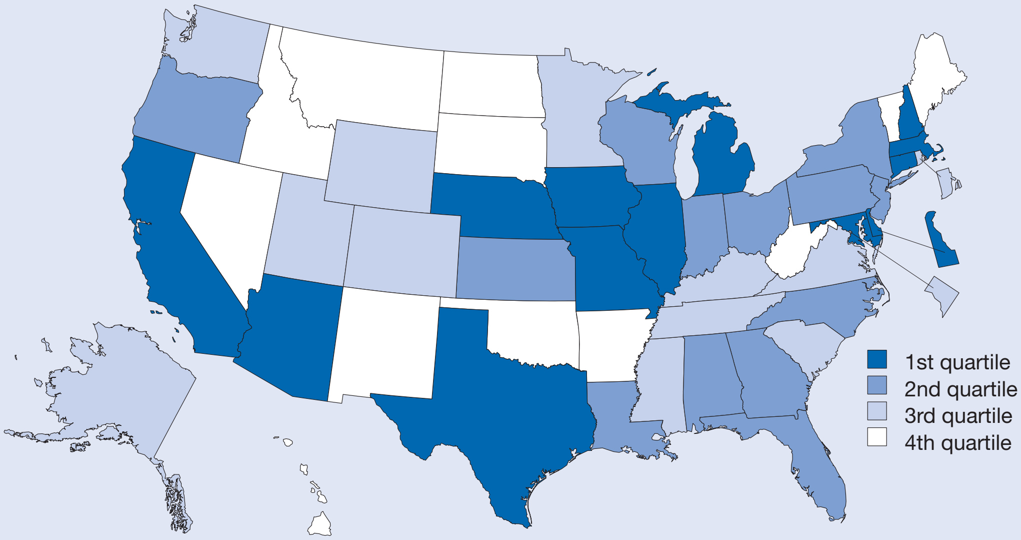
SOURCES: National Science Foundation, Division of Science Resources Statistics, Survey of Earned Doctorates and Survey of Doctorate Recipients.

Science & Engineering Indicators 2008

Academic Article Output per 1,000 S&E Doctorate Holders in Academia

Figure 8-37

Academic article output per 1,000 S&E doctorate holders in academia: 2005 and 2006



1st quartile (717–603)	2nd quartile (595–524)	3rd quartile (505–410)	4th quartile (399–233)
Arizona	Alabama	Alaska	Arkansas
California	Florida	Colorado	Hawaii
Connecticut	Georgia	District of Columbia	Idaho
Delaware	Indiana	Kentucky	Maine
Illinois	Kansas	Minnesota	Montana
Iowa	Louisiana	Mississippi	Nevada
Maryland	New Jersey	Rhode Island	New Mexico
Massachusetts	New York	South Carolina	North Dakota
Michigan	North Carolina	Tennessee	Oklahoma
Missouri	Ohio	Utah	South Dakota
Nebraska	Oregon	Virginia	Vermont
New Hampshire	Pennsylvania	Washington	West Virginia
Texas	Wisconsin	Wyoming	

SOURCES: Thomson Scientific ISI database; ipIQ, Inc.; and National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients. See table 8-37.

Findings

- Between 1997 and 2005, the number of scientific and technical articles increased by 16% and the number of S&E doctorate holders increased by nearly 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; this may indicate that academic article output is lower at the beginning and end of academic careers.
- 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 S&E 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. Academic institutions include both 2-year and 4-year schools.

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 5,161 in 2005. 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 8-37

Academic article output per 1,000 S&E doctorate holders in academia, by state: 1997, 2001, 2005, and 2006

State	Academic article output			S&E doctorate holders in academia			Academic articles/ 1,000 academic doctorate holders		
	1997	2001	2005	1997	2001	2006	1997	2001	2005/2006
United States	144,319	147,450	167,720	245,670	261,780	295,390	587	563	568
Alabama	1,910	1,899	1,996	4,640	3,050	3,510	412	623	569
Alaska[a]	163	186	245	450	530	580	362	351	422
Arizona	2,257	2,199	2,459	3,050	3,340	4,080	740	658	603
Arkansas[a]	603	608	743	1,520	1,640	1,960	397	371	379
California	17,512	18,115	20,807	26,050	26,790	30,800	672	676	676
Colorado	2,524	2,630	2,853	4,550	5,120	5,840	555	514	489
Connecticut	2,808	2,755	3,145	4,000	4,420	4,770	702	623	659
Delaware[a]	499	560	638	750	840	950	665	667	672
District of Columbia	1,224	1,211	1,267	2,210	2,840	2,600	554	426	487
Florida	4,186	4,256	5,424	6,850	8,250	9,590	611	516	566
Georgia	3,255	3,576	4,190	5,780	6,450	7,750	563	554	541
Hawaii[a]	574	539	618	1,380	1,570	1,680	416	343	368
Idaho[a]	295	309	347	780	980	1,490	378	315	233
Illinois	6,893	7,007	7,776	10,620	11,090	12,040	649	632	646
Indiana	3,103	3,095	3,557	4,680	5,710	6,220	663	542	572
Iowa	2,273	2,226	2,401	3,100	3,220	3,510	733	691	684
Kansas[a]	1,199	1,251	1,362	2,260	2,270	2,600	531	551	524
Kentucky	1,380	1,356	1,642	3,040	3,240	3,640	454	419	451
Louisiana	1,895	1,828	2,064	3,580	3,470	3,470	529	527	595
Maine[a]	247	234	303	1,340	1,200	1,240	184	195	244
Maryland	4,391	4,935	5,506	6,400	6,100	7,680	686	809	717
Massachusetts	9,143	9,597	10,695	11,810	13,390	15,380	774	717	695
Michigan	4,880	5,078	5,841	7,850	8,820	9,580	622	576	610
Minnesota	2,435	2,388	2,680	4,490	5,540	5,810	542	431	461
Mississippi	629	692	843	1,940	2,000	2,020	324	346	417
Missouri	3,160	3,229	3,469	5,770	5,710	5,660	548	565	613
Montana[a]	272	328	380	1,020	810	1,230	267	405	309
Nebraska[a]	1,030	1,011	1,167	2,360	1,960	1,930	436	516	605
Nevada[a]	370	447	532	980	1,260	1,630	378	355	326
New Hampshire[a]	605	614	776	1,130	1,240	1,240	535	495	626
New Jersey	3,102	3,054	3,422	5,290	5,860	6,530	586	521	524
New Mexico	808	780	840	2,450	2,910	2,990	330	268	281
New York	12,381	12,406	13,624	20,900	21,770	23,290	592	570	585
North Carolina	4,958	5,141	6,087	7,740	9,050	10,300	641	568	591
North Dakota[a]	269	271	362	900	660	970	299	411	373
Ohio	5,170	5,078	5,597	9,750	9,920	10,690	530	512	524
Oklahoma	919	925	1,034	2,680	2,800	2,890	343	330	358
Oregon	1,613	1,556	1,920	2,690	3,250	3,640	600	479	527
Pennsylvania	8,194	8,362	9,588	12,150	13,590	16,250	674	615	590
Rhode Island[a]	852	862	942	1,730	1,730	2,060	492	498	457
South Carolina	1,210	1,351	1,528	3,230	3,030	3,730	375	446	410
South Dakota[a]	140	131	165	700	640	690	200	205	239
Tennessee	2,255	2,285	2,767	4,720	4,800	5,740	478	476	482
Texas	8,755	9,040	10,626	13,760	14,270	17,240	636	633	616
Utah	1,570	1,570	1,777	3,080	3,100	3,600	510	506	494
Vermont[a]	380	412	423	1,140	1,050	1,060	333	392	399
Virginia	3,014	3,104	3,509	5,830	7,180	8,050	517	432	436
Washington	3,207	3,339	3,697	5,410	6,390	7,320	593	523	505
West Virginia[a]	417	388	419	1,190	1,150	1,350	350	337	310
Wisconsin	3,190	3,046	3,451	5,390	5,210	6,000	592	585	575
Wyoming[a]	200	190	216	560	570	520	357	333	415
Puerto Rico[a]	168	186	204	640	1,070	1,250	263	174	163

[a] Estimates for S&E doctorate holders may vary between 10% and 25% because geography is not part of the sample design.

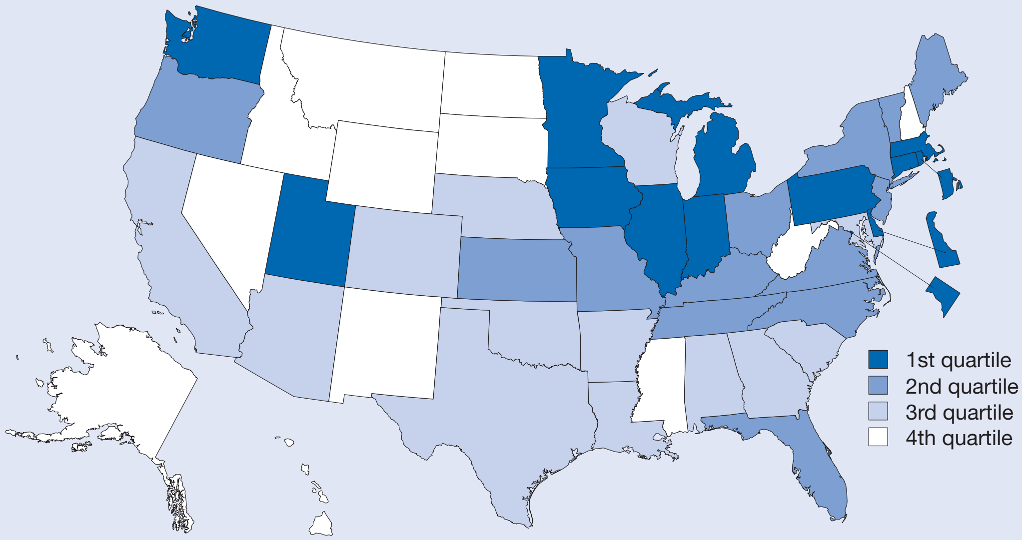
NOTES: Data on U.S. S&E doctorate holders classified by employer location. Data on 2006 S&E doctorate holders are preliminary.

SOURCES: Thomson Scientific ISI database; ipIQ, Inc.; and National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients.

Science & Engineering Indicators 2008

Academic Article Output per $1 Million of Academic R&D

Figure 8-38
Academic article output per $1 million of academic R&D: 2005



1st quartile (5.50–4.01)	2nd quartile (3.95–3.58)	3rd quartile (3.56–3.14)	4th quartile (2.99–1.59)
Connecticut	Florida	Alabama	Alaska
Delaware	Kansas	Arizona	Hawaii
District of Columbia	Kentucky	Arkansas	Idaho
Illinois	Maine	California	Mississippi
Indiana	Missouri	Colorado	Montana
Iowa	New Jersey	Georgia	Nevada
Massachusetts	New York	Louisiana	New Hampshire
Michigan	North Carolina	Maryland	New Mexico
Minnesota	Ohio	Nebraska	North Dakota
Pennsylvania	Oregon	Oklahoma	South Dakota
Rhode Island	Tennessee	South Carolina	West Virginia
Utah	Vermont	Texas	Wyoming
Washington	Virginia	Wisconsin	

SOURCES: Thomson Scientific ISI database; ipIQ, Inc.; and National Science Foundation, Division of Science Resources Statistics, Academic Research and Development Expenditures (various years). See table 8-38.

Findings

- From 1995 to 2005, the number of academic publications rose from 146,000 to nearly 168,000, an increase of 15%.
- In 2005, academic researchers produced an average of 4.3 publications per $1 million of academic R&D, compared with 7.5 in 1995. This partly reflects the effect of general price inflation (28% during this time period), but may also indicate rising academic research costs.
- The value for this indicator decreased for all states between 1995 and 2005.

This indicator shows the relationship between the number of academic publications and the expenditure for academic R&D. A high value for this indicator means that a state's academic institutions have a high publications output relative to their R&D spending. Academic institutions include both 2-year and 4-year schools. 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 5,161 in 2005. 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 the 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 8-38
Academic article output per $1 million of academic R&D, by state: 1995, 2000, and 2005

