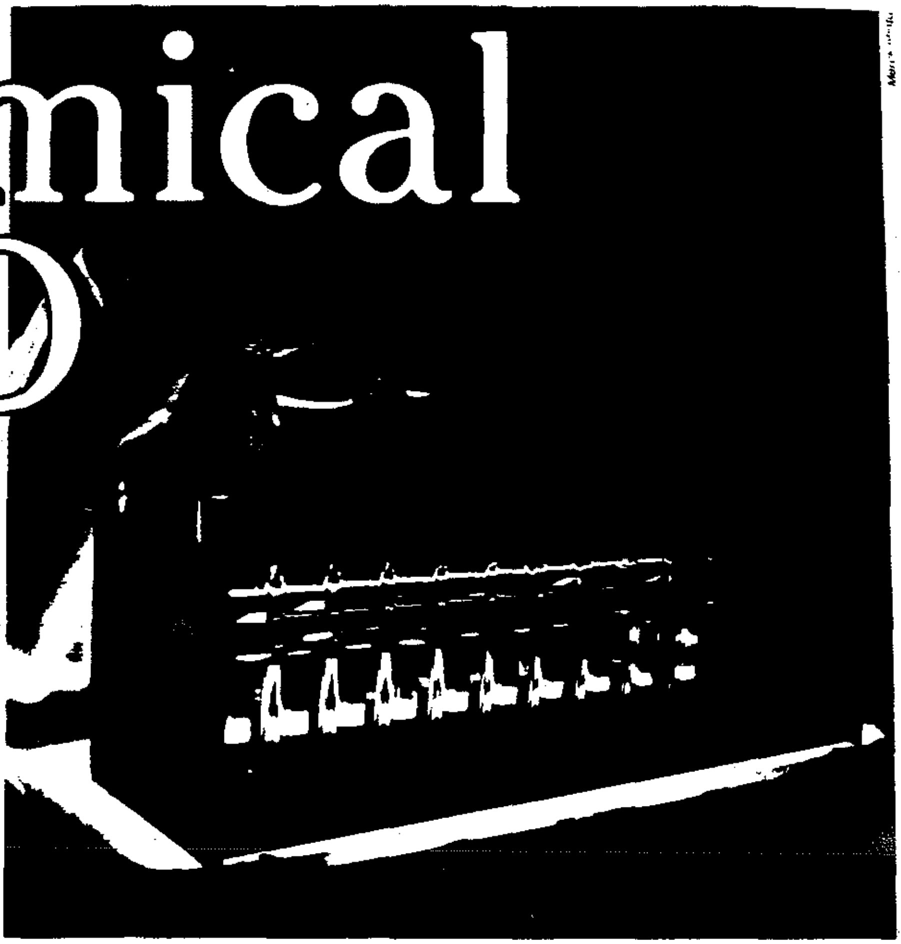
Facts & Figures for Chemical R&D



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Research and development in the U.S. is growing modestly. Total expenditures for R&D are expected to top $122 billion in 1987, an increase of 6% over R&D spending from all sources last year. That's the smallest year-to-year change in the past decade, a decade that has seen R&D funding nearly triple, in current dollars, from 1977's $42.8 billion. For the decade as a whole, R&D spending in the U.S. has been growing 11% per year—nearly twice the rate at which it is growing now.

Still, although significantly more modest than in the recent past, the increase in R&D funding expected this year does represent real growth, outpacing anticipated inflation by some 2%. In keeping with the recent pattern, about half that money comes from the federal government—$60 billion in 1987—and almost all the rest from industry. Universities and other nonprofit institutions will kick in a relatively modest $4.2 billion, only 3% of the total, this year.

Government spending for R&D is actually growing a good deal

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faster than federal spending as a whole. If Gramm-Rudman deficit reduction targets are to be met in this year's budget—an event that most observers consider unlikely—the overall federal budget probably will rise only a very modest 1% for the year ending Sept. 30. Federal R&D support, by contrast, is expected to be up 7% for 1987 as a whole. In general, the Reagan Administration and Congress have been relatively kind to R&D budgets during the past seven years, doubling federal support for R&D from its pre-Reagan level of $29.5 billion in 1980. Even when inflation is taken into account, federal R&D support has grown 46% since 1980.

Until recently, industrial support for R&D has kept pace with the federal effort. In 1986 and again in 1987, however, preliminary figures indicate that industry's support for R&D is lagging behind that of government. R&D spending by all industry is expected to rise 5% this year, following a 6% increase in 1986 and one of 7% in 1985. Federal support over the same period rose, on average, 10% per year.

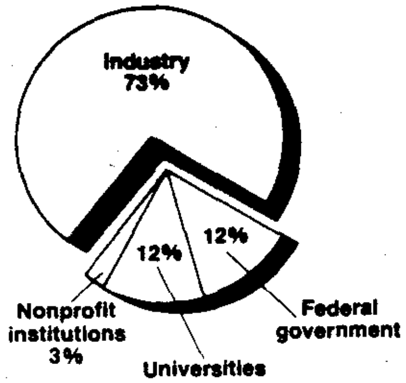
Considered in a broader context, however, current levels of support for R&D in the U.S. are quite high. R&D spending appears to be leveling off at about 2.7% of gross national product. For most of the past two decades it has been considerably lower than that, reaching its most recent nadir in 1978 at just above 2.1%. Not since the mid-1960s, when massive efforts in space and defense led the federal government to spend twice what industry did to support R&D, has such a large fraction of the nation's total output of goods and services, as measured by GNP, been devoted to supporting R&D. Though the rate of growth may be declining, overall support for R&D in the U.S. appears strong.

Chemical R&D, of course, is only a small piece of the total R&D picture. Just how much of the total national effort focuses on chemistry is never easy to measure, in part because the point where chemical R&D breaks off and R&D begins in some closely related field—materials science, say, or biotechnology—has never been clearly defined.

This year, separating out that part of the overall R&D effort that can reasonably be called chemical is even harder than usual. That's because some of the key data, particularly on the industrially financed half of the R&D picture, have yet to be compiled by the National Science Foundation. NSF is the chief source of statistical information on R&D in the U.S., and its data—collected in large part by the Census Bureau—form much of the basis of this special report. Recent reorganizations at both the Census Bureau and NSF's division of science resources studies have delayed the compilation of some of these data by three or four months. As a result, the most recent data available for many aspects of industrial R&D spending are based on information collected in 1983, too long ago to give a precise picture of the state of that R&D effort now.

Of the federally funded half of U.S. R&D, the biggest share—69% for the 1987 fiscal year—is funded by the Defense Department. Defense's share of the federal R&D budget has been climbing steadily in recent years, from a level of about 45% that prevailed throughout the late 1970s. That shift parallels another one that is taking place, name-

Almost three quarters of all R&D is by industry



1987 total R&D spending = $122.3 billion

Source: National Science Foundation

ly that more and more federal funds are going into the development part of R&D—72% in 1987, up from 64% five years ago. The Defense Department is the overwhelming source of federal development funds, supplying almost 90% in 1987.

Chemical research also finds its single largest federal patron in the Defense Department, which in the 1987 budget year is expected to spend $185 million for it. That's 28% of total federal chemical research support, which is estimated to reach $671 million. Defense Department support is up 10% from 1986 levels. Growing even faster is support from the National Science Foundation, which expects a 17% boost in its funding for chemical research in fiscal 1987. That would bring its support to $132 million, nearly to the level of the second largest supporter of chemical research in the federal government—the Department of Energy, which expects to spend $139 million on such research in fiscal 1987, down 6% from 1986. In fact, except for the Defense Department and NSF, all the major supporters of chemical research in the federal government will decrease their spending in this area in 1987. The net effect is a 3% rise overall for federal support for chemical research—no change at all when inflation is taken into account.

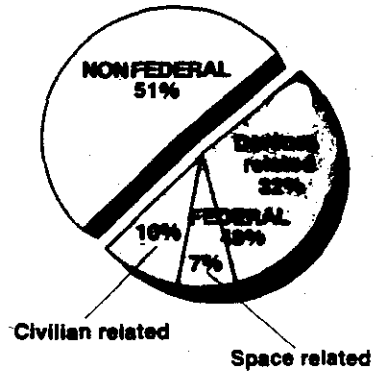
At universities, where half of the nation's basic research is performed, overall budgets for basic research were up a healthly 8% in 1986. Funds for applied R&D, which together account for only a third of total R&D spending at universities, also were up 8% in 1986. Spending at universities on chemical R&D reached $450 million in 1986, also an 8% hike from 1985. The federal government is the principal funder of university R&D—supplying nearly two thirds of the $11.1 billion universities expect to spend on R&D in 1987.

Though universities have a major role in performing basic research in the U.S., they trail far behind industry when it comes to carrying out applied research or development. In fact, industry will do 73% of the total R&D conducted in the U.S. this year, a fraction that has held essentially constant for the past decade. Universities and government-run R&D facilities each perform about equal shares of the remainder.

Historically, the overall chemicals and allied products industry performs about 70% of all the applied R&D done on chemicals or drugs by industry. R&D performed by companies in the chemicals and allied products industry is estimated to have increased 10% in 1986 to $9.5 billion. That level of growth is off a bit from the 12% average annual rate of increase for the past decade. When adjusted for inflation, however, the real growth in spending for 1986, at 7%, is slightly better than the 6% annual rate for the decade as a whole.

Growth in R&D at major industrial chemical companies was not so high as that for the chemicals and allied products industry as a whole in 1986—up only 4%. Some of this difference comes about because drug companies, which are part of the chemicals and allied products industry, are increasing their R&D spending faster than are basic chemical companies. Another contributing factor is a major divestment that took place at Union Carbide in 1986. The company sold off nearly $2 billion of its assets, largely in consumer products fields. The much smaller Union Carbide spent less on R&D in 1986 than its predecessor company had in 1985. When this change is taken into account, major chemical company R&D spending rose 7% in 1986. □

Federal funds account for half of all U.S. R&D

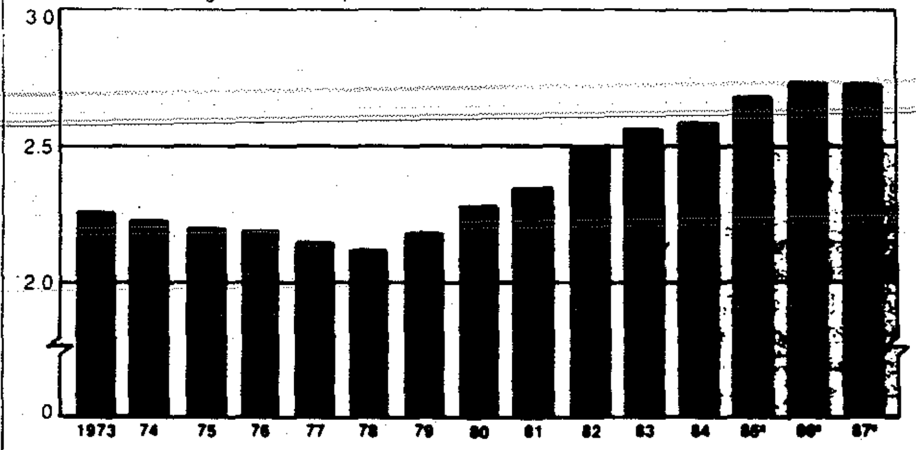


1987 total R&D spending = $122.3 billion

Source: National Science Foundation

R&D share of U.S. GNP levels off after rise of early 1980s

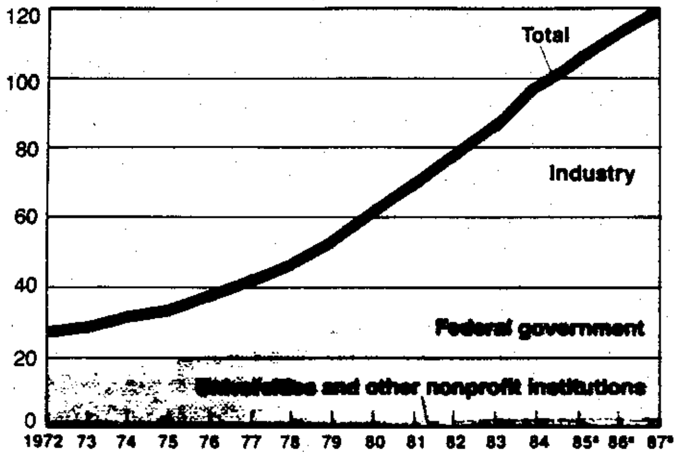
Total R&D as % of gross national product



a C&EN estimates Source: National Science Foundation

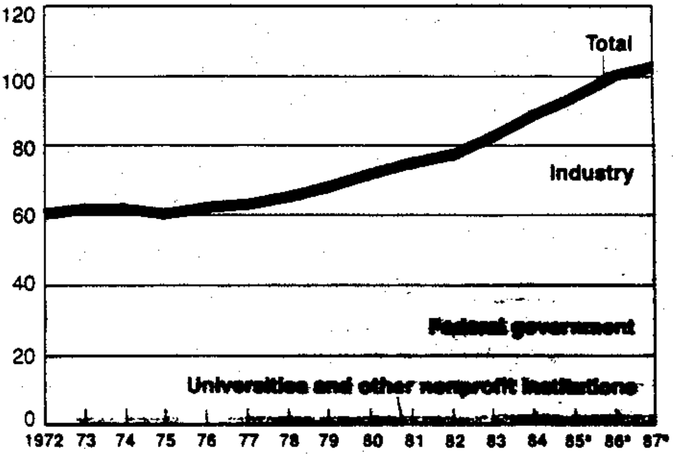
Although U.S. outlays for R&D are up fourfold in the past 15 years . . .

Sources of R&D funds, $ billions, current



. . . they are only two thirds higher if inflation is taken into account

Sources of R&D funds, $ billions, constant (1982)



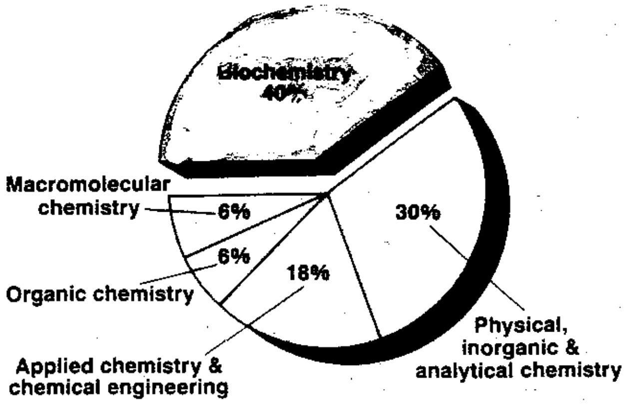
a C&EN estimates. Source: National Science Foundation

SOURCES OF R&D FUNDS: **Industry and federal government each contribute nearly half**

	$ Billions (current)											Annual change	
	1987a	1986a	1985a	1984	1983	1982	1981	1980	1979	1978	1977	1986–87	1977–87
Industry	$ 58.1	$ 55.3	$ 52.2	$48.8	$43.5	$40.1	$35.9	$30.9	$26.1	$22.5	$19.6	5%	11%
Federal government	60.0	56.0	51.8	45.6	40.7	36.5	33.4	29.5	26.8	23.9	21.6	7	11
Universities and colleges	2.7	2.5	2.3	2.0	1.9	1.7	1.5	1.3	1.2	1.0	0.9	8	12
Other nonprofit institutions	1.5	1.4	1.3	1.2	1.1	1.0	1.0	0.9	0.8	0.8	0.7	7	8
TOTAL	$122.3	$115.2	$107.5	$97.6	$87.2	$79.3	$71.8	$62.6	$54.9	$48.1	$42.8	6%	11%
ANNUAL CHANGE	6%	7%	10%	12%	10%	10%	15%	14%	14%	12%	10%		
	$ Billions (1982, constant)												
Industry	$ 48.8	$ 48.3	$46.8	$45.2	$41.9	$40.1	$38.3	$36.1	$33.2	$31.1	$29.2	1%	5%
Federal government	50.4	48.9	46.5	42.3	39.2	36.5	35.7	34.5	34.3	33.2	32.2	3	5
Universities and colleges	2.3	2.2	2.1	1.9	1.8	1.7	1.6	1.6	1.5	1.4	1.3	5	6
Other nonprofit institutions	1.3	1.2	1.2	1.1	1.1	1.0	1.0	1.1	1.1	1.1	1.0	8	3
TOTAL	$102.7	$100.6	$96.4	$90.5	$83.9	$79.3	$76.6	$73.2	$70.1	$66.8	$63.7	2%	5%
ANNUAL CHANGE	2%	4%	7%	8%	6%	4%	5%	4%	5%	5%	2%		

a C&EN estimates. Source: National Science Foundation

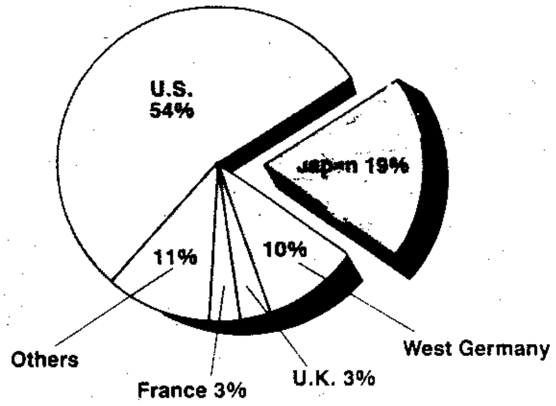
Two fifths of chemistry papers are in biochemistry



1986 total papers[a] = 474,429

[a] Number of abstracts of papers published in *Chemical Abstracts*.
Source: Chemical Abstracts Service

Japanese now receive nearly 20% of U.S. patents



1986 total U.S. patents issued = 70,860

Source: U.S. Patent & Trademark Office

PERFORMERS OF R&D: Industry's share is six times that of government

	$ Billions (current)											Annual change	
	1987[a]	1986[a]	1985[a]	1984	1983	1982	1981	1980	1979	1978	1977	1986–87	1977–87
Industry	$ 88.7	$ 84.4	$ 78.2	$71.5	$63.4	$58.0	$51.8	$44.5	$38.2	$33.3	$29.8	5%	12%
Federal government	15.1	13.4	13.0	11.6	10.6	9.1	8.4	7.6	7.4	6.8	6.0	13	10
Universities and colleges	10.7	10.3	9.5	8.5	7.8	7.3	6.8	6.1	5.4	4.6	4.1	4	10
University-associated FFRDCs[b]	4.0	3.8	3.5	3.1	2.7	2.5	2.5	2.2	1.9	1.7	1.4	5	11
Other nonprofit institutions	3.7	3.4	3.3	3.0	2.7	2.4	2.3	2.2	2.0	1.7	1.5	9	9
TOTAL	**$122.3**	**$115.2**	**$107.5**	**$97.6**	**$87.2**	**$79.3**	**$71.8**	**$62.6**	**$54.9**	**$48.1**	**$42.8**	**6%**	**11%**
	$ Billions (1982, constant)												
Industry	$ 74.5	$ 73.7	$70.1	$66.9	$61.0	$58.0	$55.1	$51.9	$48.7	$46.1	$44.3	1%	5%
Federal government	12.7	11.7	11.7	10.8	10.2	9.1	9.0	9.0	9.5	9.5	9.0	9	4
Universities and colleges	9.0	9.0	8.5	7.9	7.5	7.3	7.3	7.2	6.9	6.4	6.1	0	4
University-associated FFRDCs[b]	3.4	3.3	3.1	2.9	2.6	2.5	2.7	2.7	2.5	2.4	2.1	3	5
Other nonprofit institutions	3.1	3.0	3.0	2.8	2.6	2.4	2.4	2.5	2.5	2.3	2.2	3	3
TOTAL	**$102.7**	**$100.6**	**$96.4**	**$90.5**	**$83.9**	**$79.3**	**$76.6**	**$73.2**	**$70.1**	**$66.8**	**$63.7**	**2%**	**5%**

[a] C&EN estimates. [b] Federally funded R&D centers. Those administered by both industry and by nonprofit institutions are included in totals for their respective sectors
Source: National Science Foundation

CHARACTER OF R&D: Uniform growth in all three sectors

	$ Billions (current)											Annual change	
	1987[a]	1986[a]	1985[a]	1984	1983	1982	1981	1980	1979	1978	1977	1986–87	1977–87
Basic research	$ 14.7	$ 13.8	$ 13.0	$12.1	$11.0	$ 9.9	$ 9.2	$ 8.1	$ 7.3	$ 6.4	$ 5.5	7%	10%
Applied research	26.4	24.7	23.4	22.3	20.4	18.5	16.9	14.1	12.3	10.8	9.7	7	11
Development	81.2	76.5	71.1	62.9	55.8	50.9	45.8	40.5	35.3	30.9	27.5	6	11
TOTAL	**$122.3**	**$115.2**	**$107.5**	**$97.6**	**$87.2**	**$79.3**	**$71.8**	**$62.6**	**$54.9**	**$48.1**	**$42.8**	**6%**	**11%**
	$ Billions (1982, constant)												
Basic research	$ 12.3	$ 12.1	$11.7	$11.2	$10.6	$ 9.9	$ 9.8	$ 9.5	$ 9.3	$ 8.9	$ 8.3	2%	4%
Applied research	22.2	21.6	21.0	20.7	19.6	18.5	18.0	16.5	15.8	15.1	14.5	3	4
Development	68.2	66.8	63.8	58.3	53.7	50.9	48.8	47.3	45.0	42.8	40.9	2	5
TOTAL	**$102.7**	**$100.6**	**$96.4**	**$90.5**	**$83.9**	**$79.3**	**$76.6**	**$73.2**	**$70.1**	**$66.8**	**$63.7**	**2%**	**5%**

[a] C&EN estimates **Source:** National Science Foundation

PATENT ACTIVITY OF U.S. COMPANIES:[a] Significant decline for chemicals in 1986

Number of patents issued	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977	Total 1977-86
CHEMICAL COMPANIES											
Dow Chemical	371	335	328	246	276	260	249	217	334	297	**2,913**
Du Pont	329	342	348	326	283	343	289	227	386	431	**3,304**
Ciba-Geigy	244	305	290	244	281	345	309	248	347	354	**2,987**
Union Carbide	208	242	231	182	202	262	211	197	215	224	**2,174**
PPG Industries	124	128	137	137	177	189	166	118	190	196	**1,562**
Monsanto	110	100	138	136	131	211	205	144	264	192	**1,631**
American Cyanamid	92	115	111	128	129	188	205	143	225	215	**1,551**
Olin	81	117	112	85	80	80	106	82	99	91	**933**
Ethyl	77	105	76	44	31	43	51	25	41	46	**539**
International Flavors & Fragrances	76	104	95	87	87	96	76	60	80	52	**813**
Stauffer Chemical	75	104	95	81	87	94	93	80	132	116	**957**
Celanese	66	67	94	57	56	58	56	44	71	70	**639**
Hercules	43	41	39	37	30	52	23	24	49	51	**389**
W. R. Grace	42	45	57	52	49	68	72	56	76	63	**580**
Rohm & Haas	33	31	37	55	49	77	74	77	95	94	**622**
GAF	12	23	19	21	32	47	48	54	57	26	**339**
TOTAL[b]	**1983**	**2204**	**2207**	**1918**	**1980**	**2413**	**2233**	**1796**	**2661**	**2518**	**21,913**
ANNUAL CHANGE	**−10%**	**0%**	**15%**	**−3%**	**−18%**	**8%**	**24%**	**−33%**	**6%**	**−9%**	

[a] Includes U.S. chemical companies or U.S.-based subsidiaries of foreign companies that have received more than 999 U.S. patents since 1962. [b] These totals include patents issued to the chemical companies shown in this table only. **Source:** U.S. Patent & Trademark Office

U.S. PATENTS: Those of foreign origin rose 2% in 1986 as those of U.S. origin declined 4%

Number of patents issued	1986	1985	1984	1983	1982	1981	1980	1979[a]	1978	1977	Total 1977-86
U.S. origin	**38,124**	**39,554**	**38,365**	**32,871**	**33,896**	**39,223**	**37,356**	**30,079**	**41,254**	**41,485**	**372,207**
to U.S. corporations	27,324	28,944	28,002	24,038	24,085	27,623	25,967	21,145	29,421	29,566	**266,115**
to U.S. government	1,011	1,124	1,228	1,043	1,003	1,117	1,232	961	1,233	1,484	**11,436**
to individuals in the U.S.	9,461	9,243	8,887	7,562	8,539	10,241	9,940	7,804	10,399	10,249	**92,325**
to foreign-owned corporations in the U.S.	328	243	248	228	269	242	217	169	201	186	**2,331**
Foreign origin	**32,736**	**32,107**	**28,835**	**23,989**	**23,992**	**26,548**	**24,463**	**18,775**	**24,848**	**23,784**	**260,077**
to U.S.-owned corporations abroad	2,231	2,274	2,032	1,660	1,715	1,839	1,694	1,364	1,961	1,970	**18,740**
to foreign corporations	26,196	25,721	22,985	19,019	18,589	20,549	18,665	14,447	18,875	17,879	**202,925**
to foreign governments	471	483	440	336	368	249	253	186	249	215	**3,250**
to foreign individuals	3,838	3,629	3,378	2,974	3,320	3,911	3,851	2,778	3,763	3,720	**35,162**
TOTAL	**70,860**	**71,661**	**67,200**	**56,860**	**57,888**	**65,771**	**61,819**	**48,854**	**66,102**	**65,269**	**632,284**
% FOREIGN	**46.2%**	**44.8%**	**42.9%**	**42.2%**	**41.4%**	**40.4%**	**39.6%**	**38.4%**	**37.6%**	**36.4%**	**41.1%**

[a] Patent figures were low in 1979 because the U.S. Patent & Trademark Office was short of funds to print patents it might otherwise have issued. **Source:** U.S. Patent & Trademark Office

HOLDERS OF U.S. PATENTS: Japan's share doubles in past decade

% of patents	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977	Total 1977-86	Total 1963-76
U.S. origin	**54**	**55**	**57**	**58**	**59**	**60**	**60**	**62**	**62**	**64**	**59**	**73**
Foreign origin[a]	**46**	**45**	**43**	**42**	**41**	**40**	**40**	**38**	**38**	**36**	**41**	**27**
Japan	19	18	17	15	14	13	12	11	10	10	14	5
West Germany	10	9	9	10	9	10	9	9	9	8	9	7
U.K.	3	3	3	3	4	4	4	4	4	4	4	4
France	3	3	3	3	3	3	3	3	3	3	3	3
Switzerland	2	2	2	2	2	2	2	2	2	2	2	2
Canada	2	2	2	2	2	2	2	2	2	2	2	2
Sweden	1	1	1	1	1	1	1	1	1	1	1	1
Italy	1	1	1	1	1	1	1	1	1	1	1	1
Netherlands	1	1	1	1	1	1	1	1	1	1	1	1
U.S.S.R.	—	—	—	—	—	1	1	1	1	1	—	—
Others	2	—	—	—	—	—	—	—	—	—	3	2

[a] Data for individual countries may not equal this number because of rounding. **Source:** U.S. Patent & Trademark Office

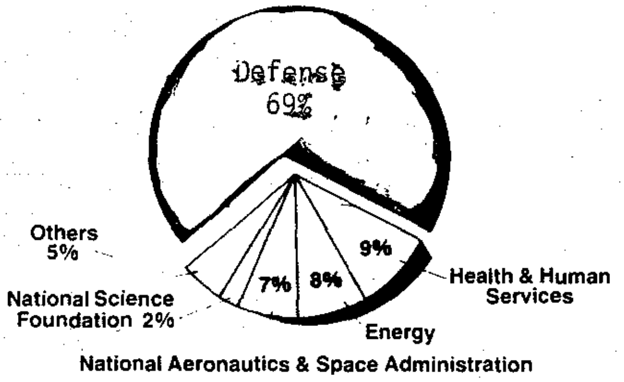
ABSTRACTS OF PAPERS IN *CHEMICAL ABSTRACTS:* Biochemistry's share holds steady at 40%