	Academic article output			Academic R&D ($millions)			Academic articles/ $1 million academic R&D		
State	1995	2000	2005	1995	2000	2005	1995	2000	2005
United States	146,122	143,922	167,720	19,438	25,317	39,369	7.52	5.68	4.26
Alabama	1,925	1,772	1,996	337	428	590	5.71	4.14	3.38
Alaska	165	174	245	72	108	154	2.29	1.61	1.59
Arizona	2,318	2,179	2,459	380	466	720	6.10	4.68	3.42
Arkansas	518	572	743	94	132	210	5.51	4.33	3.54
California	18,004	17,634	20,807	2,667	4,065	6,273	6.75	4.34	3.32
Colorado	2,568	2,504	2,853	399	545	826	6.44	4.59	3.45
Connecticut	2,811	2,788	3,145	381	468	669	7.38	5.96	4.70
Delaware	515	520	638	54	78	116	9.54	6.67	5.50
District of Columbia	1,233	1,244	1,267	188	246	303	6.56	5.06	4.18
Florida	4,154	4,247	5,424	609	852	1,449	6.82	4.98	3.74
Georgia	2,959	3,294	4,190	684	927	1,274	4.33	3.55	3.29
Hawaii	615	557	618	78	161	240	7.88	3.46	2.58
Idaho	257	277	347	62	74	120	4.15	3.74	2.89
Illinois	6,979	6,910	7,776	832	1,171	1,771	8.39	5.90	4.39
Indiana	3,182	3,069	3,557	377	509	759	8.44	6.03	4.69
Iowa	2,352	2,198	2,401	324	418	548	7.26	5.26	4.38
Kansas	1,226	1,286	1,362	182	258	349	6.74	4.98	3.90
Kentucky	1,280	1,337	1,642	155	277	452	8.26	4.83	3.63
Louisiana	1,946	1,787	2,064	330	409	580	5.90	4.37	3.56
Maine	258	272	303	34	58	82	7.59	4.69	3.70
Maryland	4,431	4,598	5,506	762	1,071	1,679	5.81	4.29	3.28
Massachusetts	9,128	9,347	10,695	1,165	1,486	2,079	7.84	6.29	5.14
Michigan	4,965	4,885	5,841	779	1,008	1,456	6.37	4.85	4.01
Minnesota	2,574	2,259	2,680	342	418	560	7.53	5.40	4.79
Mississippi	621	653	843	118	217	353	5.26	3.01	2.39
Missouri	3,368	3,052	3,469	404	614	893	8.34	4.97	3.88
Montana	256	313	380	70	99	171	3.66	3.16	2.22
Nebraska	1,091	979	1,167	159	208	360	6.86	4.71	3.24
Nevada	390	443	532	87	106	178	4.48	4.18	2.99
New Hampshire	596	592	776	93	151	287	6.41	3.92	2.70
New Jersey	2,919	2,993	3,422	442	568	867	6.60	5.27	3.95
New Mexico	766	802	840	232	244	346	3.30	3.29	2.43
New York	12,818	12,146	13,624	1,780	2,292	3,604	7.20	5.30	3.78
North Carolina	5,189	5,073	6,087	720	1,040	1,652	7.21	4.88	3.68
North Dakota	263	242	362	60	67	150	4.38	3.61	2.41
Ohio	5,156	5,064	5,597	646	918	1,531	7.98	5.52	3.66
Oklahoma	949	906	1,034	190	252	292	4.99	3.60	3.54
Oregon	1,648	1,665	1,920	260	346	536	6.34	4.81	3.58
Pennsylvania	8,244	8,037	9,588	1,151	1,552	2,354	7.16	5.18	4.07
Rhode Island	858	853	942	99	130	200	8.67	6.56	4.71
South Carolina	1,179	1,285	1,528	228	294	486	5.17	4.37	3.14
South Dakota	128	135	165	22	28	67	5.82	4.82	2.46
Tennessee	2,296	2,278	2,767	311	405	726	7.38	5.62	3.81
Texas	8,997	8,795	10,626	1,511	2,038	3,074	5.95	4.32	3.46
Utah	1,539	1,559	1,777	202	308	400	7.62	5.06	4.44
Vermont	403	405	423	55	65	117	7.33	6.23	3.62
Virginia	3,007	3,075	3,509	453	554	914	6.64	5.55	3.84
Washington	3,189	3,288	3,697	494	644	901	6.46	5.11	4.10
West Virginia	419	376	419	54	73	145	7.76	5.15	2.89
Wisconsin	3,278	3,025	3,451	482	662	998	6.80	4.57	3.46
Wyoming	192	178	216	40	43	83	4.80	4.14	2.60
Puerto Rico	171	192	204	70	75	100	2.44	2.56	2.04

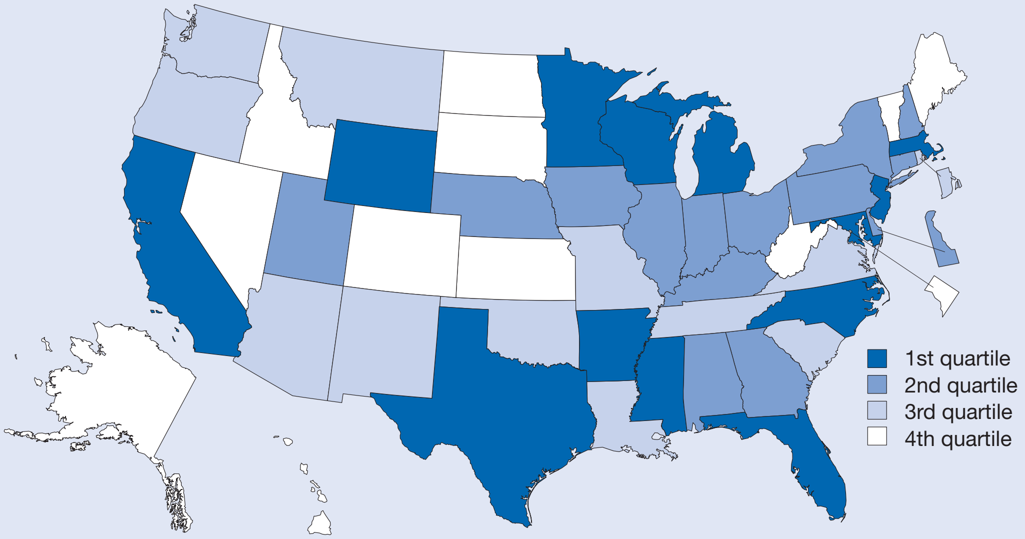
NOTES: In 2000 and 2005, academic R&D reported for all institutions. In 1995, academic R&D reported for doctorate-granting institutions only.

SOURCES: Thomson Scientific ISI database; ipIQ, Inc.; and National Science Foundation, Division of Science Resources Statistics, Academic Research and Development Expenditures (various years).

Science & Engineering Indicators 2008

Academic Patents Awarded per 1,000 S&E Doctorate Holders in Academia

Figure 8-39
Academic patents awarded per 1,000 S&E doctorate holders in academia: 2005 and 2006



1st quartile (20.2–8.9)	2nd quartile (8.8–6.3)	3rd quartile (5.5–4.1)	4th quartile (3.8–0.0)
Arkansas	Alabama	Arizona	Alaska
California	Connecticut	Louisiana	Colorado
Florida	Delaware	Missouri	District of Columbia
Maryland	Georgia	Montana	Hawaii
Massachusetts	Illinois	New Mexico	Idaho
Michigan	Indiana	Oklahoma	Kansas
Minnesota	Iowa	Oregon	Maine
Mississippi	Kentucky	Rhode Island	Nevada
New Jersey	Nebraska	South Carolina	North Dakota
North Carolina	New Hampshire	Tennessee	South Dakota
Texas	New York	Virginia	Vermont
Wisconsin	Ohio	Washington	West Virginia
Wyoming	Pennsylvania		
	Utah		

SOURCES: Patent and Trademark Office, Technology Assessment and Forecast Branch, U.S. Colleges and Universities—Utility Patent Grants, Calendar Years 1969–2005; and National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients. See table 8-39.

Findings

- Throughout the United States, the number of patents awarded to academic institutions increased from more than 2,400 in 1997 to more than 2,700 in 2005, an increase of 11%, while the number of academic S&E doctorate holders rose by 20% between 1997 and 2006.
- In 2005, 9.2 academic patents were produced nationally for each 1,000 S&E doctorate holders employed in academia, slightly lower than the 10.0 patents produced in 1997.
- In 2003, states varied widely on this indicator, with values ranging from 0 to 20.2 patents per 1,000 S&E doctorate holders employed in academia, indicating a difference in patenting philosophy or mix of industries that these academic institutions deal with.
- California and Massachusetts showed both the highest levels of academic patenting activity and the highest levels of venture capital investment.

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 R&D 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 number of academic-owned utility patents to the size of the doctoral S&E workforce in academia. Academia includes both 2-year and 4-year institutions. Utility patents, commonly known as patents for inventions, include any new, useful, or improved method, process, machine, device, manufactured item, or chemical compound, and represent a key measure of intellectual property. This indicator 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 8-39

Academic patents awarded per 1,000 S&E doctorate holders in academia, by state: 1997, 2001, 2005, and 2006

	Patents awarded to academic institutions			S&E doctorate holders in academia			Academic patents/ 1,000 academic S&E doctorate holders		
State	1997	2001	2005	1997	2001	2006	1997	2001	2005/2006
United States	2,447	3,219	2,725	245,670	261,780	295,390	10.0	12.3	9.2
Alabama	23	40	28	4,640	3,050	3,510	5.0	13.1	8.0
Alaska[a]	2	0	0	450	530	580	4.4	0.0	0.0
Arizona	21	17	22	3,050	3,340	4,080	6.9	5.1	5.4
Arkansas[a]	8	28	19	1,520	1,640	1,960	5.3	17.1	9.7
California	409	638	622	26,050	26,790	30,800	15.7	23.8	20.2
Colorado	32	31	14	4,550	5,120	5,840	7.0	6.1	2.4
Connecticut	34	37	41	4,000	4,420	4,770	8.5	8.4	8.6
Delaware[a]	4	5	7	750	840	950	5.3	6.0	7.4
District of Columbia	28	13	7	2,210	2,840	2,600	12.7	4.6	2.7
Florida	94	103	128	6,850	8,250	9,590	13.7	12.5	13.3
Georgia	45	75	68	5,780	6,450	7,750	7.8	11.6	8.8
Hawaii[a]	6	4	6	1,380	1,570	1,680	4.3	2.5	3.6
Idaho[a]	0	0	0	780	980	1,490	0.0	0.0	0.0
Illinois	81	109	84	10,620	11,090	12,040	7.6	9.8	7.0
Indiana	39	17	39	4,680	5,710	6,220	8.3	3.0	6.3
Iowa	51	67	29	3,100	3,220	3,510	16.5	20.8	8.3
Kansas[a]	7	18	6	2,260	2,270	2,600	3.1	7.9	2.3
Kentucky	16	20	23	3,040	3,240	3,640	5.3	6.2	6.3
Louisiana	26	42	18	3,580	3,470	3,470	7.3	12.1	5.2
Maine[a]	0	2	1	1,340	1,200	1,240	0.0	1.7	0.8
Maryland	66	114	98	6,400	6,100	7,680	10.3	18.7	12.8
Massachusetts	188	218	213	11,810	13,390	15,380	15.9	16.3	13.8
Michigan	104	105	110	7,850	8,820	9,580	13.2	11.9	11.5
Minnesota	50	65	63	4,490	5,540	5,810	11.1	11.7	10.8
Mississippi	6	12	18	1,940	2,000	2,020	3.1	6.0	8.9
Missouri	40	55	28	5,770	5,710	5,660	6.9	9.6	4.9
Montana[a]	4	4	5	1,020	810	1,230	3.9	4.9	4.1
Nebraska[a]	27	21	14	2,360	1,960	1,930	11.4	10.7	7.3
Nevada[a]	2	4	2	980	1,260	1,630	2.0	3.2	1.2
New Hampshire[a]	3	10	10	1,130	1,240	1,240	2.7	8.1	8.1
New Jersey	52	81	58	5,290	5,860	6,530	9.8	13.8	8.9
New Mexico	19	17	16	2,450	2,910	2,990	7.8	5.8	5.4
New York	224	283	201	20,900	21,770	23,290	10.7	13.0	8.6
North Carolina	96	148	106	7,740	9,050	10,300	12.4	16.4	10.3
North Dakota[a]	5	4	3	900	660	970	5.6	6.1	3.1
Ohio	75	93	72	9,750	9,920	10,690	7.7	9.4	6.7
Oklahoma	17	22	14	2,680	2,800	2,890	6.3	7.9	4.8
Oregon	27	23	16	2,690	3,250	3,640	10.0	7.1	4.4
Pennsylvania	138	213	117	12,150	13,590	16,250	11.4	15.7	7.2
Rhode Island[a]	9	19	11	1,730	1,730	2,060	5.2	11.0	5.3
South Carolina	14	14	18	3,230	3,030	3,730	4.3	4.6	4.8
South Dakota[a]	2	2	0	700	640	690	2.9	3.1	0.0
Tennessee	25	42	24	4,720	4,800	5,740	5.3	8.8	4.2
Texas	125	155	157	13,760	14,270	17,240	9.1	10.9	9.1
Utah	38	48	26	3,080	3,100	3,600	12.3	15.5	7.2
Vermont[a]	3	3	4	1,140	1,050	1,060	2.6	2.9	3.8
Virginia	49	41	37	5,830	7,180	8,050	8.4	5.7	4.6
Washington	42	56	40	5,410	6,390	7,320	7.8	8.8	5.5
West Virginia[a]	2	4	0	1,190	1,150	1,350	1.7	3.5	0.0
Wisconsin	65	74	77	5,390	5,210	6,000	12.1	14.2	12.8
Wyoming[a]	4	3	5	560	570	520	7.1	5.3	9.6
Puerto Rico[a]	0	5	0	640	1,070	1,250	0.0	4.7	0.0

[a] Estimates for S&E doctorate holders may vary between 10% and 25% because geography is not part of the sample design.

NOTES: Data on U.S. S&E doctorate holders classified by employer location. Data on 2006 S&E doctorate holders in academia are preliminary.

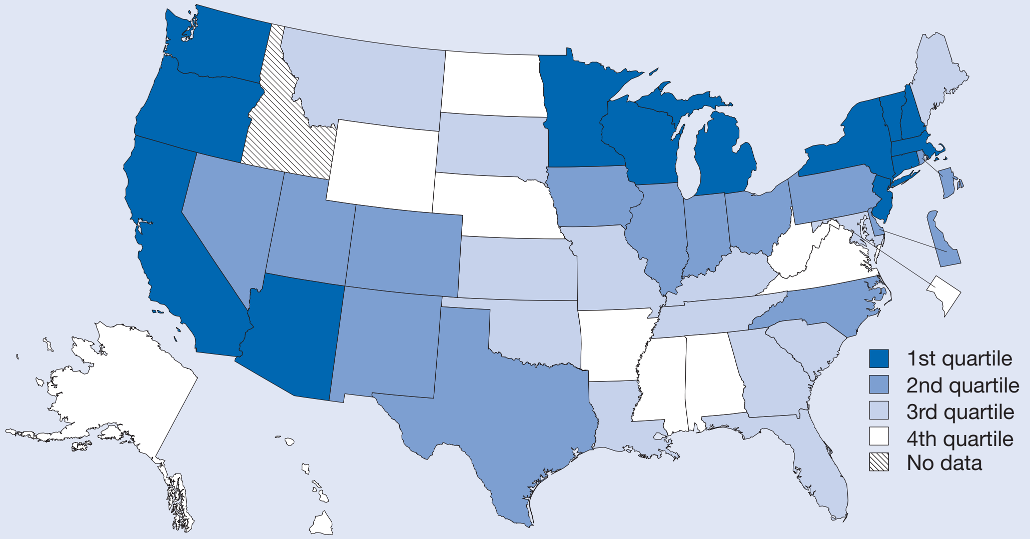
SOURCES: Patent and Trademark Office, Technology Assessment and Forecast Branch, U.S. Colleges and Universities—Utility Patent Grants, Calendar Years 1969–2005; and National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients.