	1986	1985	1984	1983	1982	1981	1976	Percentage point change, 1976–86
BIOCHEMISTRY	40.4%	40.5%	40.5%	38.3%	39.5%	39.0%	38.8%	1.6%
	% of all biochemistry abstracts							
Mammalian hormones[a]	12.5%	12.3%	12.4%	12.9%	12.2%	6.8%	5.9%	6.6%
Pharmacology	12.2	12.3	11.6	11.8	12.0	12.4	12.0	0.2
Mammalian biochemistry[a]	10.8	11.1	11.3	11.1	11.6	15.6	16.3	−5.5
Toxicology	7.8	7.9	8.0	8.5	8.1	8.7	6.4	1.4
Immunochemistry	6.1	5.3	4.8	4.2	4.4	3.4	—	—
Biochemical genetics[b]	6.1	5.2	4.2	3.8	3.3	—	—	—
Microbial biochemistry[a]	5.7	5.7	5.2	5.1	5.3	5.6	5.0	0.7
Enzymes	5.6	5.6	5.8	6.1	5.9	5.9	6.4	−0.8
Plant biochemistry[a]	5.2	5.5	6.2	5.9	6.2	5.8	6.1	−0.9
Biochemical methods	5.0	4.9	4.9	4.9	4.6	5.7	—	—
General biochemistry	4.7	4.9	5.3	5.8	6.0	7.5	7.1	−2.4
Others	18.3	19.3	20.3	19.9	20.4	22.6	34.8	—
PHYSICAL, INORGANIC, AND ANALYTICAL CHEMISTRY	29.8	29.8	28.8	29.6	28.5	28.0	27.5	2.3
	% of all physical, inorganic, and analytical chemistry abstracts							
Spectra	20.0	18.4	18.0	17.6	17.2	18.0	17.8	2.2
Nuclear chemistry	19.9	21.8	22.2	22.5	22.6	21.6	19.7	0.2
Electric phenomena	10.8	10.8	10.8	10.0	10.5	11.0	10.5	0.3
Crystallography and liquid crystals	7.0	7.5	7.8	8.3	8.7	8.9	9.7	−2.7
General physical chemistry	7.0	6.9	6.9	7.3	7.3	7.2	7.0	0.0
Analytical chemistry	6.8	6.1	6.3	6.2	5.4	5.8	6.6	0.2
Others	28.5	28.5	28.0	28.1	28.3	27.5	28.7	−0.2
APPLIED CHEMISTRY AND CHEMICAL ENGINEERING	18.2	18.4	17.6	19.4	19.5	19.1	18.8	−0.6
	% of all applied chemistry and chemical engineering abstracts							
Water, wastes, and pollution	21.9	20.2	21.0	19.6	21.7	24.0	18.6	3.3
Metals and alloys	20.8	20.0	18.9	19.1	22.2	17.9	27.8	−7.0
Mineralogical and geological chemistry	12.0	12.5	14.6	14.1	13.6	14.1	17.6	−5.6
Fossil fuels, derivatives, and related products	9.0	10.1	10.1	10.3	9.4	9.4	6.0	3.0
Unit operations and processes	7.1	7.5	7.0	7.5	6.9	6.4	4.8	2.3
Others	29.2	29.7	28.4	29.4	26.2	28.2	25.2	4.0
ORGANIC CHEMISTRY	5.9	6.4	7.6	7.3	7.2	8.7	8.7	−2.8
	% of all organic chemistry abstracts							
Physical organic chemistry	27.3	30.6	32.0	30.5	31.5	37.0	38.4	−11.1
Organometallic and organometalloidal compounds	18.3	16.2	17.1	16.3	14.8	8.3	8.7	9.6
Heterocyclic compounds[a]	15.0	16.1	15.6	16.2	15.6	18.2	17.4	−2.4
Carbohydrates	7.8	5.7	5.7	5.8	5.8	5.4	5.1	2.7
Aromatic compounds[a]	7.3	6.3	6.3	7.1	7.2	8.7	8.0	−0.7
Biomolecules and their synthetic analogs[b]	5.0	4.9	4.4	4.5	3.7	—	—	—
Aliphatic compounds[a]	4.4	4.2	3.6	4.3	5.2	6.6	6.5	−2.1
Amino acids, peptides, and proteins[a]	3.9	4.6	4.8	4.5	4.4	4.2	4.3	−0.4
Others	11.0	11.4	10.5	10.8	11.8	11.6	11.6	—
MACROMOLECULAR CHEMISTRY	5.7	4.9	5.5	5.4	5.3	5.2	6.2	−0.5
	% of all macromolecular chemistry abstracts							
Synthetic high polymers	34.1	34.1	34.0	34.4	34.7	30.3	28.3	5.8
Plastics manufacture and uses	23.8	25.3	24.2	24.4	21.9	26.4	26.8	−3.0
Cellulose, lignin, paper, and other wood products	9.8	9.1	9.6	9.1	9.7	10.1	9.1	0.7
Textiles	8.8	8.2	7.3	7.9	8.9	9.9	11.1	−2.3
Coatings, inks, and related products	7.2	7.2	7.8	6.6	7.6	7.5	7.6	−0.4
Synthetic elastomers and natural rubber	6.7	6.8	7.3	7.5	7.8	7.9	8.6	−1.9
Others	9.6	9.3	9.8	10.1	9.4	7.9	8.5	1.1

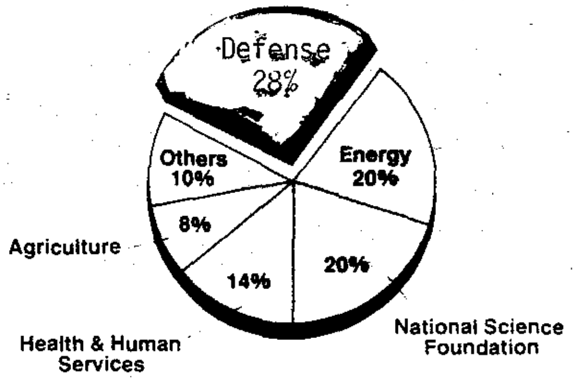
How to read this table: Using biochemistry as an example, 40.4% of all the papers abstracted by Chemical Abstracts Service in 1986 are in the various subdisciplines of biochemistry; 12.5% of all abstracts in biochemistry, in turn, are in the subdiscipline of mammalian hormones, 12.2% of biochemistry abstracts are in pharmacology, and so on. a Definition of section changed in 1982. b New section in 1982. **Source:** Chemical Abstracts Service

Defense's share of federal support grows

Defense gets nearly 70% of federal R&D funding but less than a third of funds for chemistry



Estimated fiscal 1987 total federal R&D obligations = $59.2 billion



Estimated fiscal 1987 federal chemistry research obligations = $671 million

Source: National Science Foundation

FEDERAL OBLIGATIONS FOR R&D: **Up strongly thanks to big boost for military funds**

$ Millions	1987[a]	1986[a]	1985	1984	1983	1982	Annual change 1986–87	Annual change 1982–87
Defense	**$40,678.8**	**$33,646.3**	**$29,791.5**	**$25,372.9**	**$22,992.8**	**$20,622.6**	**21%**	**15%**
Air Force	17,356.5	13,757.5	13,260.9	12,091.6	10,812.6	9,357.9	26	13
Navy	10,700.8	10,137.3	9,127.4	7,605.6	6,068.2	5,845.1	6	13
Army	5,710.2	4,850.2	4,570.8	4,225.5	3,998.1	3,760.5	18	9
Defense agencies[b]	6,775.3	4,790.7	2,781.7	1,391.5	2,052.3	1,618.1	41	33
Health & Human Services	**5,270.8**	**5,611.3**	**5,451.0**	**4,830.7**	**4,352.5**	**3,940.7**	**−6**	**6**
National Institutes of Health	4,672.3	4,977.3	4,827.7[a]	4,257.4	3,789.2	3,433.1	−6	3
Alcohol, Drug Abuse & Mental Health Administration	383.1	396.2	377.6	337.2	302.2	248.1	−3	9
Energy	**4,770.7**	**4,691.6**	**4,996.0**	**4,673.6**	**4,536.7**	**4,708.2**	**2**	**0**
National Aeronautics & Space Administration	**3,926.0**	**3,478.4**	**3,327.2**	**2,821.9**	**2,661.6**	**3,077.9**	**13**	**5**
National Science Foundation	**1,508.3**	**1,333.5**	**1,345.6**	**1,202.8**	**1,062.0**	**975.3**	**13**	**9**
Agriculture	**909.2**	**923.0**	**943.0**	**866.2**	**847.6**	**797.3**	**−1**	**3**
Agricultural Research Service	497.0	463.1	469.7	451.3	443.4	404.9	7	4
Cooperative State Research Service	234.4	263.1	284.3	235.7	232.3	219.0	−11	1
Forest Service	111.5	120.1	113.1	108.4	107.7	112.1	−7	0
Interior	**350.6**	**388.3**	**391.7**	**410.9**	**382.5**	**381.1**	**−10**	**−2**
Geological Survey	207.6	218.6	214.9	208.9	157.0	152.6	−5	6
Environmental Protection Agency	**309.6**	**333.6**	**320.4**	**261.2**	**240.7**	**335.1**	**−7**	**−2**
Commerce	**300.9**	**391.1**	**398.8**	**358.2**	**335.0**	**336.3**	**−23**	**−2**
National Oceanic & Atmospheric Administration	196.3	268.1	269.8	244.3	222.0	222.0	−27	−2
National Bureau of Standards	91.4	99.3	100.5	95.5	95.0	88.8	−8	1
Others	**1,184.7**	**1,264.7**	**1,367.1**	**1,426.5**	**1,300.1**	**1,258.1**	**−6**	**−1**
TOTAL	**$59,209.6**	**$52,061.8**	**$48,332.3**	**$42,224.9**	**$38,711.5**	**$36,432.6**	**14%**	**10%**
ANNUAL CHANGE	**14%**	**8%**	**14%**	**9%**	**6%**	**4%**		

Note: Fiscal years. a Estimated. b Includes Defense Advanced Research Projects Agency, Defense Nuclear Agency, and others. **Source:** National Science Foundation

PERFORMERS OF FEDERALLY FUNDED RESEARCH: 54% is undertaken by industry

$ Millions	1987ᵃ	1986ᵃ	1985	1984	1983	1982	Annual change 1986–87	Annual change 1982–87
Industry	$31,787.9	$26,847.9	$23,774.3	$20,361.5	$18,649.0	$18,698.6	18%	11%
Federal intramural programs	15,396.7	13,533.4	12,998.4	11,572.3	10,581.9	9,141.0	14	11
Universities and colleges	6,558.7	6,554.7	6,299.0	5,565.1	4,966.4	4,605.5	0	7
University-associated FFRDCs[b]	2,712.8	2,446.2	2,534.5	2,324.9	2,265.8	1,976.7	11	7
Nonprofit institutions	2,451.3	2,318.1	2,365.0	2,094.4	1,822.9	1,612.3	6	9
Foreign	219.8	257.8	255.9	175.8	239.5	214.3	−15	1
State and local governments	82.4	103.6	105.2	130.9	186.0	184.3	−20	−15
TOTAL	**$59,209.6**	**$52,061.8**	**$48,332.3**	**$42,224.9**	**$38,711.5**	**$36,432.6**	**14%**	**10%**

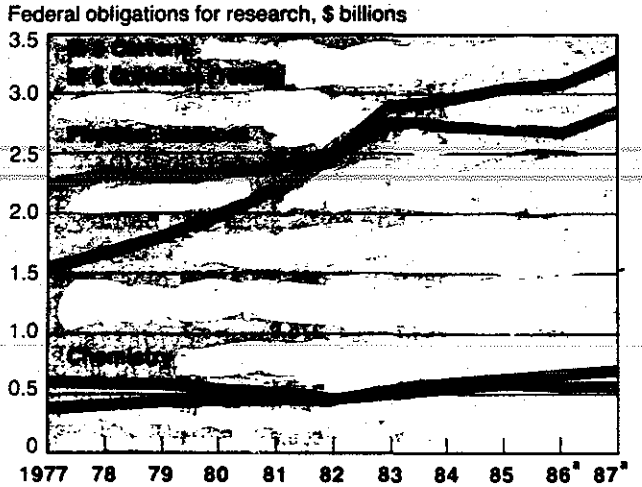
Note: Fiscal years. a Estimated. b Federally funded R&D centers. Those administered by both industry and by nonprofit institutions are included in totals for their respective sectors. **Source:** National Science Foundation

FEDERAL OBLIGATIONS FOR SCIENTIFIC DISCIPLINES: Slow growth for chemistry this year

$ Millions for research only	1987ᵃ	1986ᵃ	1985	1984	1983	1982	Annual change 1986–87	Annual change 1982–1987
Life sciences	**$ 6,289.2**	**$ 6,457.6**	**$ 6,368.2**	**$ 5,635.9**	**$ 5,177.9**	**$ 4,745.5**	**−3%**	**6%**
Engineering	**3,857.8**	**3,684.4**	**3,628.5**	**3,624.1**	**3,517.0**	**3,386.5**	**5**	**3**
Chemical	186.0	243.5	254.1	144.5	145.0	95.1	−24	14
Metallurgy and materials	465.5	464.1	439.1	341.1	332.5	309.1	0	9
Physical sciences	**3,300.3**	**3,071.8**	**3,044.0**	**2,969.0**	**2,891.4**	**2,500.4**	**7**	**6**
Chemistry	670.9	653.4	644.5	606.4	520.3	481.2	3	7
Physics	1,965.4	1,829.4	1,820.0	1,836.4	1,854.6	1,610.5	7	4
Environmental sciences	**1,483.4**	**1,458.2**	**1,403.6**	**1,275.9**	**1,251.2**	**1,148.3**	**2**	**5**
Mathematics and computer sciences	**759.0**	**665.0**	**577.5**	**440.3**	**419.4**	**350.1**	**14**	**17**
Other sciences	**1,151.4**	**1,117.7**	**1,110.3**	**1,033.6**	**996.6**	**891.4**	**3**	**5**
TOTAL	**$16,841.1**	**$16,454.7**	**$16,130.1**	**$14,978.8**	**$14,253.5**	**$13,022.2**	**2%**	**5%**
ANNUAL CHANGE	**2%**	**2%**	**8%**	**5%**	**9%**	**7%**		

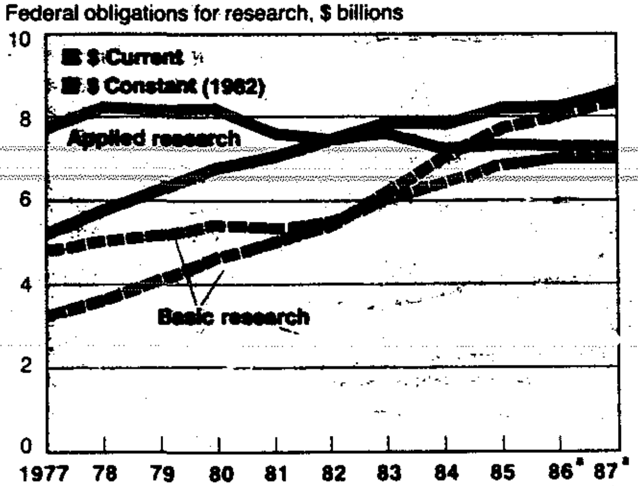
a Estimated. **Source:** National Science Foundation

Federal support for physical science little changed since 1983 in real dollars



Note: Fiscal years. a Estimated. **Source:** National Science Foundation

Government funding of basic research catching up with applied research support



Note: Fiscal years. a Estimated. **Source:** National Science Foundation

FEDERAL OBLIGATIONS FOR BASIC RESEARCH: **Little growth this year**

$ Millions	1987ᵃ	1986ᵃ	1985	1984	1983	1982	Annual change 1986–87	Annual change 1982–1987
Health & Human Services	**$3162.4**	**$3357.1**	**$3232.5**	**$2814.5**	**$2475.4**	**$2144.7**	**−6%**	**8%**
National Institutes of Health	2938.3	3133.6	3018.0ᵃ	2624.8	2313.0	2020.7	−6	8
Alcohol, Drug Abuse & Mental Health Administration	204.4	206.2	196.8	170.8	145.0	117.3	−1	12
National Science Foundation	**1422.6**	**1255.7**	**1261.8**	**1132.3**	**999.1**	**916.1**	**13**	**9**
Energy	**1063.1**	**945.9**	**942.6**	**830.4**	**767.7**	**642.2**	**12**	**11**
Defense	**995.9**	**994.3**	**861.4**	**847.9**	**785.6**	**686.7**	**0**	**8**
Navy	385.6	350.5	343.1	315.8	305.4	280.3	10	7
Air Force	284.5	234.4	198.3	192.4	164.2	145.8	21	14
Army	249.3	242.4	240.8	222.1	208.3	187.7	3	6
Defense agenciesᵇ	76.5	167.0	79.2	117.6	107.7	72.9	−54	1
National Aeronautics & Space Administration	**986.1**	**850.4**	**750.9**	**754.5**	**617.0**	**535.7**	**16**	**13**
Agriculture	**434.1**	**432.7**	**445.4**	**392.6**	**362.0**	**330.8**	**0**	**6**
Agricultural Research Service	267.2	247.6	250.2	240.6	215.3	192.9	8	7
Cooperative State Research Service	115.8	126.2	141.5	99.6	98.8	91.3	−8	5
Forest Service	43.1	50.5	44.1	41.2	38.8	38.7	−15	2
Interior	**115.7**	**137.6**	**138.3**	**125.9**	**103.0**	**76.5**	**−16**	**9**
Geological Survey	79.5	83.4	80.5	78.9	64.7	52.6	−3	9
Environmental Protection Agency	**37.0**	**39.3**	**38.6**	**29.6**	**22.2**	**32.7**	**−6**	**3**
Commerce	**19.5**	**22.1**	**23.2**	**20.6**	**19.2**	**16.9**	**−12**	**3**
National Bureau of Standards	19.1	21.2	22.1	20.2	18.4	16.5	−10	3
National Oceanic & Atmospheric Administration	0	0	0	0	0	0	—	—
Others	**111.3**	**110.0**	**124.0**	**119.1**	**108.9**	**99.3**	**1**	**2**
TOTAL	**$8347.7**	**$8145.1**	**$7818.7**	**$7067.4**	**$6260.1**	**$5481.6**	**2%**	**9%**
ANNUAL CHANGE	**2%**	**4%**	**11%**	**13%**	**14%**	**9%**		

Note: Fiscal years. a Estimated. b Includes Defense Advanced Projects Agency, Defense Nuclear Agency, and others. **Source:** National Science Foundation

FEDERAL OBLIGATIONS FOR APPLIED RESEARCH: **Increases for Defense, NASA, and NSF**

$ Millions	1987ᵃ	1986ᵃ	1985	1984	1983	1982	Annual change 1986–87	Annual change 1982–1987
Defense	**$2636.1**	**$2384.8**	**$2306.9**	**$2200.7**	**$2437.0**	**$2266.1**	**11%**	**3%**
Army	719.4	551.3	582.6	486.7	485.3	451.6	30	10
Air Force	562.2	573.4	538.4	547.7	524.2	488.1	−2	3
Navy	464.6	463.9	448.2	449.6	521.6	498.4	0	−1
Defense agenciesᵇ	889.9	776.2	737.7	716.6	905.9	828.1	15	1
Health & Human Services	**1724.0**	**1834.0**	**1795.8**	**1651.5**	**1545.4**	**1480.9**	**−6**	**3**
National Institutes of Health	1368.2	1452.8	1410.1ᵃ	1285.6	1165.2	1103.8	−6	4
Alcohol, Drug Abuse & Mental Health Administration	177.5	188.8	179.7	165.2	155.4	128.7	−6	7
National Aeronautics & Space Administration	**1396.5**	**1114.4**	**1032.7**	**954.7**	**927.8**	**871.4**	**25**	**10**
Energy	**913.3**	**1080.4**	**1198.4**	**1194.5**	**1193.4**	**1053.9**	**−15**	**−3**
Agriculture	**444.0**	**458.8**	**465.6**	**442.2**	**455.5**	**435.7**	**−3**	**0**
Agricultural Research Service	202.4	188.1	191.8	183.7	202.6	186.2	8	2
Cooperative State Research Service	118.7	136.9	142.8	136.2	133.5	127.7	−13	−1
Forest Service	65.4	66.7	65.7	63.9	65.1	69.0	−2	−1
Commerce	**236.7**	**304.4**	**301.0**	**276.1**	**266.6**	**260.2**	**−22**	**−2**
National Oceanic & Atmospheric Administration	163.6	229.7	224.4	197.7	166.9	188.5	−29	−3
National Bureau of Standards	63.5	65.6	64.5	63.5	63.1	57.4	−3	2
Interior	**210.9**	**227.5**	**231.0**	**254.3**	**264.7**	**275.0**	**−7**	**−5**
Geological Survey	118.2	127.8	130.0	125.1	89.9	99.4	2	6
Environmental Protection Agency	**170.9**	**180.4**	**176.0**	**142.3**	**152.4**	**210.7**	**−6**	**−4**
National Science Foundation	**85.7**	**77.8**	**63.8**	**70.5**	**62.9**	**57.1**	**10**	**8**
Others	**676.2**	**667.0**	**720.3**	**724.6**	**666.7**	**650.6**	**1**	**1**
TOTAL	**$8483.4**	**$8300.5**	**$8311.5**	**$7911.4**	**$7983.4**	**$7540.6**	**2%**	**2%**
ANNUAL CHANGE	**2%**	**0%**	**5%**	**−1%**	**6%**	**5%**		

Note: Fiscal years. a Estimated. b Includes Defense Advanced Research Projects Agency, Defense Nuclear Agency, and others. **Source:** National Science Foundation

CIRCLE 31 ON READER SERVICE CARD →

FEDERAL OBLIGATIONS FOR DEVELOPMENT: **Nearly 90% goes for military work**

$ Millions	1987[a]	1986[a]	1985	1984	1983	1982	Annual change 1986–87	Annual change 1982–87
Defense	$37,046.8	$30,287.2	$26,623.2	$22,324.3	$19,770.1	$17,669.8	22%	16%
Air Force	16,509.8	12,949.7	12,524.3	11,351.5	10,124.2	8,724.0	27	14
Navy	9,850.6	9,322.9	8,336.1	6,840.2	5,241.2	5,066.4	6	14
Army	4,741.6	4,056.6	3,747.4	3,516.8	3,304.5	3,121.3	17	9
Defense agencies[b]	5,808.9	3,847.5	1,964.8	557.3	1,038.7	717.1	51	52
Energy	2,794.4	2,665.3	2,825.0	2,648.7	2,575.6	3,012.1	5	−1
National Aeronautics & Space Administration	1,543.4	1,513.6	1,543.6	1,112.7	1,116.8	1,670.7	2	−2
Health & Human Services	384.3	420.2	422.7	364.7	331.7	335.2	−9	3
National Institutes of Health	365.8	390.9	399.6[a]	347.0	311.0	308.7	−6	3
Alcohol, Drug Abuse & Mental Health Administration	1.2	1.2	1.1	1.2	1.8	2.1	0	−11
Environmental Protection Agency	102.6	113.9	105.8	89.2	66.1	91.7	−10	2
Commerce	44.7	64.6	74.6	61.5	50.2	60.2	−31	−6
National Oceanic & Atmospheric Administration	32.5	38.4	45.4	46.6	33.1	33.5	−15	−1
National Bureau of Standards	8.8	12.5	14.0	11.8	13.6	14.9	−30	−10
Agriculture	31.1	31.5	32.0	31.3	30.0	30.8	−1	0
Agricultural Research Service	27.4	27.4	27.7	27.0	25.5	25.8	0	1
Forest Service	3.0	2.9	3.3	3.3	3.8	4.5	3	−8
Cooperative State Research Service	0	0	0	0	0	0	—	—
Interior	24.0	23.2	22.4	30.7	24.8	29.6	3	−4
Geological Survey	9.9	7.4	4.4	4.9	2.3	0.5	34	82
National Science Foundation	0	0	0	0	0	2.2	—	—
Others	397.2	487.6	552.6	583.0	492.7	508.1	−19	−5
TOTAL	$42,368.5	$35,607.1	$32,202.1	$27,246.1	$24,458.0	$23,410.4	19%	13%
ANNUAL CHANGE	19%	11%	18%	11%	4%	3%		

Note: Fiscal years. a Estimated. b Includes Defense Advanced Research Projects Agency, Defense Nuclear Agency, and others. **Source:** National Science Foundation

UNIVERSITY RESEARCH: **Not much change in funding overall, but chemistry gets more**

Federal obligations, $ millions	1987[a]	1986[a]	1985	1984	1983	1982	Annual change 1986–87	Annual change 1982–87
Life sciences	$3124.8	$3288.8	$3192.2	$2800.2	$2460.0	$2205.0	−5%	7%
Physical sciences	816.9	757.2	749.7	697.8	596.5	559.1	8	8
Chemistry	287.0	259.7	266.8	242.3	205.7	189.6	11	9
Physics	429.8	406.5	401.8	375.2	328.8	306.0	6	7
Engineering	577.8	559.0	507.1	474.2	408.7	361.5	3	10
Chemical	43.7	48.8	45.6	51.2	23.6	19.4	−10	18
Metallurgy and materials	121.1	125.9	107.2	87.7	86.0	75.3	−4	10
Environmental sciences	410.2	380.2	361.1	319.5	316.9	274.7	8	8
Mathematics and computer sciences	338.3	302.8	253.1	181.6	172.4	139.7	12	19
Other sciences	360.6	367.4	347.8	304.1	297.8	255.7	−2	7
TOTAL	$5628.6	$5655.4	$5411.0	$4777.4	$4252.3	$3795.7	0%	8%
ANNUAL CHANGE	0%	5%	13%	12%	12%	2%		

Note: Fiscal years. a Estimated. **Source:** National Science Foundation

UNIVERSITY BASIC RESEARCH: **More than half goes for life sciences**

Federal obligations, $ millions	1987[a]	1986[a]	1985	1984	1983	1982	Annual change 1986–87	Annual change 1982–87
Life sciences	$2267.5	$2379.2	$2306.8	$1979.6	$1701.7	$1483.7	−5%	9%
Physical sciences	714.1	646.7	628.8	581.9	502.2	455.3	10	9
Chemistry	259.3	227.9	234.9	212.1	181.9	165.3	14	9
Physics	362.3	332.8	317.0	293.9	264.7	238.6	9	9
Engineering	448.0	419.7	366.6	340.3	295.5	259.0	7	12
Chemical	33.7	29.9	27.6	29.6	18.9	16.8	13	15
Metallurgy and materials	108.7	116.3	95.8	79.9	76.8	69.6	−7	9
Environmental sciences	380.4	350.2	330.7	288.9	284.3	256.0	9	8
Mathematics and computer sciences	202.1	202.0	172.1	152.6	146.8	118.8	0	11
Other sciences	202.2	187.8	169.0	147.4	147.2	120.5	8	11
TOTAL	$4214.3	$4186.5	$3974.0	$3490.7	$3077.7	$2693.3	1%	9%
ANNUAL CHANGE	1%	5%	14%	13%	14%	9%		

Note: Fiscal years. a Estimated. **Source:** National Science Foundation

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BASIC RESEARCH IN PHYSICAL SCIENCE: **NSF, Defense score biggest gains for chemistry**

Federal obligations, $ millions	1987[a] Physical sciences	1987[a] Chemistry	1986[a] Physical sciences	1986[a] Chemistry	1985 Physical sciences	1985 Chemistry	1984 Physical sciences	1984 Chemistry	1983 Physical sciences	1983 Chemistry
Energy	$ 852.5	$112.1	$ 743.1	$108.5	$ 736.1	$102.3	$ 688.4	$108.4	$ 639.2	$104.3
National Aeronautics & Space Administration	535.6	7.8	437.7	5.1	377.9	10.2	338.7	5.4	329.5	7.7
National Science Foundation	380.7	128.9	340.6	109.9	347.9	112.7	330.2	106.8	283.5	88.5
Defense	213.2	82.1	212.7	73.9	185.5	70.1	212.2	60.0	198.4	55.6
Navy	87.5	30.3	84.8	26.1	73.9	26.7	100.4	20.7	98.0	18.7
Air Force	77.6	32.7	63.9	27.0	54.1	22.8	48.3	20.3	39.3	17.5
Army	46.2	19.0	51.7	20.8	54.3	20.6	59.8	19.1	58.7	19.4
Defense agencies[b]	1.8	0	12.3	0	3.2	0	3.7	0	2.5	0
Health & Human Services	81.4	73.4	86.8	78.3	83.6	75.4	72.0	65.0	61.8	55.0
National Institutes of Health	79.3	71.4	84.6	76.1	81.5[a]	73.3[a]	70.8	63.8	60.9	54.2
Alcohol, Drug Abuse & Mental Health Administration	2.1	2.0	2.2	2.1	2.1	2.1	1.2	1.2	0.9	0.9
Agriculture	33.5	33.3	35.6	33.5	35.6	33.6	45.4	43.5	40.0	38.2
Agricultural Research Service	26.9	25.5	25.0	23.7	25.2	23.9	37.4	36.0	33.5	32.2
Cooperative State Research Service	4.6	4.6	6.1	6.1	6.4	6.4	5.4	5.4	4.1	4.1
Forest Service	3.9	3.2	4.6	3.7	4.0	3.3	2.6	2.1	2.4	1.9
Commerce	15.9	5.2	18.1	8.7	19.7	7.2	16.3	4.8	15.7	4.7
National Bureau of Standards	15.9	5.2	17.6	6.3	18.9	6.4	16.3	4.8	15.7	4.6
Interior	7.0	5.5	7.9	6.3	7.6	6.0	7.1	5.6	2.9	1.8
Geological Survey	7.0	5.5	7.9	6.3	7.6	6.0	7.1	5.6	2.6	1.8
Environmental Protection Agency	3.4	2.9	3.6	3.1	3.5	3.0	3.0	3.0	2.3	1.9
Others	17.8	0.4	15.6	0.2	16.6	0.3	14.7	0.9	13.5	3.5
TOTAL	$2141.0	$451.3	$1901.7	$425.4	$1814.0	$420.8	$1728.0	$403.4	$1587.2	$362.2
ANNUAL CHANGE	13%	6%	5%	1%	5%	4%	9%	11%	14%	16%