Science & Engineering Indicators 2008

Patents Awarded per 1,000 Individuals in S&E Occupations

Figure 8-40

Patents awarded per 1,000 individuals in S&E occupations: 2006



1st quartile (34.2–17.4)	2nd quartile (16.6–11.2)	3rd quartile (10.9–7.3)	4th quartile (7.1–1.0)	No data
Arizona	Colorado	Florida	Alabama	Idaho
California	Delaware	Georgia	Alaska	
Connecticut	Illinois	Kansas	Arkansas	
Massachusetts	Indiana	Kentucky	District of Columbia	
Michigan	Iowa	Louisiana	Hawaii	
Minnesota	Nevada	Maine	Mississippi	
New Hampshire	New Mexico	Maryland	Nebraska	
New Jersey	North Carolina	Missouri	North Dakota	
New York	Ohio	Montana	Virginia	
Oregon	Pennsylvania	Oklahoma	West Virginia	
Vermont	Rhode Island	South Carolina	Wyoming	
Washington	Texas	South Dakota		
Wisconsin	Utah	Tennessee		

SOURCES: U.S. Patent and Trademark Office, Electronic Information Products Division/Patent Technology Monitoring Branch, Patent Counts by Country/State and Year, Utility Patents, January 1, 1963–December 31, 2006; and Bureau of Labor Statistics, Occupational Employment and Wage Estimates. See table 8-40.

Findings

- Nearly 90,000 utility patents were awarded to inventors residing in the United States in 2006, an increase of almost 7% from the 84,000 utility patents awarded in 2004.
- In 2006, the national average for this indicator was 16.7 patents per 1,000 individuals in an S&E occupation, which was slightly higher than the average of 16.6 in 2004.
- The state of Idaho typically reports the highest values for this indicator, reflecting the presence of a high-patenting Department of Energy National Laboratory in this sparsely populated state. In 2006, this may not be evident because the Idaho data for individuals in S&E occupations were suppressed.
- Values for the remaining states varied widely, ranging from 3.4 to 34.2 patents per 1,000 individuals in S&E occupations in 2006.
- Nearly 25% of all 2006 U.S. utility patents were awarded to residents of California.

This indicator shows state patent activity normalized to the size of its S&E 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, technicians, elementary and secondary schoolteachers, and medical personnel are excluded.

Although the Patent and Trademark Office grants several types of patents, this indicator includes only utility patents, commonly known as patents for inventions. Utility patents can be granted for any new, useful, or improved method, process, machine, device, manufactured item, or chemical compound, and represent a key measure of intellectual property. The 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 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 8-40

Patents awarded per 1,000 individuals in S&E occupations, by state: 2004 and 2006

State	Patents awarded		Individuals in S&E occupations		Patents/1,000 individuals in S&E occupations	
	2004	2006	2004	2006	2004	2006
United States	84,249	89,795	5,065,330	5,383,860	16.6	16.7
Alabama	375	357	57,560	66,100	6.5	5.4
Alaska	39	36	10,660	10,720	3.7	3.4
Arizona	1,621	1,705	95,380	98,110	17.0	17.4
Arkansas	132	138	22,150	24,860	6.0	5.6
California	19,488	22,275	693,670	730,010	28.1	30.5
Colorado	2,099	2,118	126,280	133,730	16.6	15.8
Connecticut	1,577	1,652	82,820	79,380	19.0	20.8
Delaware	342	357	17,980	21,550	19.0	16.6
District of Columbia	75	63	57,750	64,120	1.3	1.0
Florida	2,456	2,600	229,950	246,190	10.7	10.6
Georgia	1,326	1,487	141,710	136,470	9.4	10.9
Hawaii	76	84	16,360	18,940	4.6	4.4
Idaho	1,785	1,663	22,310	NA	80.0	NA
Illinois	3,162	3,294	219,530	222,470	14.4	14.8
Indiana	1,280	1,165	79,120	80,110	16.2	14.5
Iowa	658	666	39,280	43,670	16.8	15.3
Kansas	448	492	52,020	48,620	8.6	10.1
Kentucky	407	413	44,350	44,680	9.2	9.2
Louisiana	343	321	42,230	40,180	8.1	8.0
Maine	134	142	15,160	15,950	8.8	8.9
Maryland	1,313	1,410	154,310	159,470	8.5	8.8
Massachusetts	3,672	4,011	186,260	198,670	19.7	20.2
Michigan	3,756	3,758	183,140	208,520	20.5	18.0
Minnesota	2,754	2,957	119,380	125,930	23.1	23.5
Mississippi	136	119	23,190	24,910	5.9	4.8
Missouri	768	721	87,200	96,420	8.8	7.5
Montana	119	121	11,390	13,010	10.4	9.3
Nebraska	191	186	31,720	32,500	6.0	5.7
Nevada	410	386	23,980	26,930	17.1	14.3
New Hampshire	626	602	24,350	27,680	25.7	21.7
New Jersey	2,957	3,172	165,150	176,460	17.9	18.0
New Mexico	370	344	33,500	30,800	11.0	11.2
New York	5,846	5,627	272,930	306,810	21.4	18.3
North Carolina	1,794	1,974	135,380	138,790	13.3	14.2
North Dakota	53	66	8,420	9,360	6.3	7.1
Ohio	2,889	2,630	180,360	185,190	16.0	14.2
Oklahoma	447	544	NA	50,770	NA	10.7
Oregon	1,725	2,060	62,570	64,520	27.6	31.9
Pennsylvania	2,883	2,842	195,730	214,910	14.7	13.2
Rhode Island	309	269	19,660	18,060	15.7	14.9
South Carolina	524	577	51,030	53,230	10.3	10.8
South Dakota	82	74	9,420	10,120	8.7	7.3
Tennessee	681	669	65,120	67,040	10.5	10.0
Texas	5,930	6,308	383,180	408,710	15.5	15.4
Utah	683	684	43,030	49,690	15.9	13.8
Vermont	400	437	11,770	12,780	34.0	34.2
Virginia	1,077	1,094	220,180	251,720	4.9	4.3
Washington	2,221	3,286	154,610	171,780	14.4	19.1
West Virginia	100	103	16,100	17,150	6.2	6.0
Wisconsin	1,658	1,688	95,230	96,860	17.4	17.4
Wyoming	52	48	6,760	7,640	7.7	6.3
Puerto Rico	19	25	20,410	23,850	0.9	1.0

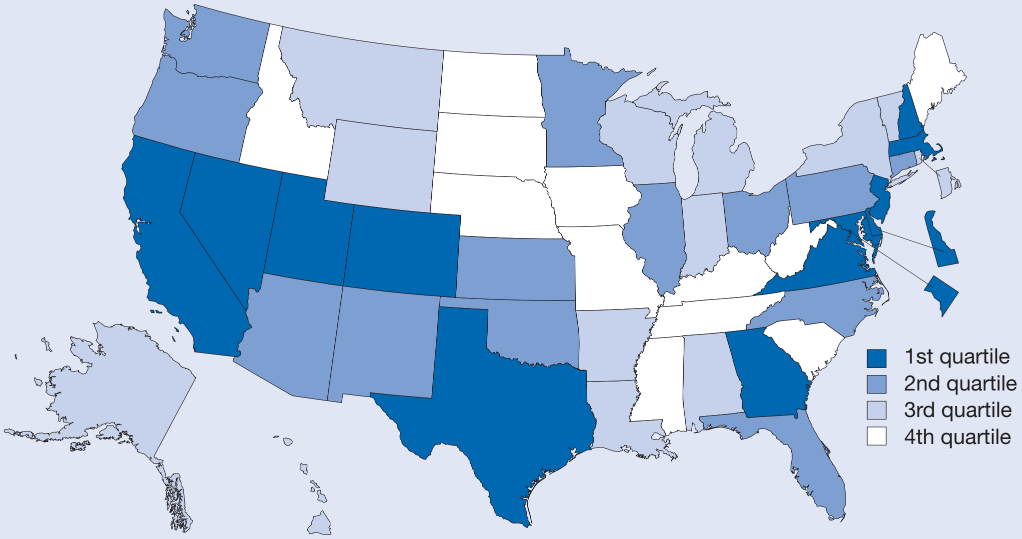
NOTE: Origin of utility patent determined by residence of first-named inventor.

SOURCES: U.S. Patent and Trademark Office, Electronic Information Products Division/Patent Technology Monitoring Branch, Patent Counts by Country/State and Year, Utility Patents, January 1, 1963–December 31, 2006; and Bureau of Labor Statistics, Occupational Employment and Wage Estimates.

Science & Engineering Indicators 2008

High-Technology Share of All Business Establishments

Figure 8-41
High-technology share of all business establishments: 2004



1st quartile (15.42%–9.07%)	2nd quartile (8.95%–7.26%)	3rd quartile (7.25%–6.36%)	4th quartile (6.35%–4.68%)
California	Arizona	Alabama	Idaho
Colorado	Connecticut	Alaska	Iowa
Delaware	Florida	Arkansas	Kentucky
District of Columbia	Illinois	Hawaii	Maine
Georgia	Kansas	Indiana	Mississippi
Maryland	Minnesota	Louisiana	Missouri
Massachusetts	New Mexico	Michigan	Nebraska
Nevada	North Carolina	Montana	North Dakota
New Hampshire	Ohio	New York	South Carolina
New Jersey	Oklahoma	Rhode Island	South Dakota
Texas	Oregon	Vermont	Tennessee
Utah	Pennsylvania	Wisconsin	West Virginia
Virginia	Washington	Wyoming	

SOURCE: Census Bureau, 1989–2004 Business Information Tracking Series, special tabulations. See table 8-41.

Findings

- The number of establishments in high-technology industries rose from more than 590,000 in 2003 to nearly 604,000 in 2004, an increase of about 14,000 or 2%.
- The percentage of U.S. establishments in high-technology industries grew from 8.17% to 8.19% of the total business establishments during the 2003–04 period. However, in 22 states the high-technology share of all business establishments declined in 2004 relative to 2003.
- Between 2003 and 2004, the largest growth in the number of establishments in high-technology industries occurred in Florida and California, which added 2,000 and 1,700 establishments, respectively.
- The state distribution of this indicator is similar to that of three other indicators: bachelor's degree holders, S&E 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 in technology-oriented occupations is at least twice the average proportion for all industries. State economies with a high percentage of 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 the years 2003 and 2004 were based on their classification according to the 2002 edition of the North American Industry Classification System (NAICS). A list of the 46 industries (by 4-digit NAICS code) that are defined as high-technology can be found in the Technical Note at the end of this chapter. Data for earlier years are not directly comparable.

Table 8-41

High-technology share of all business establishments, by state: 2003 and 2004

State	High-technology establishments		All business establishments		High-technology/ business establishments (%)	
	2003	2004	2003	2004	2003	2004
United States	590,417	603,642	7,223,240	7,366,978	8.17	8.19
Alabama	6,347	6,407	99,453	100,521	6.38	6.37
Alaska	1,345	1,358	19,037	19,309	7.07	7.03
Arizona	10,433	10,901	120,966	125,330	8.62	8.70
Arkansas	4,012	4,142	64,058	65,127	6.26	6.36
California	77,614	79,288	822,751	838,615	9.43	9.45
Colorado	15,532	16,027	143,398	146,937	10.83	10.91
Connecticut	7,827	7,794	91,207	92,710	8.58	8.41
Delaware	3,964	3,907	24,739	25,344	16.02	15.42
District of Columbia	2,589	2,695	19,357	19,503	13.38	13.82
Florida	38,118	40,165	458,823	483,693	8.31	8.30
Georgia	18,820	19,424	208,350	214,200	9.03	9.07
Hawaii	2,097	2,152	30,950	31,538	6.78	6.82
Idaho	2,515	2,582	39,582	41,205	6.35	6.27
Illinois	27,606	28,200	310,589	315,093	8.89	8.95
Indiana	9,626	9,858	147,073	149,050	6.55	6.61
Iowa	4,316	4,324	80,745	81,334	5.35	5.32
Kansas	5,716	5,900	74,637	75,600	7.66	7.80
Kentucky	5,453	5,585	90,358	91,598	6.03	6.10
Louisiana	7,218	7,192	101,933	102,866	7.08	6.99
Maine	2,466	2,541	40,519	41,131	6.09	6.18
Maryland	13,428	13,974	132,782	135,699	10.11	10.30
Massachusetts	17,183	17,305	177,910	175,426	9.66	9.86
Michigan	16,937	16,988	236,221	237,392	7.17	7.16
Minnesota	12,834	13,055	145,364	148,276	8.83	8.80
Mississippi	3,269	3,274	59,565	60,364	5.49	5.42
Missouri	9,562	9,745	149,753	153,584	6.39	6.35
Montana	2,108	2,229	33,616	34,570	6.27	6.45
Nebraska	2,797	2,864	50,213	50,803	5.57	5.64
Nevada	5,387	5,493	53,080	55,713	10.15	9.86
New Hampshire	3,511	3,559	38,119	38,707	9.21	9.19
New Jersey	24,286	24,256	237,097	240,013	10.24	10.11
New Mexico	3,322	3,385	43,386	44,071	7.66	7.68
New York	35,926	36,706	500,559	509,873	7.18	7.20
North Carolina	14,869	15,426	207,500	212,457	7.17	7.26
North Dakota	964	972	20,371	20,763	4.73	4.68
Ohio	19,875	20,120	269,202	271,078	7.38	7.42
Oklahoma	6,859	6,965	85,633	87,180	8.01	7.99
Oregon	7,500	7,659	102,462	104,966	7.32	7.30
Pennsylvania	22,266	22,796	297,040	300,832	7.50	7.58
Rhode Island	1,976	2,043	29,172	29,900	6.77	6.83
South Carolina	5,869	6,048	98,735	100,947	5.94	5.99
South Dakota	1,206	1,234	24,314	24,693	4.96	5.00
Tennessee	8,196	8,226	129,458	131,355	6.33	6.26
Texas	45,062	45,522	481,804	489,782	9.35	9.29
Utah	5,474	5,716	60,011	62,644	9.12	9.12
Vermont	1,453	1,498	21,747	22,072	6.68	6.79
Virginia	18,868	19,758	182,783	188,533	10.32	10.48
Washington	13,171	13,480	166,229	170,848	7.92	7.89
West Virginia	2,257	2,259	40,225	40,732	5.61	5.55
Wisconsin	9,035	9,249	141,560	143,739	6.38	6.43
Wyoming	1,353	1,396	18,804	19,262	7.20	7.25
Puerto Rico	NA	NA	NA	NA	NA	NA

NA = not available

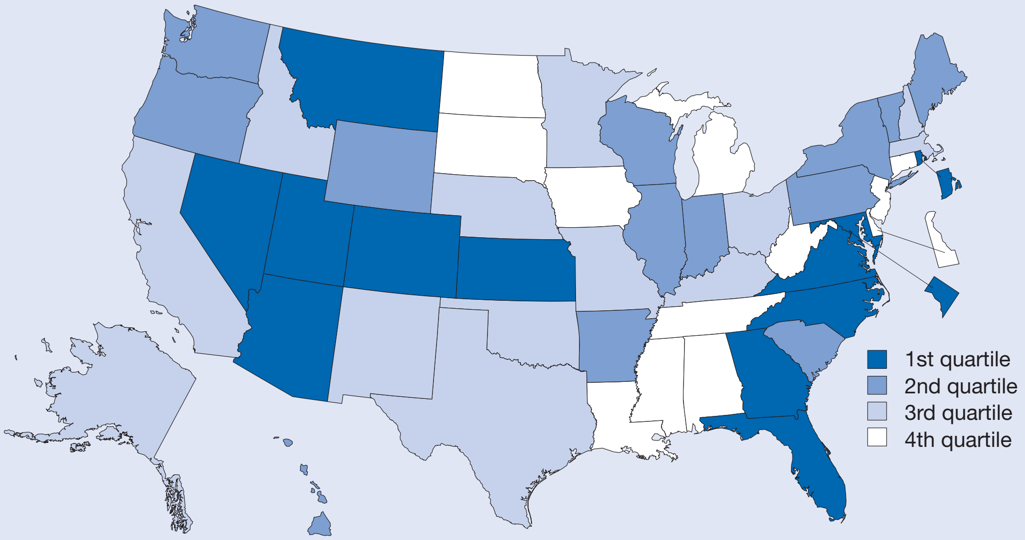
SOURCE: Census Bureau, 1989–2004 Business Information Tracking Series, special tabulations.

Science & Engineering Indicators 2008

Net High-Technology Business Formations as Share of All Business Establishments

Figure 8-42

Net high-technology business formations as share of all business establishments: 2004



1st quartile (0.45%–0.21%)	2nd quartile (0.20%–0.14%)	3rd quartile (0.13%–0.08%)	4th quartile (0.06% to –0.21%)
Arizona	Arkansas	Alaska	Alabama
Colorado	Hawaii	California	Connecticut
District of Columbia	Illinois	Idaho	Delaware
Florida	Indiana	Kentucky	Iowa
Georgia	Maine	Massachusetts	Louisiana
Kansas	New York	Minnesota	Michigan
Maryland	Oregon	Missouri	Mississippi
Montana	Pennsylvania	Nebraska	New Jersey
Nevada	South Carolina	New Hampshire	North Dakota
North Carolina	Vermont	New Mexico	South Dakota
Rhode Island	Washington	Ohio	Tennessee
Utah	Wisconsin	Oklahoma	West Virginia
Virginia	Wyoming	Texas	

SOURCE: Census Bureau, 1989–2004 Business Information Tracking Series, special tabulations. See table 8-42.

Findings

- In 2004, 11,598 net new businesses in high-technology industries were formed in the United States. From a base of approximately 7 million total business establishments, 84,155 new business establishments were formed in high-technology industries and 72,557 ceased operation in those same industries.
- Net business formations cannot be used to directly link the number of high-technology business establishments in 2003 and 2004. In addition to the births and deaths that occurred during 2004, the total number of 2004 high-technology establishments also includes business establishments that were reclassified during 2004. There were 12,387 establishments that were in operation in both 2003 and 2004 and were classified in a high-technology NAICS code in 2003 but not in 2004. Similarly, there were 14,014 establishments that were in operation in both 2003 and 2004 that were not classified with a high-technology NAICS code in 2003 but acquired one in 2004.
- Four states had net losses of business establishments in high-technology industries in 2004.
- Utah and Virginia showed the highest rates of net high-technology business formations in 2004. However, the largest numbers of net new businesses were formed in Florida and California.

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 or can vary considerably 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 2003 and 2004 were based on their classification according to the 2002 edition of the North American Industry Classification System (NAICS). A list of the 46 industries (by 4-digit NAICS code) that are defined as high-technology can be found in the Technical Note at the end of this chapter. Data for earlier years are not directly comparable. Company births and deaths are determined from Employer Identification Numbers in the Census Bureau records; thus, changes in company name, ownership, or address are not counted as business formations or business deaths.

Table 8-42

Net high-technology business formations as share of all business establishments, by state: 2004

State	Net high-technology business formations	All business establishments	High-technology formations/business establishments (%)
United States	11,598	7,366,978	0.16
Alabama	63	100,521	0.06
Alaska	22	19,309	0.11
Arizona	357	125,330	0.28
Arkansas	123	65,127	0.19
California	1,099	838,615	0.13
Colorado	490	146,937	0.33
Connecticut	-47	92,710	-0.05
Delaware	-52	25,344	-0.21
District of Columbia	66	19,503	0.34
Florida	1,743	483,693	0.36
Georgia	642	214,200	0.30
Hawaii	51	31,538	0.16
Idaho	54	41,205	0.13
Illinois	452	315,093	0.14
Indiana	208	149,050	0.14
Iowa	12	81,334	0.01
Kansas	160	75,600	0.21
Kentucky	116	91,598	0.13
Louisiana	-38	102,866	-0.04
Maine	81	41,131	0.20
Maryland	475	135,699	0.35
Massachusetts	156	175,426	0.09
Michigan	44	237,392	0.02
Minnesota	185	148,276	0.12
Mississippi	7	60,364	0.01
Missouri	195	153,584	0.13
Montana	108	34,570	0.31
Nebraska	64	50,803	0.13
Nevada	169	55,713	0.30
New Hampshire	30	38,707	0.08
New Jersey	-80	240,013	-0.03
New Mexico	37	44,071	0.08
New York	702	509,873	0.14
North Carolina	514	212,457	0.24
North Dakota	-1	20,763	0.00
Ohio	204	271,078	0.08
Oklahoma	75	87,180	0.09
Oregon	156	104,966	0.15
Pennsylvania	474	300,832	0.16
Rhode Island	67	29,900	0.22
South Carolina	175	100,947	0.17
South Dakota	16	24,693	0.06
Tennessee	39	131,355	0.03
Texas	401	489,782	0.08
Utah	283	62,644	0.45
Vermont	42	22,072	0.19
Virginia	845	188,533	0.45
Washington	346	170,848	0.20
West Virginia	16	40,732	0.04
Wisconsin	215	143,739	0.15
Wyoming	37	19,262	0.19
Puerto Rico	NA	NA	NA

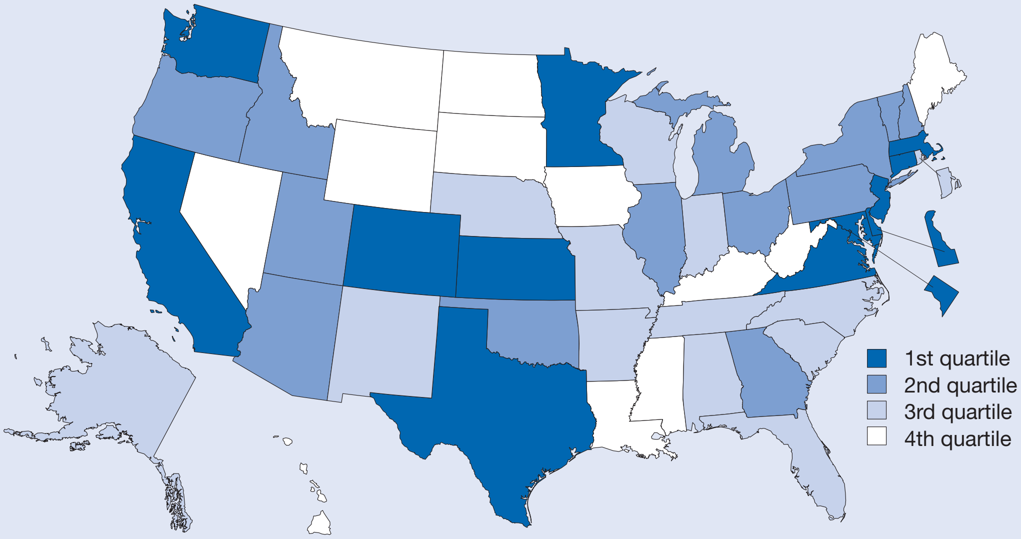
NA = not available

SOURCE: Census Bureau, 1989–2004 Business Information Tracking Series, special tabulations.

Science & Engineering Indicators 2008

Employment in High-Technology Establishments as Share of Total Employment

Figure 8-43
Employment in high-technology establishments as share of all employment: 2004



1st quartile (16.03%–12.93%)	2nd quartile (12.49%–10.74%)	3rd quartile (10.63%–8.42%)	4th quartile (8.12%–5.54%)
California	Arizona	Alabama	Hawaii
Colorado	Georgia	Alaska	Iowa
Connecticut	Idaho	Arkansas	Kentucky
Delaware	Illinois	Florida	Louisiana
District of Columbia	Michigan	Indiana	Maine
Kansas	New Hampshire	Missouri	Mississippi
Maryland	New York	Nebraska	Montana
Massachusetts	Ohio	New Mexico	Nevada
Minnesota	Oklahoma	North Carolina	North Dakota
New Jersey	Oregon	Rhode Island	South Dakota
Texas	Pennsylvania	South Carolina	West Virginia
Virginia	Utah	Tennessee	Wyoming
Washington	Vermont	Wisconsin	

SOURCE: Census Bureau, 1989–2004 Business Information Tracking Series, special tabulations. See table 8-43.

Findings

- Employment in high-technology industries in the United States declined slightly between 2003 and 2004, continuing a trend that was observed during the 1998–2002 period.
- Nationwide this indicator declined from 11.96 in 2003 to 11.61 in 2004, or about 3%; only 10 states and the District of Columbia showed increases in high-technology employment as a share of total employment.
- Washington and Texas reported the loss of 72,000 and 57,000 jobs, respectively, in high-technology industries in 2004.
- On this indicator, states varied greatly in 2004, ranging from 5.5% to 16.0% of their workforce employed in high-technology industries.
- 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 in technology-oriented 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 2003 and 2004 were based on their classification according to the 2002 edition of the North American Industry Classification System (NAICS). A list of the 46 industries (by 4-digit NAICS code) that are defined as high-technology can be found in the Technical Note at the end of this chapter. Data for earlier years are not directly comparable.

Table 8-43

Employment in high-technology establishments as share of all employment, by state: 2003 and 2004

	Employment in high-technology establishments		All employment		High-technology/ all employment (%)	
State	2003	2004	2003	2004	2003	2004
United States	13,563,122	13,356,596	113,373,663	115,049,548	11.96	11.61
Alabama	152,879	158,927	1,597,265	1,628,733	9.57	9.76
Alaska	21,851	22,107	216,707	223,099	10.08	9.91
Arizona	234,603	238,462	1,997,990	2,043,729	11.74	11.67
Arkansas	95,180	101,124	988,822	1,007,283	9.63	10.04
California	1,781,830	1,767,202	12,986,496	13,260,306	13.72	13.33
Colorado	274,979	265,613	1,883,883	1,908,126	14.60	13.92
Connecticut	210,114	204,107	1,550,615	1,537,160	13.55	13.28
Delaware	52,349	54,164	385,098	391,647	13.59	13.83
District of Columbia	54,314	57,250	422,912	436,791	12.84	13.11
Florida	576,274	587,452	6,548,276	6,863,196	8.80	8.56
Georgia	413,384	411,977	3,386,590	3,451,802	12.21	11.94
Hawaii	25,777	26,203	458,952	473,181	5.62	5.54
Idaho	55,706	53,738	466,379	488,557	11.94	11.00
Illinois	646,285	617,306	5,204,887	5,216,180	12.42	11.83
Indiana	219,598	219,694	2,540,554	2,586,282	8.64	8.49
Iowa	102,387	96,100	1,232,709	1,241,688	8.31	7.74
Kansas	155,023	153,046	1,109,699	1,115,930	13.97	13.71
Kentucky	121,838	119,167	1,471,622	1,489,285	8.28	8.00
Louisiana	137,029	129,722	1,603,492	1,623,431	8.55	7.99
Maine	35,184	36,221	488,788	494,165	7.20	7.33
Maryland	315,887	323,966	2,088,552	2,151,093	15.12	15.06
Massachusetts	460,984	455,749	2,974,164	2,979,251	15.50	15.30
Michigan	499,133	486,706	3,884,881	3,895,217	12.85	12.49
Minnesota	315,994	309,303	2,381,860	2,392,481	13.27	12.93
Mississippi	66,566	61,858	912,004	928,181	7.30	6.66
Missouri	254,299	257,290	2,387,245	2,420,994	10.65	10.63
Montana	20,296	20,452	302,932	314,806	6.70	6.50
Nebraska	68,975	69,724	774,858	774,187	8.90	9.01
Nevada	61,847	64,648	970,678	1,021,842	6.37	6.33
New Hampshire	63,264	63,907	540,132	550,869	11.71	11.60
New Jersey	550,224	558,921	3,578,674	3,609,297	15.38	15.49
New Mexico	60,399	61,149	571,057	580,443	10.58	10.53
New York	823,992	798,462	7,415,430	7,431,893	11.11	10.74
North Carolina	349,424	345,316	3,337,552	3,365,050	10.47	10.26
North Dakota	20,584	20,176	258,878	265,632	7.95	7.60
Ohio	531,491	512,352	4,769,406	4,761,492	11.14	10.76
Oklahoma	132,887	133,871	1,184,312	1,194,830	11.22	11.20
Oregon	152,140	147,549	1,338,380	1,355,101	11.37	10.89
Pennsylvania	566,406	551,971	5,028,650	5,106,171	11.26	10.81
Rhode Island	35,806	36,577	427,369	434,600	8.38	8.42
South Carolina	163,373	164,035	1,550,227	1,560,401	10.54	10.51
South Dakota	18,890	19,897	299,723	307,944	6.30	6.46
Tennessee	219,898	217,191	2,298,836	2,346,903	9.57	9.25
Texas	1,158,481	1,101,175	8,049,300	8,116,465	14.39	13.57
Utah	99,856	101,547	900,331	934,939	11.09	10.86
Vermont	29,402	27,572	256,401	256,040	11.47	10.77
Virginia	459,017	489,703	2,932,471	3,054,221	15.65	16.03
Washington	401,413	329,698	2,292,462	2,268,155	17.51	14.54
West Virginia	46,635	46,172	561,317	568,581	8.31	8.12
Wisconsin	233,967	245,257	2,382,979	2,434,580	9.82	10.07
Wyoming	15,008	14,820	180,866	187,318	8.30	7.91
Puerto Rico	NA	NA	NA	NA	NA	NA