Note: Fiscal years. a Estimated. b Includes Defense Advanced Research Projects Agency, Defense Nuclear Agency, and others. **Source:** National Science Foundation

ENGINEERING RESEARCH: **Support for chemical engineering drops sharply this year but is still twice th**

$ Millions	1987[a] Engineering	1987[a] Chemical engineering	1987[a] Metallurgy & materials	1986[a] Engineering	1986[a] Chemical engineering	1986[a] Metallurgy & materials	1985 Engineering	1985 Chemical engineering
Defense	$1624.9	$ 54.5	$281.1	$1523.9	$ 50.3	$277.9	$1502.0	$ 53.3
Air Force	488.1	3.2	36.9	472.7	3.3	34.3	423.9	1.7
Army	434.9	23.5	41.3	336.1	20.9	37.7	344.3	26.7
Navy	409.9	27.8	120.1	408.5	26.1	121.1	421.2	24.8
Defense agencies[b]	292.1	0	82.8	306.6	0	84.8	312.6	0.1
National Aeronautics & Space Administration	1270.0	0.9	23.4	1021.6	0.8	17.7	931.6	0.6
Energy	322.0	58.8	73.6	463.6	126.2	68.7	511.3	136.6
National Science Foundation	231.3	41.2	47.6	196.6	34.4	42.1	193.3	32.6
Interior	68.6	4.4	25.4	94.9	4.9	40.9	106.2	4.6
Transportation	44.1	0.4	1.0	53.9	0.7	2.5	49.4	0.6
Environmental Protection Agency	43.7	17.5	2.5	46.6	18.1	2.7	44.8	18.0
Commerce	38.0	2.3	10.5	43.7	1.9	11.2	38.8	1.7
Agriculture	28.9	5.8	0	29.1	5.8	0	28.7	5.6
Others	186.3	0.3	0.5	212.5	0.4	0.4	227.4	0.4
TOTAL	$3857.8	$186.0	$465.5	$3686.4	$243.5	$464.1	$3628.5	$254.1
ANNUAL CHANGE	5%	−24%	0%	2%	−4%	6%	6%	76%

Note: Fiscal years. a Estimated. b Includes Defense Advanced Projects Agency, Defense Nuclear Agency, and others. **Source:** National Science Foundation

APPLIED RESEARCH IN PHYSICAL SCIENCE: **Chemical funding down slightly this year**

$ Millions[b]	1987[a]		1986[a]		1985		1984		1983	
	Physical sciences	Chemistry	Physical sciences	Chemistry	Physical sciences	Chemistry	Physical sciences	Chemistry	Physical sciences	Chemistry
Energy	$ 511.6	$ 24.9	$ 538.7	$ 37.3	$ 606.1	$ 40.6	$ 603.5	$ 32.0	$ 584.8	$ 13.3
Defense	434.8	102.7	415.1	93.4	412.0	86.3	477.2	79.8	562.0	66.3
Army	129.7	71.0	116.4	62.1	124.2	57.5	77.4	47.2	86.9	39.9
Air Force	59.0	17.0	60.2	17.3	57.5	16.7	58.6	16.4	54.5	13.7
Navy	55.6	13.9	53.9	13.4	50.7	11.6	69.2	15.9	135.2	12.3
Defense agencies[c]	190.5	0.8	184.6	0.6	179.6	0.4	272.1	0.3	285.4	0.3
National Aeronautics & Space Administration	81.9	6.0	79.9	6.0	76.3	6.1	25.6	1.9	40.4	1.7
Commerce	34.0	9.8	35.1	10.4	35.2	10.5	36.9	10.5	33.9	9.3
National Bureau of Standards	25.1	8.5	25.0	8.4	25.3	9.0	28.1	9.3	26.7	8.1
National Oceanic & Atmospheric Administration	8.9	1.3	10.1	2.0	9.9	1.4	8.9	1.3	7.2	1.2
Health & Human Services	26.5	23.0	28.4	24.6	27.3	23.6	24.7	21.3	22.6	19.2
National Institutes of Health	24.6	21.1	26.1	22.4	25.4[a]	21.8[a]	23.6	20.3	21.5	18.1
Alcohol, Drug Abuse & Mental Health Administration	1.9	1.9	2.3	2.2	1.9	1.9	1.1	1.1	1.2	1.1
Agriculture	24.2	22.2	25.8	23.8	26.4	24.4	27.3	25.5	27.6	25.6
Agricultural Research Service	13.9	12.9	12.9	12.0	13.1	12.2	16.9	15.6	18.6	17.2
Cooperative State Research Service	6.8	6.8	9.3	9.3	9.7	9.7	8.1	8.1	6.7	6.7
Forest Service	3.5	2.4	3.6	2.5	3.5	2.4	2.4	1.8	2.3	1.7
Environmental Protection Agency	15.4	14.1	16.1	14.9	15.7	14.5	13.8	12.9	13.9	12.8
Interior	14.5	12.5	16.2	13.9	15.5	13.3	15.7	13.6	5.5	4.4
Geological Survey	14.5	12.5	16.2	13.9	15.5	13.3	14.9	12.8	4.7	3.8
National Science Foundation	12.5	3.1	11.3	2.7	11.8	2.9	10.9	3.1	9.4	3.9
Others	3.9	1.3	3.3	1.0	3.8	1.4	5.4	2.4	4.2	1.6
TOTAL	$1159.3	$219.6	$1170.0	$228.0	$1230.1	$223.6	$1241.0	$203.0	$1304.3	$158.1
ANNUAL CHANGE	−1%	−4%	−5%	2%	−1%	10%	−5%	28%	1%	−7%

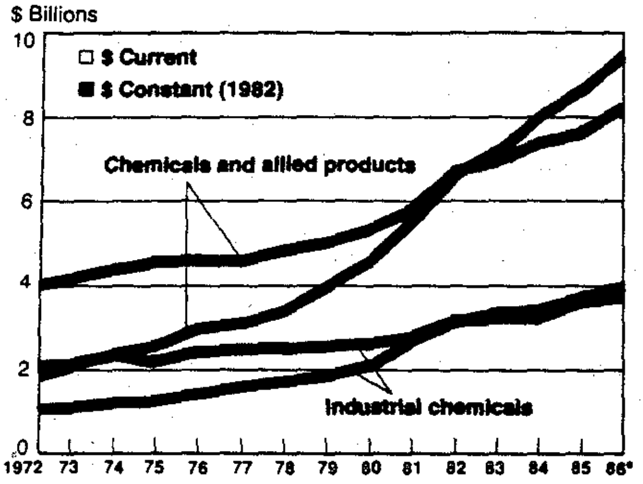
Note: Fiscal years. a Estimated. b Obligations. c Includes Defense Advanced Research Projects Agency, Defense Nuclear Agency, and others. **Source:** National Science Foundation

the level of five years ago

1985	1984			1983			1982		
Metallurgy & materials	Engineering	Chemical engineering	Metallurgy & materials	Engineering	Chemical engineering	Metallurgy & materials	Engineering	Chemical engineering	Metallurgy & materials
$260.9	$1488.4	$ 38.4	$180.3	$1573.9	$ 44.9	$179.3	$1473.3	$39.0	$159.3
28.6	439.5	3.5	30.3	419.3	3.1	38.2	387.3	2.9	35.1
42.2	324.8	23.5	35.5	318.9	29.3	28.4	297.2	24.4	31.7
121.1	398.4	11.3	53.9	395.5	11.9	50.0	378.0	11.6	49.3
69.0	325.7	0.2	60.6	440.2	0.6	62.8	410.8	0.2	43.1
15.8	967.8	0.3	14.2	799.6	1.0	19.1	771.7	0.4	16.2
68.4	439.0	46.1	68.7	440.2	51.9	62.6	420.8	1.1	61.2
42.7	164.9	27.7	27.3	142.5	21.5	27.3	128.9	18.8	26.4
39.8	111.4	4.5	42.2	91.4	0.4	31.5	87.1	1.4	32.8
1.5	51.1	1.2	1.9	56.1	1.0	1.4	48.3	0.5	1.0
2.6	37.8	17.8	0	47.8	16.7	3.5	76.4	26.0	5.2
6.9	35.3	1.8	6.4	37.4	1.3	7.8	32.0	2.0	7.1
0	56.7	6.4	0	54.7	6.2	0	51.2	5.8	0
0.5	271.7	0.3	0.1	273.4	0.1	0	296.8	0.1	0
$439.1	$3624.1	$144.5	$341.1	$3517.0	$145.0	$332.5	$3386.5	$96.1	$309.1
29%	3%	0%	3%	4%	53%	8%	10%	36%	21%

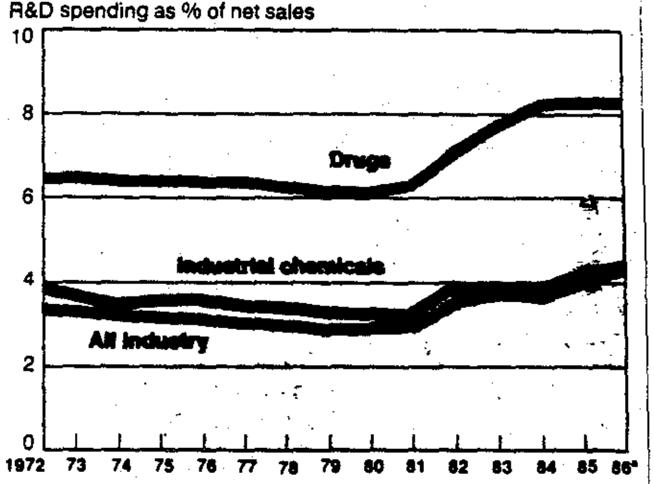
Industrial support for R&D up only 5%

With inflation low, chemical companies' R&D outlays rise smartly in real terms



a C&EN estimates. Source: National Science Foundation

Outlays for industrial R&D are rising at slightly faster rate than industrial sales



a C&EN estimates. Source: National Science Foundation

TOTAL FUNDS FOR INDUSTRIAL R&D: Drug producers continue to set a fast pace

$ Millions	1986a	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976	Annual change 1985–86	Annual change 1976–86
Chemicals and allied products	$ 9,500	$ 8,667	$ 8,028	$ 7,293	$ 6,659	$ 5,625	$ 4,636	$ 4,038	$ 3,580	$ 3,202	$ 3,017	10%	12%
Industrial chemicals	4,150	3,915	3,512	3,411	3,301	2,802	2,197	1,962	1,798	1,668	1,524	6	11
Drugs	4,070	3,548	4,516	3,882	3,358	2,823	1,777	1,517	1,308	1,117	1,091	15	14
Other chemicals	1,280	1,204					662	559	474	417	401	6	12
Other industries	74,900	69,512	63,442	56,110	51,337	46,185	39,869	34,188	29,724	26,623	23,980	8	12
TOTAL	$84,400	$78,179	$71,470	$63,403	$57,996	$51,810	$44,505	$38,226	$33,304	$29,825	$26,997	8%	12%

a C&EN estimates. Source: National Science Foundation

COMPANY FUNDS FOR INDUSTRIAL R&D: Chemical industry spends about a sixth of the total

$ Millions	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976	1975	Annual change 1984–85	Annual change 1975–85
Chemicals and allied products	$ 8,352	$ 7,797	$ 6,845	$ 6,226	$ 5,205	$ 4,264	$ 3,692	$ 3,250	$ 2,907	$ 2,751	$ 2,490	7%	13%
Industrial chemicals	3,618	3,289	2,970	2,879	2,393	1,856	1,617	1,473	1,387	1,275	1,173	10	12
Drugs	3,545	3,381	2,937	2,490	2,064	1,756	2,075	1,777	1,520	1,476	1,317	5	14
Other chemicals	1,189	1,126	938	856	747	653						6	
Other industries	43,344	40,511	36,016	33,286	30,223	26,212	22,016	18,865	16,433	14,685	13,092	7	13
TOTAL	$51,696	$48,308	$42,861	$39,512	$35,428	$30,476	$25,708	$22,115	$19,340	$17,436	$15,582	7%	13%

Source: National Science Foundation

FEDERAL FUNDS FOR INDUSTRIAL R&D: Of little significance for the chemical industry

$ Millions	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976	1975	Annual change 1984–85	Annual change 1975–85
Chemicals and allied products	$ 316	$ 232	$ 448	$ 434	$ 421	$ 372	$ 346	$ 330	$ 295	$ 266	$ 236	36%	3%
Industrial chemicals	298	223	440	423	409	341	345	325	281	249	218	34	3
Drugs and other chemicals	18	9	8	11	12	31	1	5	14	17	18	100	0
Other industries	26,168	22,930	20,094	18,049	15,961	13,657	12,172	10,859	10,190	9295	8369	14	12
TOTAL	$26,484	$23,162	$20,542	$18,483	$16,382	$14,029	$12,518	$11,189	$10,485	$9561	$8605	14%	12%

Source: National Science Foundation

R&D BY U.S. COMPANIES ABROAD: Relatively small but expanding steadily

$ Millions	1986[a]	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976	Annual change 1985–86	Annual change 1976–86
Chemicals and allied products	$ 900	$ 816	$ 793	$ 732	$ 684	$ 715	$ 603	$ 500	$ 395	$ 332	$ 312	10%	11%
Industrial and other chemicals	440	409	363	354	313	287	245	199	151	133	108	8	15
Drugs	460	406	430	378	371	428	357	301	244	199	204	13	8
Other industries	3100	2931	2786	2544	2413	2679	2562	2254	1814	1545	1347	6	9
TOTAL	$4000	$3747	$3579	$3276	$3097	$3393	$3165	$2754	$2209	$1877	$1659	7%	9%