NA = not available

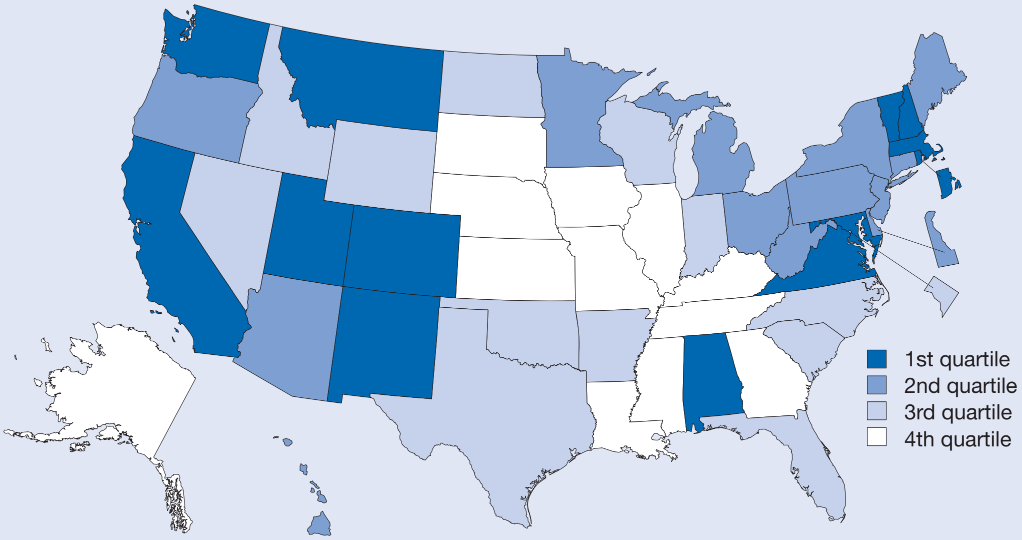
SOURCE: Census Bureau, 1989–2004 Business Information Tracking Series, special tabulations.

Science & Engineering Indicators 2008

SBIR Average Annual Federal Funding per $1 Million of Gross Domestic Product

Figure 8-44

Average annual federal SBIR funding per $1 million of gross domestic product: 2003–05



1st quartile ($825–$187)	2nd quartile ($180–$98)	3rd quartile ($96–$56)	4th quartile ($53–$19)
Alabama	Arizona	Arkansas	Alaska
California	Connecticut	District of Columbia	Georgia
Colorado	Delaware	Florida	Illinois
Maryland	Hawaii	Idaho	Iowa
Massachusetts	Maine	Indiana	Kansas
Montana	Michigan	Nevada	Kentucky
New Hampshire	Minnesota	North Carolina	Louisiana
New Mexico	New Jersey	North Dakota	Mississippi
Rhode Island	New York	Oklahoma	Missouri
Utah	Ohio	South Carolina	Nebraska
Vermont	Oregon	Texas	South Dakota
Virginia	Pennsylvania	Wisconsin	Tennessee
Washington	West Virginia	Wyoming	

SOURCES: Small Business Administration, Office of Technology, SBIR program statistics (various years); and Bureau of Economic Analysis, Gross Domestic Product data. See table 8-44.

Findings

- Strong growth has occurred in the SBIR program in recent years as total annual awards have increased from nearly $1 billion in 1995–97 to nearly $1.9 billion in 2003–05.
- 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 nearly $400 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). The total award dollars include both Phase 1 and Phase 2 SBIR awards.

Because of year-to-year fluctuations, this indicator is calculated using 3-year averages. The average annual SBIR award dollars won by small businesses in a state are divided by the average annual gross domestic product. A high value indicates that small business firms in a state are doing cutting-edge development work that attracts federal support.

Table 8-44

Average annual federal SBIR funding per $1 million of gross domestic product, by state: 1995–97, 1999–2001, and 2003–05

State	Average SBIR funding ($thousands) 1995–97	1999–2001	2003–05	Average state GDP ($millions) 1999–97	1999–2001	2003–05	SBIR funding ($)/ $1 million of GDP 1995–97	1999–2001	2003–05
United States	998,381	1,087,387	1,877,206	7,687,788	9,669,468	11,630,863	130	112	161
Alabama	21,780	18,081	34,425	98,165	115,060	141,085	222	157	244
Alaska	416	589	682	25,924	25,988	35,114	16	23	19
Arizona	14,899	20,981	29,176	113,354	157,470	196,152	131	133	149
Arkansas	146	1,459	4,989	56,168	67,114	81,480	3	22	61
California	222,268	224,699	396,052	965,361	1,256,262	1,512,772	230	179	262
Colorado	38,530	57,727	82,889	117,345	168,741	200,047	328	342	414
Connecticut	31,192	18,208	30,596	128,332	158,588	182,418	243	115	168
Delaware	4,307	4,785	6,756	29,220	41,706	52,591	147	115	128
District of Columbia	2,589	4,650	4,342	48,037	59,612	77,376	54	78	56
Florida	21,025	24,095	41,373	362,477	470,440	610,954	58	51	68
Georgia	7,493	11,933	17,979	214,879	289,137	337,970	35	41	53
Hawaii	2,993	3,800	8,306	37,151	40,216	50,665	81	94	164
Idaho	1,013	1,320	4,061	28,213	34,424	42,245	36	38	96
Illinois	12,097	17,018	25,857	379,354	461,469	533,420	32	37	48
Indiana	5,505	5,537	12,985	155,901	191,784	227,136	35	29	57
Iowa	665	1,704	3,777	77,010	89,406	110,490	9	19	34
Kansas	2,857	2,984	4,825	68,058	82,635	99,304	42	36	49
Kentucky	2,708	2,629	4,271	95,764	113,498	131,782	28	23	32
Louisiana	1,344	1,988	4,372	115,288	129,752	163,236	12	15	27
Maine	2,046	2,770	6,172	28,743	35,344	42,730	71	78	144
Maryland	42,552	53,590	103,691	144,187	181,466	228,970	295	295	453
Massachusetts	152,375	164,626	253,901	208,863	269,358	307,791	730	611	825
Michigan	20,248	17,629	41,062	264,568	332,602	364,853	77	53	113
Minnesota	17,242	14,500	26,135	141,752	182,733	220,748	122	79	118
Mississippi	1,006	1,739	3,675	56,030	64,421	76,193	18	27	48
Missouri	2,222	3,963	8,067	145,677	176,017	205,118	15	23	39
Montana	1,285	5,630	7,429	18,053	21,414	27,744	71	263	268
Nebraska	943	1,969	3,359	47,547	55,440	68,282	20	36	49
Nevada	1,656	2,751	6,871	54,003	73,284	99,109	31	38	69
New Hampshire	14,564	12,825	20,737	34,703	42,670	51,324	420	301	404
New Jersey	30,943	32,380	49,318	281,557	345,025	408,629	110	94	121
New Mexico	18,184	21,530	22,009	44,225	50,361	63,674	411	428	346
New York	47,360	40,693	88,804	630,846	771,996	906,645	75	53	98
North Carolina	11,556	12,646	28,500	203,755	274,008	327,113	57	46	87
North Dakota	742	1,391	2,020	15,552	17,711	23,107	48	79	87
Ohio	34,970	43,771	76,282	308,011	369,113	423,068	114	119	180
Oklahoma	2,135	2,943	8,718	74,657	89,102	112,137	29	33	78
Oregon	14,841	13,359	22,383	89,588	109,208	132,828	166	122	169
Pennsylvania	34,431	37,231	73,221	327,334	390,814	463,770	105	95	158
Rhode Island	2,417	3,791	8,200	27,094	33,200	41,731	89	114	196
South Carolina	1,072	3,439	7,927	90,070	112,824	133,440	12	30	59
South Dakota	681	1,011	1,047	18,793	22,861	29,159	36	44	36
Tennessee	8,812	9,078	9,660	142,663	175,027	213,225	62	52	45
Texas	33,955	40,169	80,597	554,252	719,492	907,514	61	56	89
Utah	9,660	9,285	15,231	50,776	67,170	81,617	190	138	187
Vermont	2,820	3,477	5,875	14,661	17,799	21,878	192	195	269
Virginia	60,204	64,819	101,364	196,908	260,061	326,233	306	249	311
Washington	23,336	25,187	48,596	162,503	220,700	254,859	144	114	191
West Virginia	503	2,516	6,677	37,408	41,982	49,815	13	60	134
Wisconsin	8,930	11,030	19,944	141,561	175,562	207,053	63	63	96
Wyoming	863	1,462	2,021	15,447	17,401	24,269	56	84	83
Puerto Rico	23	207	503	45,392	62,917	78,896	1	3	6

GDP = gross domestic product; SBIR = Small Business Innovation Research

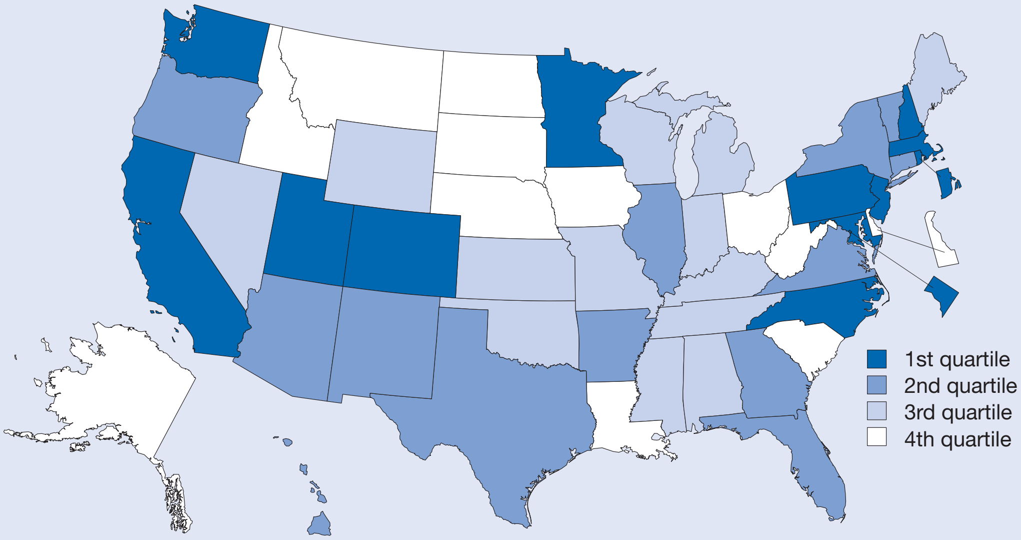
NOTES: GDP reported in current dollars.

SOURCES: Small Business Administration, Office of Technology, SBIR program statistics (various years); Bureau of Economic Analysis, Gross Domestic Product data; and Government of Puerto Rico, Office of the Governor.

Science & Engineering Indicators 2008

Venture Capital Disbursed per $1,000 of Gross Domestic Product

Figure 8-45
Venture capital disbursed per $1,000 of gross domestic product: 2006



1st quartile ($8.51–$1.31)	2nd quartile ($1.30–$0.29)	3rd quartile ($0.28–$0.10)	4th quartile ($0.09–$0.00)
California	Arizona	Alabama	Alaska
Colorado	Arkansas	Indiana	Delaware
District of Columbia	Connecticut	Kansas	Idaho
Maryland	Florida	Kentucky	Iowa
Massachusetts	Georgia	Maine	Louisiana
Minnesota	Hawaii	Michigan	Montana
New Hampshire	Illinois	Mississippi	Nebraska
New Jersey	New Mexico	Missouri	North Dakota
North Carolina	New York	Nevada	Ohio
Pennsylvania	Oregon	Oklahoma	South Carolina
Rhode Island	Texas	Tennessee	South Dakota
Utah	Vermont	Wisconsin	West Virginia
Washington	Virginia	Wyoming	

SOURCES: PricewaterhouseCoopers, Venture Economics, and National Venture Capital Association, MoneyTree Survey, special tabulations; and Bureau of Economic Analysis, Gross Domestic Product data. See table 8-45.

Findings

- The amount of venture capital invested in the United States increased approximately 10-fold, from only $11 billion in 1996 to a record $106 billion in 2000, before falling to $26 billion in 2006 (in current dollars).
- In 2006, the state average for venture capital disbursed per $1,000 GDP was $1.98, which was larger than the $1.47 invested in 1996 but only about one-half the fraction of GDP invested in 2001.
- Venture capital is concentrated in relatively few states. Companies in California received 48% of the total venture capital disbursed in the United States in 2006, followed by companies in Massachusetts with 11%.
- The distribution of venture capital among states is becoming more limited. Twenty-one states reported lower values for this indicator in 2006 than in 1996.
- The state distribution of venture capital was similar to that for the high-technology indicators.

Venture capital represents an important source of funding for startup 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 domestic product (GDP). A high value indicates that companies in those states are successfully attracting venture capital to fuel their growth.