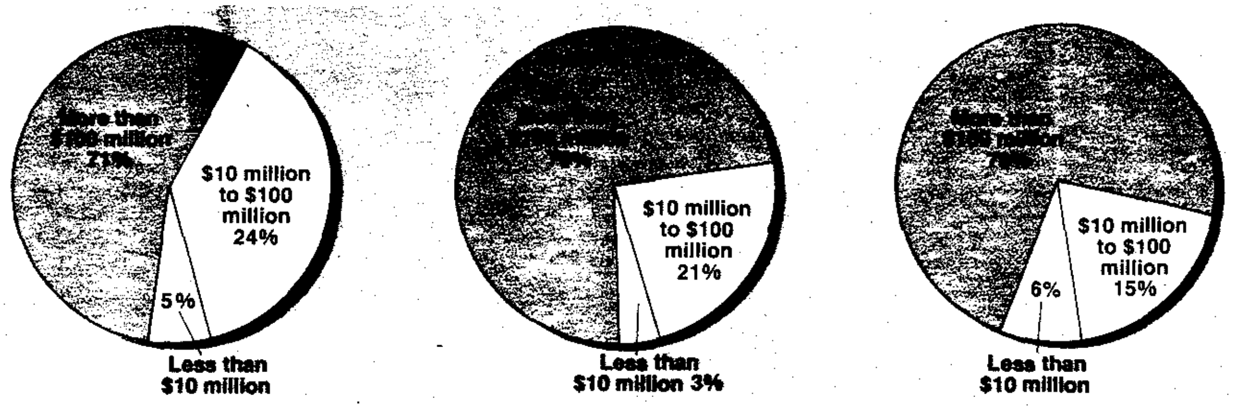
a C&EN estimates. **Source:** National Science Foundation

CHEMICAL R&D SPENDING: Slight rise last year largely reflects Carbide's major divestments

$ Millions	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976	1986 R&D spending as % of sales
Air Products	$ 61	$ 51	$ 44	$ 40	$ 37	$ 32	$ 30	$ 24	$ 23	$ 24	$ 19	3.1%
American Cyanamid	278	251	232	208	185	166	148	130	108	96	83	7.3
Dow Chemical	605	547	507	492	460	404	314	269	232	203	188	5.4
Du Pont[a]	1070	1080	1000	875	775	647	591	509	461	367	353	9.0
Ethyl	47	47	40	39	39	37	34	29	25	28	25	3.0
W. R. Grace	94	92	81	73	64	57	45	42	37	32	28	2.5
Hercules	71	76	72	74	74	65	57	50	43	40	37	2.7
International Flavors	39	34	32	32	31	30	29	27	24	20	16	6.3
Lubrizol	51	44	33	37	36	33	28	23	21	19	17	5.2
Monsanto	596	470	370	290	264	233	208	161	136	132	114	8.7
Nalco Chemical	33	32	32	30	33	30	28	21	17	14	12	4.5
Olin	56	53	52	49	45	38	31	26	25	25	23	3.3
Pennwalt	45	39	36	33	31	27	24	22	23	21	19	4.1
Petrolite	12	12	12	13	10	8	7	6	5	5	4	4.3
PPG Industries	204	176	150	127	127	119	103	83	70	61	56	4.3
Rohm & Haas	133	124	109	100	92	77	67	54	49	45	43	6.4
Union Carbide[b]	148	275	265	245	240	207	166	161	156	156	143	2.4
TOTAL	$3543	$3403	$3067	$2757	$2543	$2210	$1910	$1637	$1455	$1288	$1180	5.7%
ANNUAL CHANGE	4%	11%	11%	8%	15%	16%	17%	13%	13%	9%	8%	

a Figures exclude petroleum and coal segments. b Union Carbide divested a substantial part of its businesses in 1986; on a pro forma basis, R&D spending was $181 million in 1985 and $178 million in 1984. **Source:** Company data

Companies whose annual R&D budgets top $100 million do more than 70% of all R&D



1985 chemicals and allied products R&D funds = $8.7 billion

1985 industrial chemicals R&D funds = $3.9 billion

1985 industry R&D funds = $78.2 billion

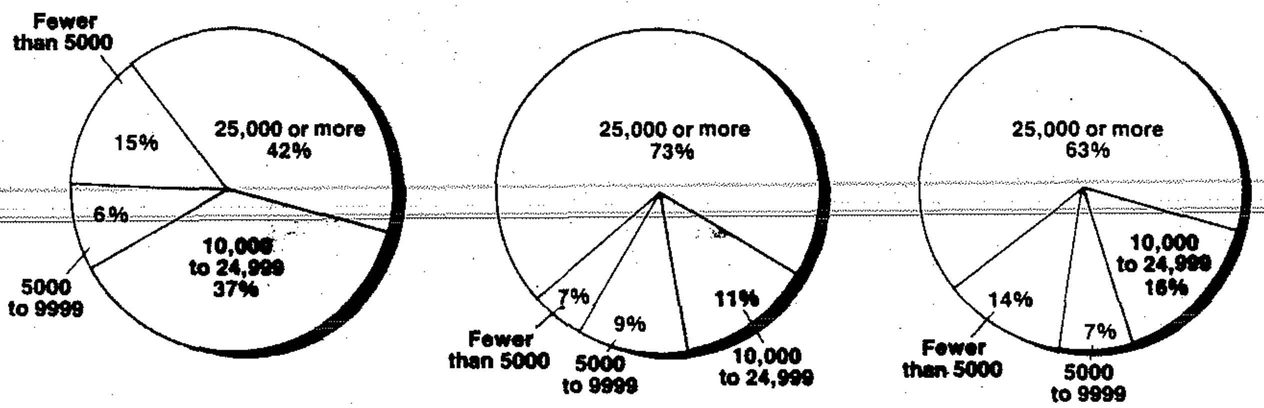
Note: Ranges indicate size of companies' 1985 R&D program. **Source:** National Science Foundation

R&D SCIENTISTS AND ENGINEERS IN INDUSTRY: **Increasing faster for chemicals**

												Annual change	
Thousands[a]	**1986**	**1985**	**1984**	**1983**	**1982**	**1981**	**1980**	**1979**	**1978**	**1977**	**1976**	**1985–86**	**1976–86**
Chemicals and allied products	**71.3**	**67.0**	**67.1**	**66.0**	**61.6**	**54.7**	**51.4**	**50.0**	**48.3**	**46.4**	**44.4**	6%	5%
Industrial chemicals	26.8	25.0	26.7	27.2	25.9	21.6	20.9	21.4	21.3	20.6	20.1	7	3
Drugs	33.3	30.7	30.1	28.2	25.6	23.3	21.6	20.8	19.5	17.8	16.6	8	7
Other chemicals	11.2	11.3	10.3	10.6	10.1	9.8	8.9	7.8	7.5	8.0	7.8	−1	4
Other industries	**509.0**	**493.2**	**477.4**	**456.1**	**448.2**	**433.1**	**399.2**	**373.9**	**356.1**	**336.4**	**320.0**	3	5
TOTAL	**580.3**	**560.2**	**544.5**	**522.1**	**509.8**	**487.8**	**450.6**	**423.9**	**404.4**	**382.8**	**364.4**	4%	5%

Note: Data as of January of each year. a Full-time equivalent. **Source:** National Science Foundation

Chemical companies with 10,000 to 25,000 employees perform more than a third of R&D



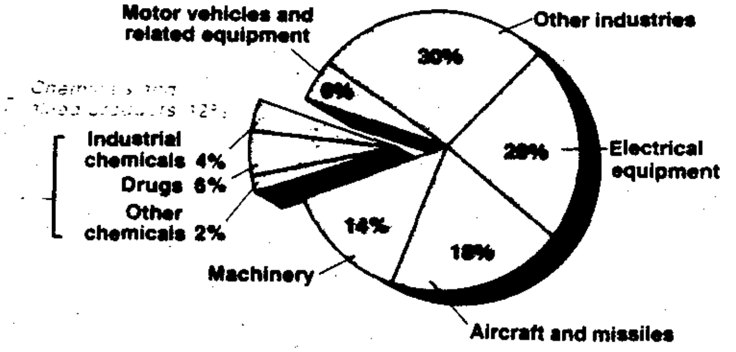
1985 chemicals and allied products R&D funds = $8.4 billion[a]

1985 industrial chemicals R&D funds = $3.6 billion[a]

1985 industry R&D funds = $51.7 billion[a]

Note: Ranges indicate companies' number of employees in 1985. a Excludes federal funding. **Source:** National Science Foundation

Chemical and drug companies provide jobs for 12% of all industrial scientists and engineers



1986 total industrial R&D scientists and engineers[a] = 580,300

a Full-time equivalent, as of January 1986. **Source:** National Science Foundation

R&D SCIENTISTS AND ENGINEERS PER 1000 EMPLOYEES: At new high in chemical industry

	1986	1984	1983	1982	1981	1980	1979	1978	1977	1976	1975
Chemicals and allied products	55	54	54	51	44	42	42	43	42	40	41
Industrial chemicals	42	44	45	44	37	36	36	38	38	36	38
Drugs	93	88	82	74	66	60	62	65	62	64	59
Other chemicals	38	37	36	36	33	30	27	27	29	28	29
All industry	36	38	35	33	29	27	27	27	27	27	26

Source: National Science Foundation

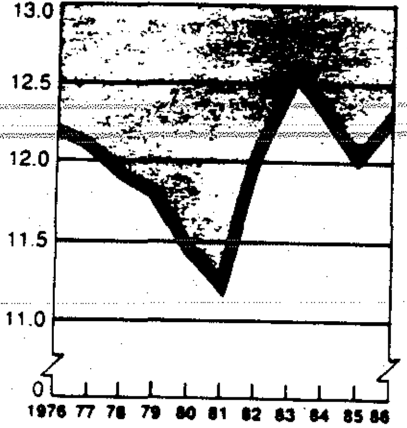
COST PER INDUSTRIAL R&D SCIENTIST OR ENGINEER: More than doubled in past decade

$ Thousands	1986	1984	1983	1982	1981	1980	1979	1978	1977	1976	1975
Chemicals and allied products	$125.2	$119.1	$109.6	$104.4	$ 96.6	$ 87.4	$79.6	$72.8	$67.6	$66.5	$60.9
Industrial chemicals	151.1	135.1	126.6	124.3	118.0	103.4	92.8	84.2	79.6	74.7	67.5
Drugs	a	111.2	100.7	a	a	79.2	71.4	64.8	59.9	63.4	60.9
Other chemicals	a	a	a	a	a	66.5	66.5	61.6	53.8	50.8	43.2
All industry	$137.0	$129.7	$118.9	$112.4	$103.9	$ 94.9	$87.4	$80.4	$75.8	$72.2	$66.5

a Not separately available but included in chemicals and allied products. **Source:** National Science Foundation

Chemical firms' share of R&D personnel up in 1986

% of total industrial R&D scientists and engineers in the chemical industry[a]



a Full-time equivalent, as of January of each year
Source: National Science Foundation

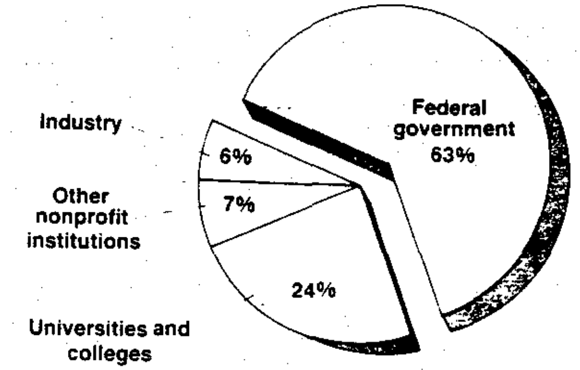
CHEMISTS IN INDUSTRY: Drugs biggest employer

Industry	% of industrial chemists				Mean salary ($ thousands)[a]		
	All chemists	B.S.	M.S.	Ph.D.	B.S.	M.S.	Ph.D.
Pharmaceuticals[b]	18%	17%	20%	17%	$40.3	$42.4	$57.2
Specialty chemicals	15	13	12	16	41.8	45.7	53.3
Basic chemicals	7	4	5	9	40.8	43.8	58.2
Plastics	5	5	6	6	42.3	47.6	56.6
Petroleum and natural gas	5	3	4	6	45.1	49.4	63.6
Agricultural chemicals	4	2	4	5	37.8	46.0	54.4
Coatings	4	5	4	3	41.6	47.7	50.6
Electronics	4	3	4	4	41.2	46.2	56.9
Food	3	5	4	2	39.8	46.2	56.5
Metals and minerals	2	4	2	1	40.2	38.8	47.0
Rubber	2	3	2	2	40.7	37.8	54.7
Biochemical products	2	1	2	2	35.1	35.5	57.5
Soaps and detergents	1	1	1	2	36.3	47.2	59.8
Paper	1	1	1	1	37.2	37.8	54.8
Other manufacturing	17	20	17	16	41.2	44.1	55.1
Nonmanufacturing	10	13	12	7	40.7	41.0	50.1

a As of March 1, 1987; to facilitate comparison, mean salaries are adjusted for differences in average length of experience for each group. b Includes personal care products. **Source:** ACS survey

University R&D increased 8% last year

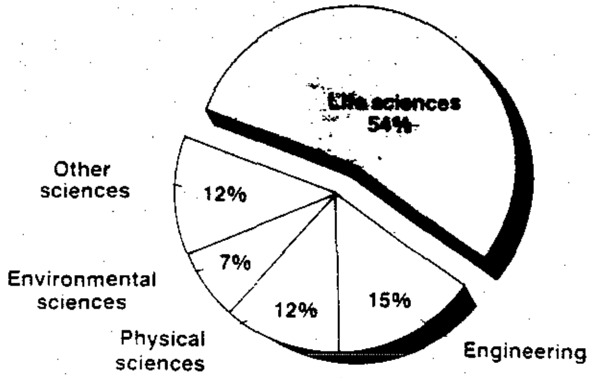
Nearly two thirds of academic R&D funding comes from federal government