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 8-45

Venture capital disbursed per $1,000 of gross domestic product, by state: 1996, 2001, and 2006

State	Venture capital disbursed ($thousands)			State GDP ($millions)			Venture capital ($)/ $1,000 GDP		
	1996	2001	2006	1996	2001	2006	1996	2001	2006
United States	11,270,035	40,664,265	26,075,607	7,659,648	10,058,169	13,149,033	1.47	4.04	1.98
Alabama	50,170	80,347	18,895	97,941	118,682	160,569	0.51	0.68	0.12
Alaska	0	0	0	26,083	26,609	41,105	0.00	0.00	0.00
Arizona	95,347	196,804	270,796	113,138	165,358	232,463	0.84	1.19	1.16
Arkansas	0	10,400	39,181	56,455	68,927	91,837	0.00	0.15	0.43
California	4,558,144	16,694,055	12,577,804	958,476	1,301,050	1,727,355	4.76	12.83	7.28
Colorado	318,354	1,263,862	643,352	116,045	178,078	230,478	2.74	7.10	2.79
Connecticut	142,694	535,779	247,117	126,744	165,025	204,134	1.13	3.25	1.21
Delaware	4,742	164,630	0	28,885	44,206	60,361	0.16	3.72	0.00
District of Columbia	7,113	162,181	114,927	47,560	63,730	87,664	0.15	2.54	1.31
Florida	412,331	895,125	317,110	362,950	497,423	713,505	1.14	1.80	0.44
Georgia	274,324	931,562	357,314	215,128	299,442	379,550	1.28	3.11	0.94
Hawaii	20,150	37,811	17,132	36,959	41,822	58,307	0.55	0.90	0.29
Idaho	133	2,700	0	28,152	35,631	49,907	0.00	0.08	0.00
Illinois	362,761	958,237	407,650	377,271	476,461	589,598	0.96	2.01	0.69
Indiana	22,766	53,755	68,932	155,512	195,196	248,915	0.15	0.28	0.28
Iowa	22,100	6,041	0	77,244	91,920	123,970	0.29	0.07	0.00
Kansas	25,162	39,923	11,000	67,965	86,430	111,699	0.37	0.46	0.10
Kentucky	31,097	23,855	34,710	94,987	115,113	145,959	0.33	0.21	0.24
Louisiana	13,660	80,450	11,450	114,967	133,689	193,138	0.12	0.60	0.06
Maine	1,467	3,878	7,649	28,636	37,129	46,973	0.05	0.10	0.16
Maryland	137,409	1,001,492	657,280	142,910	192,659	257,815	0.96	5.20	2.55
Massachusetts	1,075,645	4,779,022	2,874,103	208,288	280,509	337,570	5.16	17.04	8.51
Michigan	85,666	156,285	103,009	263,871	334,419	381,003	0.32	0.47	0.27
Minnesota	172,950	478,587	323,978	141,664	190,231	244,546	1.22	2.52	1.32
Mississippi	10,580	30,000	9,140	55,997	65,961	84,225	0.19	0.45	0.11
Missouri	47,881	248,870	62,058	145,044	182,362	225,876	0.33	1.36	0.27
Montana	0	24,820	0	17,998	22,471	32,322	0.00	1.10	0.00
Nebraska	10,436	58,963	6,500	48,317	57,438	75,700	0.22	1.03	0.09
Nevada	1,985	28,250	18,400	54,085	77,291	118,399	0.04	0.37	0.16
New Hampshire	42,628	224,616	75,857	34,823	44,279	56,276	1.22	5.07	1.35
New Jersey	402,077	1,510,888	780,017	281,806	362,987	453,177	1.43	4.16	1.72
New Mexico	22,412	14,215	30,118	43,658	51,359	75,910	0.51	0.28	0.40
New York	406,025	2,104,368	1,285,864	630,003	808,537	1,021,944	0.64	2.60	1.26
North Carolina	184,939	589,751	510,345	201,329	285,651	374,525	0.92	2.06	1.36
North Dakota	0	1,017	0	16,075	18,527	26,385	0.00	0.05	0.00
Ohio	162,972	233,615	43,508	305,413	374,719	461,302	0.53	0.62	0.09
Oklahoma	31,803	29,800	13,834	74,936	94,329	134,651	0.42	0.32	0.10
Oregon	94,973	233,391	143,287	91,166	110,916	151,301	1.04	2.10	0.95
Pennsylvania	305,140	960,191	763,712	325,515	406,713	510,293	0.94	2.36	1.50
Rhode Island	300	118,709	113,505	26,665	35,149	45,660	0.01	3.38	2.49
South Carolina	91,850	97,141	9,994	89,260	117,296	149,214	1.03	0.83	0.07
South Dakota	0	500	0	19,073	23,910	32,330	0.00	0.02	0.00
Tennessee	146,787	212,801	47,000	141,335	180,582	238,029	1.04	1.18	0.20
Texas	532,761	2,945,371	1,387,544	550,014	762,247	1,065,891	0.97	3.86	1.30
Utah	52,270	210,147	168,564	51,442	70,109	97,749	1.02	3.00	1.72
Vermont	2,000	11,600	10,143	14,632	18,828	24,213	0.14	0.62	0.42
Virginia	453,255	978,848	391,793	196,638	276,762	369,260	2.31	3.54	1.06
Washington	412,415	1,145,091	1,030,511	161,760	225,765	293,531	2.55	5.07	3.51
West Virginia	0	1,400	3,724	37,346	43,365	55,658	0.00	0.03	0.07
Wisconsin	20,361	93,121	60,300	141,755	181,936	227,230	0.14	0.51	0.27
Wyoming	0	0	6,500	15,732	18,941	29,561	0.00	0.00	0.22
Puerto Rico	4,080	32,000	14,291	45,341	69,208	86,464	0.09	0.46	0.17

GDP = gross domestic product

NOTES: GDP reported in current dollars. Preliminary Puerto Rico 2006 GDP.

SOURCES: PricewaterhouseCoopers, Venture Economics, and National Venture Capital Association, MoneyTree Survey, special tabulations; Bureau of Economic Analysis, Gross Domestic Product data; and Government of Puerto Rico, Office of the Governor.

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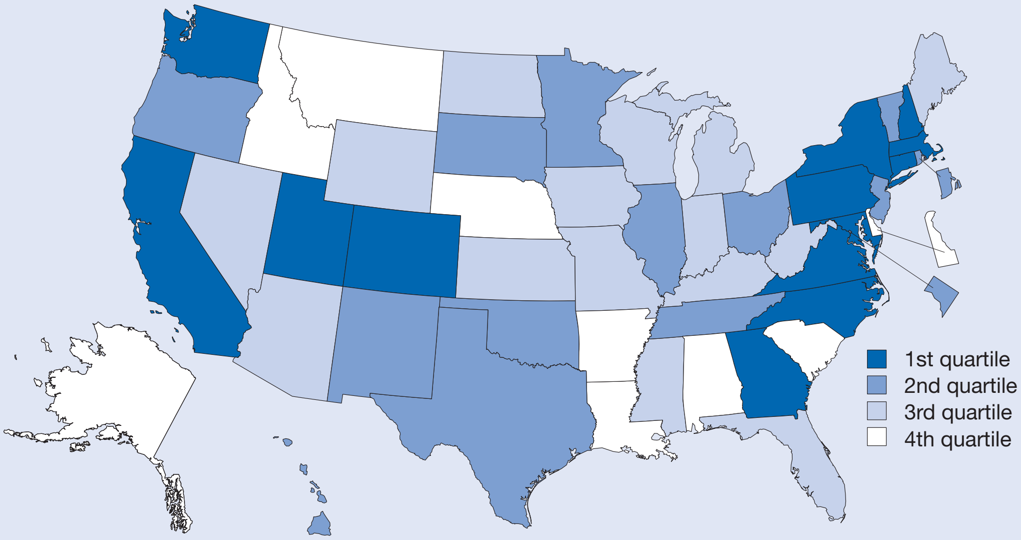
Venture Capital Deals as Share of High-Technology Business Establishments

Figure 8-46

Venture capital deals as share of high-technology business establishments: 2004



1st quartile (2.11%–0.37%)	2nd quartile (0.36%–0.16%)	3rd quartile (0.15%–0.09%)	4th quartile ($0.08%–0.00%)
California	District of Columbia	Arizona	Alabama
Colorado	Hawaii	Florida	Alaska
Connecticut	Illinois	Indiana	Arkansas
Georgia	Minnesota	Iowa	Delaware
Maryland	New Jersey	Kansas	Idaho
Massachusetts	New Mexico	Kentucky	Louisiana
New Hampshire	Ohio	Maine	Montana
New York	Oklahoma	Michigan	Nebraska
North Carolina	Oregon	Mississippi	South Carolina
Pennsylvania	Rhode Island	Missouri	
Utah	South Dakota	Nevada	
Virginia	Tennessee	North Dakota	
Washington	Texas	West Virginia	
	Vermont	Wisconsin	
		Wyoming	

SOURCE: SOURCES: PricewaterhouseCoopers, Venture Economics, and National Venture Capital Association, MoneyTree Survey, special tabulations; and Census Bureau, 1989–2004 Business Information Tracking Series, special tabulations. See table 8-46.

Findings

- The number of venture capital deals that involved U.S. companies fell from a high of 7,900 deals in 2000 to a fairly consistent value of 2,900–3,100 deals annually during the period of 2002–04.
- In 2004, the distribution of venture capital among high-technology companies was uneven between states. Companies in only five states exceeded the national average of 0.50%.
- Companies in high-technology industries located in Massachusetts were the most successful in accessing venture capital investments in 2004 with a 2.1% rate. This was less than half the rate of Massachusetts companies that received such funding in 2000. California companies in high-technology industries obtained venture capitol investment at a rate of 1.6%. No other states exceeded a rate of 1%.
- In 2004, no venture capital deals were reported in Alaska, Montana, or Nebraska.

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 8-46

Venture capital deals as share of high-technology business establishments, by state: 2003 and 2004

	Venture capital deals		High-technology establishments		Venture capital deals/ high-technology establishment (%)	
State	2003	2004	2003	2004	2003	2004
United States	2,903	3,036	590,417	603,642	0.49	0.50
Alabama	9	5	6,347	6,407	0.14	0.08
Alaska	0	0	1,345	1,358	0.00	0.00
Arizona	16	12	10,433	10,901	0.15	0.11
Arkansas	3	1	4,012	4,142	0.07	0.02
California	1,122	1,225	77,614	79,288	1.45	1.55
Colorado	72	75	15,532	16,027	0.46	0.47
Connecticut	34	32	7,827	7,794	0.43	0.41
Delaware	1	1	3,964	3,907	0.03	0.03
District of Columbia	6	8	2,589	2,695	0.23	0.30
Florida	61	57	38,118	40,165	0.16	0.14
Georgia	55	73	18,820	19,424	0.29	0.38
Hawaii	6	4	2,097	2,152	0.29	0.19
Idaho	5	2	2,515	2,582	0.20	0.08
Illinois	58	51	27,606	28,200	0.21	0.18
Indiana	8	9	9,626	9,858	0.08	0.09
Iowa	1	4	4,316	4,324	0.02	0.09
Kansas	2	9	5,716	5,900	0.03	0.15
Kentucky	3	5	5,453	5,585	0.06	0.09
Louisiana	1	3	7,218	7,192	0.01	0.04
Maine	2	3	2,466	2,541	0.08	0.12
Maryland	84	85	13,428	13,974	0.63	0.61
Massachusetts	378	365	17,183	17,305	2.20	2.11
Michigan	17	19	16,937	16,988	0.10	0.11
Minnesota	58	47	12,834	13,055	0.45	0.36
Mississippi	4	5	3,269	3,274	0.12	0.15
Missouri	23	10	9,562	9,745	0.24	0.10
Montana	1	0	2,108	2,229	0.05	0.00
Nebraska	2	0	2,797	2,864	0.07	0.00
Nevada	6	5	5,387	5,493	0.11	0.09
New Hampshire	32	23	3,511	3,559	0.91	0.65
New Jersey	88	88	24,286	24,256	0.36	0.36
New Mexico	5	8	3,322	3,385	0.15	0.24
New York	119	149	35,926	36,706	0.33	0.41
North Carolina	76	57	14,869	15,426	0.51	0.37
North Dakota	2	1	964	972	0.21	0.10
Ohio	25	32	19,875	20,120	0.13	0.16
Oklahoma	2	11	6,859	6,965	0.03	0.16
Oregon	21	27	7,500	7,659	0.28	0.35
Pennsylvania	90	92	22,266	22,796	0.40	0.40
Rhode Island	10	7	1,976	2,043	0.51	0.34
South Carolina	4	5	5,869	6,048	0.07	0.08
South Dakota	1	3	1,206	1,234	0.08	0.24
Tennessee	22	23	8,196	8,226	0.27	0.28
Texas	165	162	45,062	45,522	0.37	0.36
Utah	22	27	5,474	5,716	0.40	0.47
Vermont	6	4	1,453	1,498	0.41	0.27
Virginia	80	73	18,868	19,758	0.42	0.37
Washington	81	114	13,171	13,480	0.61	0.85
West Virginia	5	3	2,257	2,259	0.22	0.13
Wisconsin	8	10	9,035	9,249	0.09	0.11
Wyoming	1	2	1,353	1,396	0.07	0.14
Puerto Rico	1	1	NA	NA	NA	NA

NA = not available

SOURCES: PricewaterhouseCoopers, Venture Economics, and National Venture Capital Association, MoneyTree Survey, special tabulations; and Census Bureau, 1989–2004 Business Information Tracking Series, special tabulations.