Estimated fiscal 1986 academic R&D expenditures = $10.25 billion

Source: National Science Foundation

More than half of academic R&D is in the life sciences



Estimated fiscal 1986 academic R&D expenditures = $10.25 billion

Source: National Science Foundation

CHARACTER OF UNIVERSITY R&D SPENDING: Basic research gets two thirds

												Annual change	
$ Millions	**1986[a]**	**1985**	**1984**	**1983**	**1982**	**1981**	**1980**	**1979**	**1978[b]**	**1977**	**1976**	**1985–86**	**1976–86**
Basic research	$ 6,900	$6377	$5638	$5269	$4857	$4576	$4026	$3612	$3176	$2800	$2549	8%	10%
Applied research	2,760	2580[a]	2370[a]	2101	2004	1866	1691	1465	1213	1067	1015	7	11
Development	590	517[a]	495[a]	437	415	377	343	284	236	200	164	8	14
TOTAL	**$10,250**	**$9504**	**$8503**	**$7807**	**$7276**	**$6819**	**$6060**	**$5361**	**$4625**	**$4067**	**$3729**	**8%**	**11%**
ANNUAL CHANGE	**8%**	**12%**	**9%**	**7%**	**7%**	**13%**	**13%**	**16%**	**14%**	**9%**	**9%**		

Note: Data for institutional fiscal years. a C&EN estimates. b Estimated, based on data from Ph.D.-granting institutions only. **Source:** National Science Foundation

SOURCE OF UNIVERSITY R&D FUNDS: Federal share is largest, but it is falling

												Annual change	
$ Millions	**1986[a]**	**1985**	**1984**	**1983**	**1982**	**1981**	**1980**	**1979**	**1978[b]**	**1977**	**1976**	**1985–86**	**1976–86**
Federal government	$ 6,400	$6003	$5388	$4960	$4752	$4562	$4096	$3595	$3059	$2726	$2512	7%	10%
Industry	580	538	458	379	334	291	237	194	170	139	123	8	17
Universities	2,500	2258	2024	1881	1690	1520	1319	1198	1037	888	810	11	12
Other sources	770	704	633	587	500	446	409	374	359	314	284	9	10
TOTAL	**$10,250**	**$9504**	**$8503**	**$7807**	**$7276**	**$6819**	**$6060**	**$5361**	**$4625**	**$4067**	**$3729**	**8%**	**11%**

Note: Data for institutional fiscal years. a C&EN estimates. b Estimated, based on data from Ph.D.-granting institutions only. **Source:** National Science Foundation

FIELDS OF UNIVERSITY R&D SPENDING: Biggest growth for computers and math

$ Millions	1986ᵃ	1985	1984	1983	1982	1981	1980	1979	1978ᵇ	1977	1976	Annual change 1985–86	Annual change 1976–86
All sciences	**$ 8,730**	**$8120.5**	**$7296.5**	**$6695.5**	**$6250.2**	**$5857.6**	**$5195.4**	**$4593.0**	**$4023.6**	**$3566.5**	**$3297.3**	**8%**	**10%**
Life	5,510	5138.5	4607.3	4233.0	3972.4	3673.1	3216.9	2832.5	2538.0	2258.8	2101.7	7	10
Physical	1,230	1136.6	996.9	898.9	824.3	766.3	677.4	601.9	469.4	423.5	379.4	8	12
Physics	600	549.9	470.8	414.4	366.2	357.2	322.2	292.0	235.1	201.7	183.1	9	13
Chemistry	435	414.5	371.2	336.0	309.4	285.1	244.0	206.4	183.1	159.4	140.1	5	12
Environmental	755	707.0	649.5	620.5	559.3	550.3	509.1	452.9	379.4	319.4	288.5	7	10
Computer	340	277.7	222.7	175.5	149.5	113.1	114.2	97.9	67.4	55.6	44.5	22	23
Mathematical	145	129.4	124.4	108.4	98.9	89.1	78.6	78.5	58.8	52.3	42.5	12	13
Others	750	731.3	635.7	659.1	645.8	645.8	599.1	539.3	483.7	458.9	440.7	3	5
Engineering	**1,520**	**1383.2**	**1206.4**	**1111.3**	**1025.8**	**961.0**	**864.9**	**768.4**	**601.1**	**498.5**	**431.7**	**10**	**13**
Chemical	115	109.0	96.2	90.8	83.6	83.2	67.6	na	na	na	na	6	na
TOTAL	**$10,250**	**$9503.7**	**$8503.0**	**$7806.8**	**$7276.1**	**$6818.6**	**$6060.3**	**$5361.4**	**$4624.7**	**$4067.0**	**$3729.0**	**8%**	**11%**
ANNUAL CHANGE	**8%**	**12%**	**9%**	**7%**	**7%**	**13%**	**13%**	**16%**	**14%**	**9%**	**9%**		

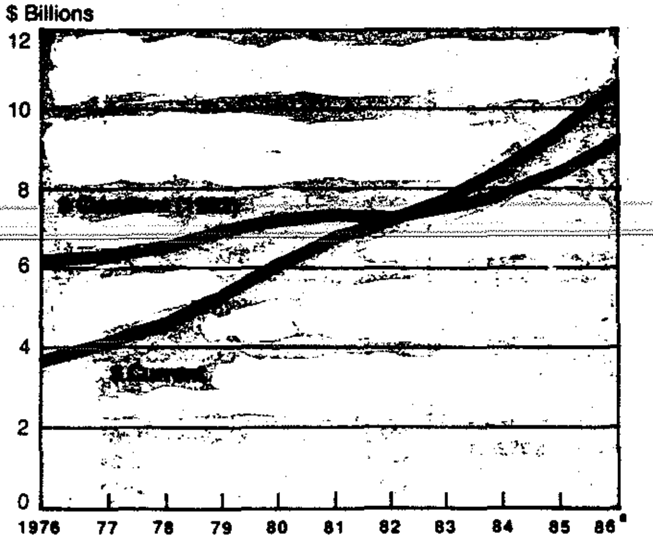
Note: Data for institutional fiscal years. a C&EN estimates. b NSF estimates, based on data from Ph.D.-granting institutions only. na = not available. **Source:** National Science Foundation

FEDERALLY FINANCED R&D SPENDING AT UNIVERSITIES: Growth slows in physical science

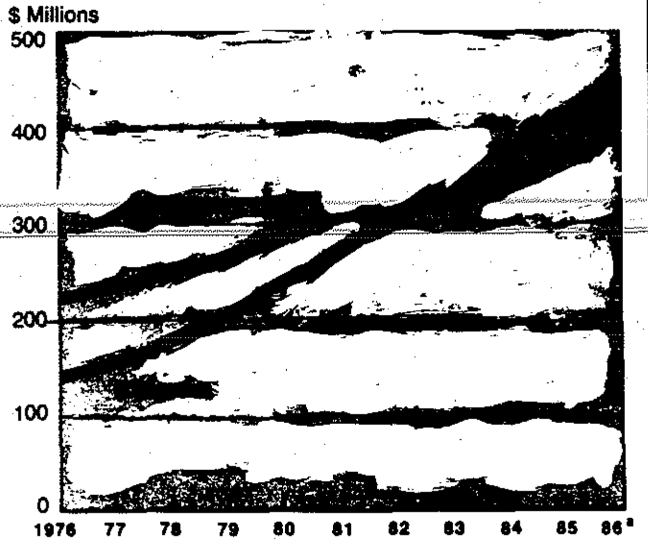
$ Millions	1986ᵃ	1985	1984	1983	1982	1981	1980	1979	1978ᵇ	1977	1976	Annual change 1985–86	Annual change 1976–86
All sciences	**$5420**	**$5145.0**	**$4609.4**	**$4221.8**	**$4054.0**	**$3899.3**	**$3500.6**	**$3068.9**	**$2651.2**	**$2389.4**	**$2221.3**	**5%**	**9%**
Life	3290	3138.7	2793.9	2565.3	2494.4	2364.2	2094.0	1818.8	1626.4	1474.0	1380.8	5	9
Physical	920	883.3	779.3	698.5	650.0	619.0	554.8	490.7	392.3	338.8	305.4	4	12
Physics	480	454.7	387.9	340.0	306.2	308.7	279.9	252.5	199.2	171.9	156.1	6	12
Chemistry	320	308.4	278.9	248.6	231.1	216.8	189.4	156.5	138.0	121.5	107.9	4	11
Environmental	500	480.7	451.5	427.9	392.2	392.7	372.5	329.2	275.1	238.6	211.8	4	9
Computer	230	193.1	161.6	127.8	107.0	93.5	77.0	69.2	41.2	37.5	32.9	19	21
Mathematical	115	96.1	91.3	76.7	72.1	67.9	61.1	60.4	44.1	40.6	32.9	20	13
Others	365	353.1	331.8	325.5	338.4	361.9	341.2	300.6	272.0	259.9	257.4	3	4
Engineering	**980**	**857.5**	**778.6**	**737.9**	**698.2**	**662.5**	**595.4**	**526.4**	**407.5**	**338.7**	**290.5**	**14**	**13**
Chemical	65	57.9	54.4	52.1	49.6	55.2	46.1	na	na	na	na	12	na
TOTAL	**$6400**	**$6002.6**	**$5388.0**	**$4959.7**	**$4752.2**	**$4561.8**	**$4096.0**	**$3595.3**	**$3058.7**	**$2726.1**	**$2511.9**	**7%**	**10%**
ANNUAL CHANGE	**7%**	**11%**	**9%**	**4%**	**4%**	**11%**	**14%**	**18%**	**12%**	**9%**	**10%**		

Note: Data for institutional fiscal years. a C&EN estimates. b NSF estimates, based on data from Ph.D.-granting institutions only. na = not available. **Source:** National Science Foundation.

Money for academic R&D, in constant dollars, is growing strongly . . .



. . . and funding for R&D in chemistry also forges higher in real terms



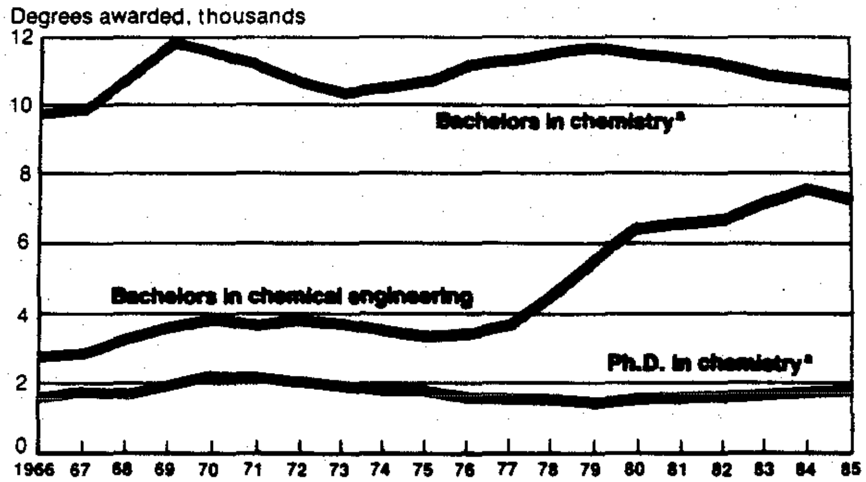
Note: Data for institutional fiscal years. a C&EN estimates. **Source:** National Science Foundation

TOP 10 UNIVERSITIES IN R&D SPENDING: 21% of total goes to top 10 institutions

$ Millions, fiscal 1985	Physical sciences	Chemistry[a]	Engineering	Environmental sciences	Life sciences	Math and computer sciences	Other sciences[b]	Total
1 Johns Hopkins U	$ 58.3	$ 4.2	$ 116.8	$ 28.3	$ 99.6	$ 71.7	$ 13.9	$ 388.6
2 Massachusetts Inst. of Technology	70.7	12.4	103.8	12.5	31.1	13.4	11.5	243.0
3 U of Wisconsin, Madison	23.7	5.2	21.8	17.8	115.8	7.4	21.9	208.4
4 Cornell U	36.2	6.3	30.6	5.2	114.5	6.6	10.1	203.2
5 Stanford U	35.2	7.1	58.3	3.2	83.1	14.1	5.3	199.2
6 U of Minnesota	11.2	3.3	18.1	3.7	127.2	3.4	9.7	173.3
7 U of Washington	11.6	2.0	11.9	18.0	99.8	3.8	18.9	164.0
8 U of Michigan	11.4	2.3	23.0	9.6	79.3	3.7	36.7	163.7
9 U of California, Berkeley	31.8	9.9	31.9	2.4	62.6	2.8	18.4	149.9
10 U of California, Los Angeles	15.5	6.7	18.5	8.8	93.3	1.2	12.4	149.7
TOTAL, TOP 10 INSTITUTIONS	$ 305.7	$ 59.4	$ 434.7	$109.4	$ 906.4	$128.1	$158.7	$2043.0
TOTAL, ALL INSTITUTIONS	$1136.6	$308.4	$1383.2	$707.0	$5138.5	$407.1	$731.3	$9503.7

a Included in physical sciences. b Includes social sciences, psychology, and other sciences not listed separately. **Source:** National Science Foundation

Fewer degrees awarded at undergraduate level



Note: Academic fiscal years. a Excludes biochemistry and geochemistry.
Source: National Center for Education Statistics

CHEMICAL DEGREES: Doctorates increase

Academic fiscal year	Bachelors	Masters	Ph.D.s
DEGREES IN CHEMISTRY			
1966	9,735	1839	1571
1967	9,872	1831	1744
1968	10,847	2014	1757
1969	11,807	2070	1941
1970	11,617	2146	2208
1971	11,183	2284	2160
1972	10,721	2259	1971
1973	10,226	2230	1882
1974	10,525	2138	1828
1975	10,649	2006	1824
1976	11,107	1796	1623
1977	11,322	1775	1571
1978	11,474	1892	1525
1979	11,643	1765	1518
1980	11,446	1733	1551
1981	11,347	1654	1622
1982	11,062	1751	1722
1983	10,746	1604	1746
1984	10,704	1667	1744
1985	10,482	1719	1789
DEGREES IN CHEMICAL ENGINEERING			
1966	2848	994	354
1967	2869	949	305
1968	3211	1156	367
1969	3557	1136	409
1970	3720	1045	438
1971	3615	1100	406
1972	3663	1154	394
1973	3636	1051	397
1974	3454	1045	400
1975	3142	990	346
1976	3203	1031	308
1977	3581	1086	291
1978	4615	1237	259
1979	5655	1149	304
1980	6383	1271	284
1981	6527	1267	300
1982	6740	1285	311
1983	7145	1304	319
1984	7475	1514	330
1985	7146	1544	418

a Excludes biochemistry and geochemistry.
Source: National Center for Education Statistics

TOP 10 UNIVERSITY R&D CENTERS: 40% of funding goes to support work in physical sciences