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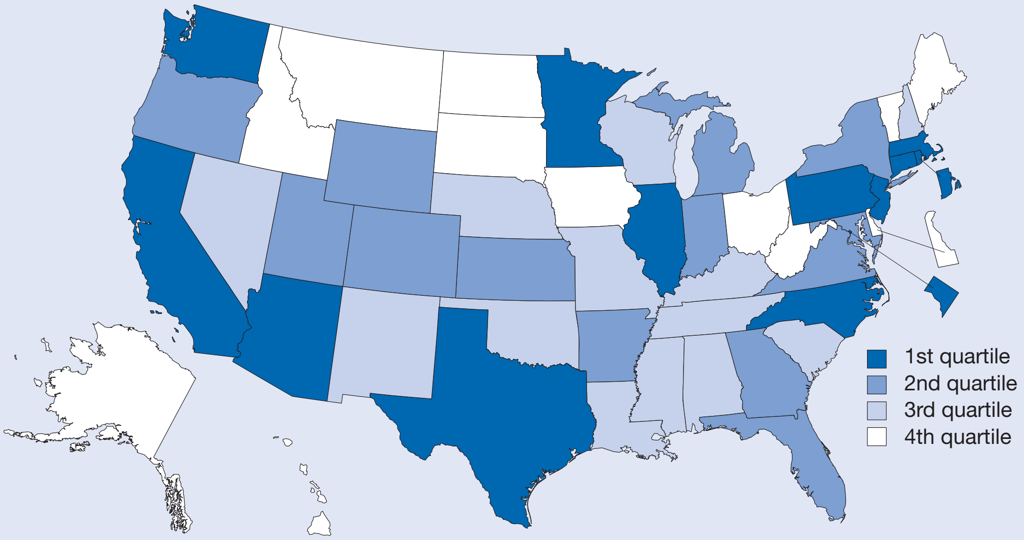
Venture Capital Disbursed per Venture Capital Deal

Figure 8-47
Venture capital disbursed per venture capital deal: 2006



1st quartile ($16.22–$7.29)	2nd quartile ($6.87–$4.62)	3rd quartile ($4.34–$2.17)	4th quartile ($1.91–$0.00)
Arizona	Arkansas	Alabama	Alaska
California	Colorado	Kentucky	Delaware
Connecticut	Florida	Louisiana	Hawaii
District of Columbia	Georgia	Mississippi	Idaho
Illinois	Indiana	Missouri	Iowa
Massachusetts	Kansas	Nebraska	Maine
Minnesota	Maryland	Nevada	Montana
New Jersey	Michigan	New Hampshire	North Dakota
North Carolina	New York	New Mexico	Ohio
Pennsylvania	Oregon	Oklahoma	South Dakota
Rhode Island	Utah	South Carolina	Vermont
Texas	Virginia	Tennessee	West Virginia
Washington	Wyoming	Wisconsin	

SOURCE: PricewaterhouseCoopers, Venture Economics, and National Venture Capital Association, MoneyTree Survey, special tabulations. See table 8-47.

Findings

- The size of the average venture capital investment in the United States rose over the past decade to more than $7 million per deal in 2006. This average represented an increase in investment size from $4 million per deal in 1996 and $5 million per deal in 1998 but a decline from $13 million per deal in 2000.
- The total number of venture capital deals began to rise again during the past few years, increasing from 2,872 in 2004 to 3,519 in 2006.
- The state distribution on this indicator was skewed in 2006; only 11 states and the District of Columbia were above the national average, and 7 states reported no venture capital investments.
- The value of this indicator has shown a high level of variability during the past decade both at the national level and for individual states.

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 and type of company.

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-three states reported fewer than 10 venture capital deals in 2006. In such states, a single large or small venture capital investment can significantly affect the value of this indicator.

Table 8-47
Venture capital disbursed per venture capital deal, by state: 1996, 2001, and 2006

	Venture capital disbursed ($thousands)			Venture capital deals			Venture capital/deal ($millions)		
State	1996	2001	2006	1996	2001	2006	1996	2001	2006
United States	11,270,037	40,664,265	26,075,607	2,566	4,473	3,519	4.39	9.09	7.41
Alabama	50,170	80,347	18,895	8	16	7	6.27	5.02	2.70
Alaska	0	0	0	0	0	0	0.00	0.00	0.00
Arizona	95,347	196,804	270,796	28	32	31	3.41	6.15	8.74
Arkansas	0	10,400	39,181	0	3	6	0.00	3.47	6.53
California	4,558,144	16,694,055	12,577,804	1,018	1,528	1,495	4.48	10.93	8.41
Colorado	318,354	1,263,862	643,352	79	113	96	4.03	11.18	6.70
Connecticut	142,694	535,779	247,117	44	69	30	3.24	7.76	8.24
Delaware	4,742	164,630	0	4	2	1	1.19	82.32	0.00
District of Columbia	7,113	162,181	114,927	4	24	14	1.78	6.76	8.21
Florida	412,331	895,125	317,110	56	113	56	7.36	7.92	5.66
Georgia	274,324	931,562	357,314	54	139	75	5.08	6.70	4.76
Hawaii	20,150	37,811	17,132	2	5	11	10.08	7.56	1.56
Idaho	133	2,700	0	1	2	0	0.13	1.35	0.00
Illinois	362,761	958,237	407,650	54	126	54	6.72	7.61	7.55
Indiana	22,766	53,755	68,932	8	6	13	2.85	8.96	5.30
Iowa	22,100	6,041	0	6	4	1	3.68	1.51	0.00
Kansas	25,162	39,923	11,000	8	9	2	3.15	4.44	5.50
Kentucky	31,097	23,855	34,710	7	4	8	4.44	5.96	4.34
Louisiana	13,660	80,450	11,450	4	11	3	3.42	7.31	3.82
Maine	1,467	3,878	7,649	5	5	4	0.29	0.78	1.91
Maryland	137,409	1,001,492	657,280	45	92	109	3.05	10.89	6.03
Massachusetts	1,075,645	4,779,022	2,874,103	287	512	380	3.75	9.33	7.56
Michigan	85,666	156,285	103,009	21	24	15	4.08	6.51	6.87
Minnesota	172,950	478,587	323,978	53	85	38	3.26	5.63	8.53
Mississippi	10,580	30,000	9,140	3	3	3	3.53	10.00	3.05
Missouri	47,881	248,870	62,058	21	18	16	2.28	13.83	3.88
Montana	0	24,820	0	0	2	0	0.00	12.41	0.00
Nebraska	10,436	58,963	6,500	5	7	3	2.09	8.42	2.17
Nevada	1,985	28,250	18,400	2	4	6	0.99	7.06	3.07
New Hampshire	42,628	224,616	75,857	16	30	22	2.66	7.49	3.45
New Jersey	402,077	1,510,888	780,017	63	151	88	6.38	10.01	8.86
New Mexico	22,412	14,215	30,118	5	4	8	4.48	3.55	3.76
New York	406,025	2,104,368	1,285,864	91	289	196	4.46	7.28	6.56
North Carolina	184,939	589,751	510,345	61	91	70	3.03	6.48	7.29
North Dakota	0	1,017	0	0	1	0	0.00	1.02	0.00
Ohio	162,972	233,615	43,508	53	43	31	3.07	5.43	1.40
Oklahoma	31,803	29,800	13,834	7	7	5	4.54	4.26	2.77
Oregon	94,973	233,391	143,287	30	44	31	3.17	5.30	4.62
Pennsylvania	305,140	960,191	763,712	82	135	101	3.72	7.11	7.56
Rhode Island	300	118,709	113,505	1	11	7	0.30	10.79	16.22
South Carolina	91,850	97,141	9,994	13	5	4	7.07	19.43	2.50
South Dakota	0	500	0	0	1	1	0.00	0.50	0.00
Tennessee	146,787	212,801	47,000	24	29	11	6.12	7.34	4.27
Texas	532,761	2,945,371	1,387,544	131	329	179	4.07	8.95	7.75
Utah	52,270	210,147	168,564	15	43	35	3.48	4.89	4.82
Vermont	2,000	11,600	10,143	1	3	9	2.00	3.87	1.13
Virginia	453,255	978,848	391,793	62	137	84	7.31	7.14	4.66
Washington	412,415	1,145,091	1,030,511	76	139	138	5.43	8.24	7.47
West Virginia	0	1,400	3,724	0	2	2	0.00	0.70	1.86
Wisconsin	20,361	93,121	60,300	8	21	19	2.55	4.43	3.17
Wyoming	0	0	6,500	0	0	1	0.00	0.00	6.50
Puerto Rico	4,080	32,000	14,291	5	5	3	0.82	6.40	4.76

SOURCE: PricewaterhouseCoopers, Venture Economics, and National Venture Capital Association, MoneyTree Survey, special tabulations.

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Technical Note: Defining High-Technology Industries

Although there is no consensus on the identity of high-technology industries, this chapter utilizes a modification of the approach employed by the Bureau of Labor Statistics (BLS). That approach is based on the intensity of high-technology employment within an industry. High-technology occupations include scientific, engineering, and technician occupations. These occupations employ workers who possess an in-depth knowledge of the theories and principles of science, engineering, and mathematics, which are generally acquired through postsecondary education in some field of technology. An industry is considered a high-technology industry if employment in technology-oriented occupations accounts for a proportion of that industry's total employment that is at least twice the 4.9% average for all industries (i.e., 9.8% or higher). Level I high-technology industries include the 14 industries in which technology-oriented employment is at least 5 times the average for all industries, or 24.7%. Level II high-technology industries

Table 8-48
2002 NAICS codes that constitute high-technology industries

NAICS code	Industry
Level I industries	
3254	Pharmaceutical and medicine manufacturing
3341	Computer and peripheral equipment manufacturing
3342	Communications equipment manufacturing
3344	Semiconductor and other electronic component manufacturing
3345	Navigational, measuring, electromedical, and control instruments manufacturing
3364	Aerospace product and parts manufacturing
5112	Software publishers
5161	Internet publishing and broadcasting
5179	Other telecommunications
5181	Internet service providers and Web search portals
5182	Data processing, hosting, and related services
5413	Architectural, engineering, and related services
5415	Computer systems design and related services
5417	Scientific research and development services
Level II industries	
1131,32	Forestry
2111	Oil and gas extraction
2211	Electric power generation, transmission, and distribution
3251	Basic chemical manufacturing
3252	Resin, synthetic rubber, and artificial synthetic fibers and filaments manufacturing
3332	Industrial machinery manufacturing
3333	Commercial and service industry machinery manufacturing
3343	Audio and video equipment manufacturing
3346	Manufacturing and reproducing magnetic and optical media
4234	Professional and commercial equipment and supplies, merchant wholesalers
5416	Management, scientific, and technical consulting services
Level III industries	
3241	Petroleum and coal products manufacturing
3253	Pesticide, fertilizer, and other agricultural chemical manufacturing
3255	Paint, coating, and adhesive manufacturing
3259	Other chemical product and preparation manufacturing
3336	Engine, turbine, and power transmission equipment manufacturing
3339	Other general purpose machinery manufacturing
3353	Electrical equipment manufacturing
3369	Other transportation equipment manufacturing
4861	Pipeline transportation of crude oil
4862	Pipeline transportation of natural gas
4869	Other pipeline transportation
5171	Wired telecommunications carriers
5172	Wireless telecommunications carriers (except satellite)
5173	Telecommunications resellers
5174	Satellite telecommunications
5211	Monetary authorities, central bank
5232	Securities and commodity exchanges
5511	Management of companies and enterprises
5612	Facilities support services
8112	Electronic and precision equipment repair and maintenance

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include the 12 industries in which the high-technology occupations are 3.0–4.9 times the average or 14.8%–24.7% of total employment. Level III high-technology industries include the 20 industries with a proportion of high-technology employment that is 2.0–2.9 times the industry average or 9.8%–14.7% of total employment.

In each case, the industry is defined by a four-digit code that is based on the listings in the 2002 North American Industry Classification System (NAICS). The 2002 NAICS codes contain a number of new additions and changes from the previous 1997 NAICS codes that were used to classify business establishments in datasets covering the period 1998–2002. Therefore, this listing of high-technology industry codes can be applied only to datasets covering the years after 2002 when the 2002 NAICS codes were used to classify business establishments.

The BLS methodology includes the "Federal Government, excluding Postal Service" in its listing of high-technology industries. However, in this chapter "high-technology industries" is used in indicators that refer to business establishments and employment in those business establishments. These indicators are intended to measure private-sector activity. For this reason, "Federal Government, excluding Postal Service" was deleted from the list of high-technology industries. With this deletion, the list of high-technology industries used in this chapter includes the 46 four-digit codes from the 2002 NAICS listing shown in table 8-48.

Reference

Hecker D. 2005. High-technology employment: A NAICS-based update. *Monthly Labor Review* 128(7):57–72.

Appendix
Methodology and Statistics

Introduction

Science and Engineering Indicators (SEI) contains data compiled from a variety of sources. The purpose of this appendix is to explain the methodological and statistical criteria used to assess possible data sources for inclusion in SEI and to develop statements about the data. It also provides some basic information about how statistical procedures and reasoning are applied.

The first section describes the statistical considerations that are part of the selection process for data sets to be included in SEI. The next section discusses the different types of data (e.g., sample surveys, censuses, and administrative records) used in the report and provides some information about each type. A section on data accuracy follows, discussing factors that can affect accuracy at all stages of the survey process. The last section discusses the statistical testing employed to determine whether differences between sample survey-based estimates are *statistically significant*, i.e., greater than could be expected by chance. The appendix concludes with a glossary of statistical terms commonly used or referred to in the text. Selected key terms appear in bold in the text.

Selection of Data Sources

Four criteria guide the selection of data for SEI:

- Representativeness. Data should represent national or international populations of interest.
- Relevance. Data sources should include indicators central to the functioning of the science and technology enterprise.
- Timeliness. Data that are not part of a time series should be timely, i.e., substantial and unmeasured changes in the population under study should not have occurred since the data were collected.
- Statistical and methodological quality. Survey methods used to acquire data should provide sufficient assurance that statements based on statistical analysis of the data are valid and reliable.

Data that are collected by U.S. government agencies and that are products of the federal statistical system meet rigorous statistical and methodological criteria as described below. Unless otherwise indicated, these data are representative of the nation as a whole and of the demographic, organizational, or geographic subgroups that comprise it.

For data collected by governments in other countries and nongovernment sources, including private survey firms and academic researchers, methodological information is examined to assess conformity with the criteria U.S. federal agencies typically use. Government statistical agencies in the developed world cooperate extensively in developing data quality standards and improving international comparability for key data, and methodological information about the data generated by this international statistical system is relatively complete.

Methodological information about data from nongovernmental sources and from governmental agencies outside the international statistical system is often less well documented. These data are evaluated and must meet basic scientific standards for representative sampling of survey respondents and adequate and unbiased coverage of the population under study, and the resulting measurements must be sufficiently relevant and meaningful to warrant publication despite methodological uncertainties that remain after the documentation has been scrutinized. The most important statistical criteria are described in general terms below and in greater detail in the following sections.

Many data sources that contain pertinent information about some segment of the S&E enterprise are not cited in SEI because their coverage of the United States as a nation is partial in terms of geography, incomplete in terms of segments of the population, or otherwise not representative. For example, data may be available only for a limited number of states or studies may be based on populations not representative of the United States as a whole. Similarly, data for other countries should cover and be representative of the entire country. (In some cases, data that have limited coverage or are otherwise insufficiently representative are referenced in sidebars.)

Data included in SEI must be of high quality. Data quality can be measured in a variety of ways, some of which are described in the following sections. Some key dimensions of quality include:

- **Validity.** Data have *validity* to the degree that they accurately measure the phenomenon they are supposed to represent.

- **Reliability.** Data have *reliability* to the degree that the same results would be produced if the same measurement or procedure were performed multiple times on the same population.
- **Lack of bias.** Data are *unbiased* to the degree that estimates from the data do not deviate from the population value of a phenomenon in a systematic fashion.

Data Sources

Much of the data cited in SEI come from surveys. Surveys strive to measure characteristics of target populations. To generalize survey results correctly to the population of interest, a survey's **target population** must be rigorously defined and the criteria determining membership in the population must be applied consistently in determining which units to include in the survey.

Some surveys are censuses (also known as **universe surveys**), in which the survey attempts to obtain data for all population units. The decennial census, in which the target population is all U.S. residents, is the most familiar census survey. SEI uses data from the Survey of Earned Doctorates, an annual census of individuals who earn doctorates from accredited U.S. institutions, for information about the numbers and characteristics of new U.S. doctorate holders.

Other surveys are **sample surveys**, in which data are obtained for only a representative portion of the population units. The Survey of Recent College Graduates, which gathers data on individuals who recently received bachelor's or master's degrees in science, engineering, and health fields from U.S. institutions, is an example of a sample survey.

A sample is a **probability sample** if each unit in the sampling frame has a known, nonzero probability of being selected for the sample. Probability samples are necessary for inferences about a population to be evaluated statistically. Except for some Asian surveys referenced in chapter 7, sample surveys included in SEI use probability sampling. In **nonprobability sampling**, a sample is selected haphazardly, purposively, or conveniently, and inferences about the population cannot be evaluated statistically. Internet surveys and phone-in polls that elicit responses from self-selected individuals are examples of nonprobability sample surveys.

In sample surveys, once a survey's target population has been defined, the next step is to establish a list of all members of that target population (i.e., a **sampling frame**). Members of the population must be selected from this list in a scientific manner so that it will be possible to generalize from the sample to the population as a whole. Surveys frequently sample from lists that to varying extents omit members of the target population, because complete lists are typically unavailable.

Surveys may be conducted of individuals or of organizations, such as businesses, universities, or government agencies. Surveys of organizations are often referred to as *establishment surveys*. An example of an establishment survey used in SEI is the Survey of Research and Development Expenditures at Universities and Colleges.

Surveys may be longitudinal or cross-sectional. In a **longitudinal survey**, the same individuals (or organizations) are surveyed repeatedly. The primary purpose of longitudinal surveys is to investigate how individuals or organizations change over time. The Survey of Doctorate Recipients is a longitudinal sample survey of individuals who received research doctorates from U.S. institutions. SEI uses results from this survey to analyze the careers of doctorate holders.

Cross-sectional surveys provide a "snapshot" at a given point of time. When conducted periodically, cross-sectional surveys produce repeated snapshots of a population, enabling analysis of how the population changes over time. However, because the same individuals or organizations are not included in each survey cycle, cross-sectional surveys cannot, in general, track changes for specific individuals or organizations. National and international assessments of student achievement in K–12 education, such as those discussed in chapter 1, are examples of repeated cross-sectional surveys. Most of the surveys cited in SEI are conducted periodically, although the frequency with which they are conducted varies.

Some of the data in SEI come from **administrative records** (data previously collected for the purpose of administering various programs). Examples of data drawn directly from administrative records in SEI include patent data from the records of government patent offices; bibliometric data on publications in S&E journals, compiled from information collected and published by the journals themselves; and data on foreign S&E workers temporarily in the United States, drawn from the administrative records of immigration agencies.

Many of the establishment surveys that SEI uses depend heavily, although indirectly, on administrative records. Universities and corporations that respond to surveys about their R&D activities often use administrative records developed for internal management or income tax reporting purposes to respond to these surveys.

Surveys are conducted using a variety of modes (e.g., mail, telephone, the Internet, or in person). They can be self- or interviewer administered. Many surveys are conducted in more than one mode. For example, the Survey of Graduate Students and Postdoctorates in Science and Engineering, a census of establishments (university departments) from which students earn S&E graduate degrees, collects most of its data via a Web-based questionnaire but also allows respondents to answer a paper questionnaire. The National Survey of College Graduates, a longitudinal sample survey that collects data on individuals with S&E-related degrees and/or occupations, is initially conducted by sending a paper questionnaire by mail. Later, potential participants who did not respond to the questionnaire are contacted via telephone or in person.

Data Accuracy

Accurate information is a primary goal of censuses and sample surveys. Accuracy can be defined as the extent to which results deviate from the true values of the characteristics in the target population. Statisticians use the term "error" to refer to this deviation. Good survey design seeks to minimize survey error.

Statisticians usually classify the factors affecting the accuracy of survey data into two categories: nonsampling and sampling errors. **Nonsampling error** applies to all surveys, including censuses, whereas **sampling error** applies only to sample surveys. The sources of nonsampling error in surveys have analogues for administrative records: the processes through which such records are created affect the degree to which the records accurately indicate the characteristics of relevant populations (e.g., patents, journal articles, immigrant scientists and engineers).

Nonsampling Error

Nonsampling error refers to error related to survey design, data collection, and processing procedures. Each stage of the survey process is a potential source of nonsampling error. For most types, there is no practical method of measuring the extent of nonsampling error. A brief description of five sources of nonsampling error follows. Although for convenience the descriptions occasionally refer to samples, they apply equally to censuses.

Specification Error. Survey questions often do not perfectly measure the concept for which they are intended as indicators. For example, the number of patents is not the same as the amount of invention.

Frame Error. The sampling frame, the list of the target population members used for selecting survey respondents, is often inaccurate. If the frame has omissions or other flaws, the survey is less representative because coverage of the target population is incomplete. Frame errors often require extensive effort to correct.

Nonresponse Error. Nonresponse errors occur because not all members of the sample respond to the survey. *Response rates* indicate what proportion of sample members respond to the survey. Other things being equal, lower response rates create a greater possibility that, had nonrespondents supplied answers to the questionnaire, the survey estimates would have been different.

Nonresponse can cause *nonresponse bias*, which occurs when the people or establishments that respond to a question, or to the survey as a whole, differ in systematic ways from those who do not respond. For example, in surveys of national populations, complete or partial nonresponse is often more likely among lower-income or less-educated respondents. Evidence of nonresponse bias is an important factor in decisions about whether survey data should be included in SEI.

Managers of high-quality surveys, such as those in the U.S. federal statistical system, do research on nonresponse patterns to assess whether and how nonresponse might bias survey estimates. SEI notes instances where reported data may be subject to substantial nonresponse bias.

The response rate does not indicate whether a survey has a problem of nonresponse bias. Surveys with high response rates sometimes have substantial nonresponse bias, and surveys with relatively low response rates, if nonrespondents do not differ from respondents on important variables, may have relatively little.

Measurement Error. There are many sources of measurement error, but respondents, interviewers, and survey questionnaires are the most important. Knowingly or unintentionally, respondents may provide incorrect information. Interviewers may inappropriately influence respondents' answers or record their answers incorrectly. The questionnaire can be a source of error if there are ambiguous, poorly worded, or confusing questions, instructions, or terms, or if the questionnaire layout is confusing.

In addition, the records or systems of information that a respondent may refer to, the mode of data collection, and the setting for the survey administration may contribute to measurement error. Perceptions about whether data will be treated as confidential may affect the accuracy of survey responses to sensitive questions about business profits or personal incomes.

Processing Error. Processing errors include errors in recording, checking, coding, and preparing survey data to make them ready for analysis.

Sampling Error

Sampling error is probably the best-known source of survey error and the most commonly reported measure of a survey's precision or accuracy. Unlike nonsampling error, sampling error can be quantitatively estimated in most scientific sample surveys.

Chance is involved in selecting the members of a sample. If the same, random procedures were used repeatedly to select samples from the population, numerous samples would be selected, each containing different members of the population with different characteristics. Each sample would produce different population estimates. When there is great variation among the samples drawn from a given population, the sampling error is high and there is a large chance that the survey estimate is far from the true population value. In a census, because the entire population is surveyed, there is no sampling error.

Sampling error is reduced when samples are large, and most of the surveys used in SEI have large samples. Sampling error is not a function of the percentage of the population in the sample (when the population is large) or the population size but is a function of the sample size, the variability of the measure of interest, and the methods used to produce estimates from the sample data.

Sampling error is measured by the standard error of the estimate, sometimes called the "margin of error." The standard error of an estimate measures how closely the estimate from a particular sample approximates the average result of all possible samples. The standard error of the estimate is expressed as a range in the size of the difference (e.g., ±2%) between the sample estimate and the average result of all possible samples.

Statistical Testing for Data From Sample Surveys

Statistical tests determine whether differences observed in sample survey data could have happened by chance, i.e., as the result of random variation in which people or establishments in the population were sampled. Differences that are very unlikely to have been produced by chance variations in sample selection are termed **statistically significant**. When SEI reports statements about differences on the basis of sample surveys, the differences are statistically significant at the .05 level. This means that, if there were no true difference in the population, the chance of drawing a sample with the observed difference would be no more than 5%.

A statistically significant difference is not necessarily large, important, or significant in the usual sense of the word. It is simply a difference that cannot be attributed to chance variation in sampling. With the large samples common in SEI data, extremely small differences can be found to be statistically significant. Conversely, quite large differences may not be statistically significant if the sample or population sizes of the groups being compared are small. Occasionally, apparently large differences are noted in the text as not being statistically significant to alert the reader that these differences may have occurred by chance.

Numerous differences are apparent in every table in SEI that reports sample data. The tables permit comparisons between different groups in the survey population and in the same population in different years. It would be impractical to test and indicate the statistical significance of all possible comparisons in tables involving sample data.

As explained in "About Science and Engineering Indicators" at the beginning of this volume, SEI presents indicators. It does not model the dynamics of the S&E enterprise, although analysts could construct models using the data in SEI. Accordingly, SEI does not make use of statistical procedures suitable for causal modeling and does not compute effect sizes for models that might be constructed using these data.

Glossary

Most glossary definitions are drawn from U.S. Office of Management and Budget, Office of Statistical Policy (2006), "Standards and Guidelines for Statistical Surveys" and U.S. Bureau of the Census (2006), "Organization of Metadata, Census Bureau Standard Definitions for Surveys and Census Metadata." In some cases, glossary definitions are somewhat more technical and precise than those in the text, where fine distinctions are omitted to improve readability.

Administrative records: Data collected for the purpose of carrying out various programs (e.g., tax collection).

Bias: Systematic deviation of the survey estimated value from the true population value. Refers to systematic errors that can occur with any sample under a specific design.

Coverage: Extent to which all elements on a frame list are members of the population and to which every element in a population appears on the frame list once and only once.

Coverage error: Discrepancy between statistics calculated on the frame population and the same statistics calculated on the target population. *Undercoverage* errors occur when target population units are missed during frame construction, and *overcoverage* errors occur when units are duplicated or enumerated in error.

Cross-sectional sample survey: Based on a representative sample of respondents drawn from a population at a particular point in time.

Estimate: A numerical value for a population parameter derived from information collected from a survey and/or other sources.

Estimation error: Difference between a survey estimate and the true value of the parameter in the target population.

Frame: A mapping of the universe elements (i.e., sampling units) onto a finite list (e.g., the population of schools on the day of the survey).

Item nonresponse: Occurs when a respondent fails to respond to one or more relevant item(s) on a survey.

Longitudinal sample survey: Follows the experiences and outcomes over time of a representative sample of respondents (i.e., a cohort).

Measurement error: Difference between observed values of a variable recorded under similar conditions and some fixed true value (e.g., errors in reporting, reading, calculating, or recording a numerical value).

Nonresponse bias: Occurs when the observed value deviates from the population parameter due to differences between respondents and nonrespondents. Nonresponse bias may occur as a result of not obtaining 100% response from the selected units.

Nonresponse error: Overall error observed in estimates caused by differences between respondents and nonrespondents. Consists of a variance component and nonresponse bias.

Nonsampling error: Includes measurement errors due to interviewers, respondents, instruments, and mode; nonresponse error; coverage error; and processing error.

Population: See “target population.”

Precision of survey results: How closely results from a sample can reproduce the results that would be obtained from a complete count (i.e., census) conducted using the same techniques. The difference between a sample result and the result from a complete census taken under the same conditions is an indication of the precision of the sample result.

Probabilistic methods: Any of a variety of methods for survey sampling that give a known, nonzero probability of selection to each member of a target population. The advantage of probabilistic sampling methods is that sampling error can be calculated. Such methods include random sampling, systematic sampling, and stratified sampling. They do not include convenience sampling, judgment sampling, quota sampling, and snowball sampling.

Reliability: Degree to which a measurement technique would yield the same result each time it is applied. A measurement can be both reliable and inaccurate.

Response bias: Deviation of the survey estimate from the true population value due to measurement error from the data collection. Potential sources of response bias include the respondent, the instrument, and the interviewer.

Response rates: Measure the proportion of the sample frame represented by the responding units in each study.

Sample design: Sampling plan and estimation procedures.

Sampling error: Error that occurs because all members of the frame population are not measured. It is associated with the variation in samples drawn from the same frame population. The sampling error equals the square root of the variance.

Standard error: Standard deviation of the sampling distribution of a statistic. Although the standard error is used to estimate sampling error, it includes some nonsampling error.

Statistical significance: Attained when a statistical procedure applied to a set of observations yields a *p* value that exceeds the level of probability at which it is agreed that the null hypothesis will be rejected.

Target population: Any group of potential sample units or individuals, businesses, or other entities of interest.

Unit nonresponse: Occurs when a respondent fails to respond to all required response items (i.e., fails to fill out or return a data collection instrument).

Universe survey: Involves the collection of data covering all known units in a population (i.e., a census).

Validity: Degree to which an estimate is likely to be true and free of bias (systematic errors).

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