$ Millions, fiscal 1985	Physical sciences	Engineering	Environmental sciences	Math and computer sciences	Total[a]
1 Lawrence Livermore Lab	$ 230.5	$ 432.2	$ 26.4	$ 95.0	$ 805.3
2 Los Alamos National Lab	335.8	233.0	16.9	64.1	704.0
3 Jet Propulsion Lab	72.7	295.2	61.8	236.5	666.2
4 Lincoln Lab	50.3[b]	186.2[b]	0	27.8[b]	264.5
5 Argonne National Lab	69.3	116.5	24.5	2.3	223.7
6 Brookhaven National Lab	134.7	29.5	9.4	0.7	199.0
7 Lawrence Berkeley Lab	103.6[b]	16.5[b]	17.6[b]	5.5[b]	174.6
8 Fermi National Accelerator Lab	151.3	0	0	0	151.3
9 Plasma Physics Lab	131.7	0	0	0	131.7
10 Stanford Linear Accelerator Center	79.7	0	0	0	79.7
All others	70.2	3.3	45.8	2.4	129.1
TOTAL, ALL FEDERALLY FUNDED R&D CENTERS	$1429.8	$1312.4	$202.4	$434.3	$3529.1

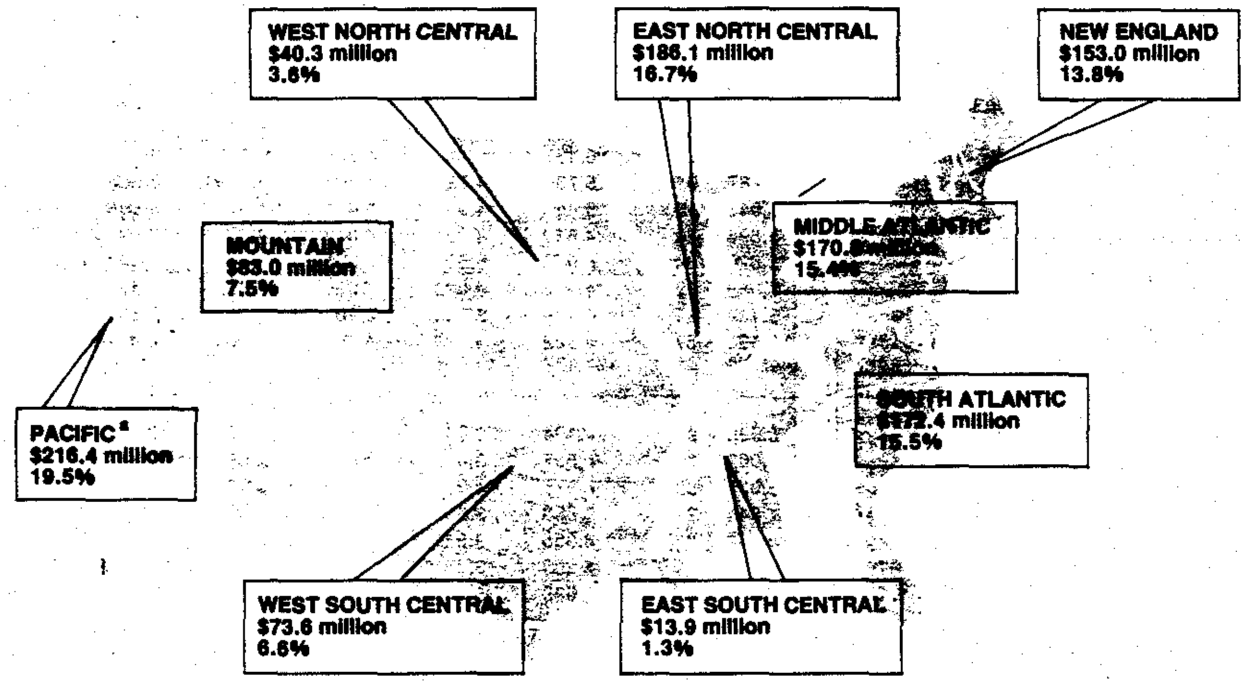
Note: Data for university-administered, federally funded R&D centers. a Includes life sciences and other sciences not listed separately. b Estimated. Source: National Science Foundation

SCHOOLS SPENDING MOST ON CHEMICAL R&D: More than 20 spent at least $5 million in 1985

Rank 1985	Rank 1984		1985 Total spending ($ thousands)	1985 % federal funds	1984	1983	1982 ($ thousands)	1981	1980	Annual change 1984-85	Annual change 1980-85
1	1	Massachusetts Inst. of Technology	$ 13,221	94%	$ 11,741	$ 8,914	$ 9,792	$ 8,222	$ 6,764	13%	14%
2	3	U of California, Berkeley	10,804	92	7,850	7,945	6,283	6,553	6,022	38	12
3	2	Harvard U	8,663	76	8,327[a]	6,898[a]	5,512[a]	6,123[a]	4,797[a]	4	13
4	5	Stanford U	8,354	85	6,809	6,375	6,116	5,564	4,788	23	12
5	6	Cornell U	7,962	79	6,710	5,717[a]	6,239[a]	4,618	3,808	19	16
6	8	California Inst. of Technology	7,605	92	6,446	6,994	6,136	6,901	6,328	18	4
7	12	U of Wisconsin, Madison	7,350	70	6,076	5,310	4,567	4,122	3,976	21	13
8	9	U of Maryland, College Park	7,289	46	6,324	6,333[a]	4,718[a]	3,109	2,766	15	21
9	4	U of California, Los Angeles	7,243	93	7,219	5,496	5,187	4,420	4,159	0	12
10	10	U of Illinois, Urbana	7,079	76	6,284	5,886	6,422	5,239	4,261	13	11
		Total, first 10 institutions	85,570	82%	73,786	65,868	60,972	54,871	47,669	16%	12%
11	16	Pennsylvania State U	6,509	90	5,124	4,729	3,564	3,413	2,973	27	17
12	26	U of Colorado	6,360	85	4,134	3,302	3,492	4,047	3,332	54	14
13	11	U of Massachusetts, Amherst	6,291	63	6,137	5,162	4,364	3,230	1,889	3	27
14	13	U of Chicago	6,287	91	5,735	4,798[a]	4,396	4,139[a]	3,958[a]	10	10
15	15	Purdue U	6,018	90	5,443	4,542	4,459	4,600	3,596	11	11
16	19	Texas A&M U	5,896	71	4,610	4,963	4,521	4,069	4,097	28	8
17	14	Indiana U	5,820	84	5,642	5,551	5,341	3,637	3,147	3	13
18	17	U of Notre Dame	5,549	92	4,760	4,022	4,020	3,855	3,457	17	10
19	27	Ohio State U	5,422	71	4,104	3,739	2,907	3,227	2,654	32	15
20	18	Columbia U, main division	5,188	87	4,662	4,281	4,700	3,564	4,437	11	3
		Total, first 20 institutions	144,910	82%	124,137	110,957	102,736	92,652	81,209	17%	12%
21	25	Yale U	5,096	90	4,134	3,341	2,875	2,781	2,023	23	20
22	20	Northwestern U	5,062	78	4,557	3,413	3,026	2,995	2,367	11	16
23	21	U of Pennsylvania	5,025	88	4,375	4,982	3,068	3,386	3,688	15	6
24	34	U of Utah	4,840	91	3,830	3,638	3,364	3,076	2,811	26	11
25	22	U of California, San Diego	4,642	87	4,355	3,910	3,894	4,430	4,425[a]	7	1
26	23	U of Oregon, main campus	4,640	85	4,255	3,351	2,971	1,389	1,119	9	33
27	7	U of Texas, Austin	4,588	47	6,639	5,938	4,843	4,779	3,970	−31	3
28	31	U of Pittsburgh	4,580	84	3,965	3,267	2,714	2,039	1,641	16	23
29	29	Johns Hopkins U	4,466	93	4,030	4,592[a]	4,721	4,066	4,652	11	−1
30	30	U of Florida	4,380	53	4,024	2,347	2,248	2,302	2,283[a]	9	14
		Total, first 30 institutions	192,229	81%	168,301	149,736	136,460	123,895	110,188	14%	12%
31	28	U of Minnesota	4,167	79	4,067	4,047	4,297	4,260	2,642	2	10
32	36	Princeton U	3,963	78	3,670	3,509	3,062	2,513	2,065	8	14
33	37	U of South Carolina	3,729	75	3,423	2,721	2,483	1,087[b]	970[a]	9	31
34	33	Georgia Inst. of Technology	3,684	56	3,846	3,401	3,327	3,660	3,655	−4	0
35	40	State U of New York, Stony Brook	3,481	67	3,084	2,607	2,783	2,691	1,966	13	12
36	38	Lehigh U	3,456	39	3,361	3,664	2,584	1,680	1,066	3	27
37	24	U of Connecticut	3,429	44	4,135	2,720	2,049	1,748	1,300	−17	21
38	44	Virginia Polytechnic Inst. & State U	3,339	59	2,633	2,206	1,740	1,581	1,612	27	16
39	39	Florida State U	3,276	32	3,137	2,500	2,959	3,012	2,791	4	3
40	—	Howard U	3,269	91	3,672	2,336	982	1,406	1,287	−11	20
		Total, first 40 institutions	228,022	79%	203,329	179,447	162,726	147,533	129,542	12%	12%
41	44	Michigan State U	3,222	60	2,869[b]	2,714	2,493	2,178	1,638	12	14
42	41	U of North Carolina, Chapel Hill	3,201	90	2,945	2,397	2,240	2,016	1,789	9	12
43	32	U of Rochester	3,196	90	3,858	3,167	3,123	2,966	2,089	−17	9
44	—	U of California, Irvine	3,142	97	2,177	1,777	1,661	1,915	1,398	44	18
45	—	U of California, Santa Barbara	3,060	89	2,172	1,902	1,698	1,834	1,434	41	16
46	—	U of Virginia	3,046	71	2,516	2,069	1,778	1,781	1,203	21	20
47	—	Iowa State U	2,988	41	2,239	1,903	1,462	1,272	1,159	33	21
48	—	U of Washington	2,964	68	2,340	2,162	2,276	1,500	1,326	27	17
49	40	Wayne State U	2,093	99	3,071	2,645	2,656	2,261	2,163	−32	−1
50	—	Syracuse U	2,900	52	2,110	2,171	2,868	2,259	764	37	31
		Total, first 50 institutions	$258,644	78%	$229,626	$202,354	$184,981	$167,515	$144,505	13%	12%
		NATIONAL TOTAL	$414,529	74%	$371,182	$336,025	$308,371	$285,520	$244,454	12%	11%

Note: Data for institutional fiscal years. a Estimated. b Imputed. Source: National Science Foundation

East and West Coast schools account for 64% of R&D spending in physical sciences



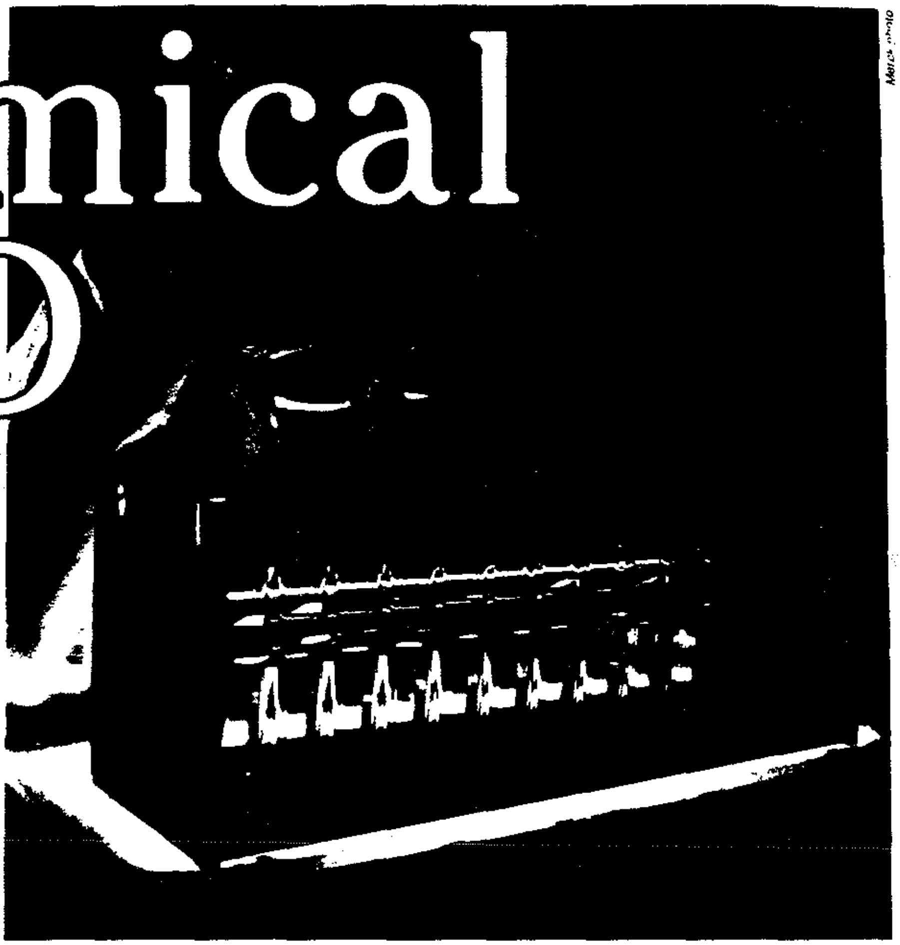
Key to map: Using the Middle Atlantic states as an example, $170.8 million, or 15.4%, of all R&D expenditures in the physical sciences by all Ph.D.-granting universities and colleges are made in this geographical area. **Note:** Data are based on R&D expenditures of $1.11 billion in the physical sciences during the 1985 fiscal year.
a Includes Alaska, Hawaii, and outlying areas. **Source:** National Science Foundation

GRADUATE SCIENCE STUDENTS: **Chemistry, biochemistry, chemical engineering total 8%**

												Annual change	
Thousands	**1985**	**1984**	**1983**	**1982**	**1981**	**1980**	**1979**	**1978**	**1977**	**1976**	**1975**	**1984-85**	**1975-85**
Physical sciences	**29.4**	**28.4**	**27.7**	**26.5**	**25.8**	**25.4**	**24.9**	**24.7**	**24.8**	**24.8**	**24.5**	4%	2%
Chemistry	17.3	16.6	16.5	15.8	15.2	15.1	14.9	14.8	14.6	14.4	14.1	4	2
Physics	11.3	11.0	10.5	10.0	9.9	9.6	9.3	9.2	9.5	9.6	9.6	3	2
Life sciences	**93.8**	**92.5**	**91.2**	**90.7**	**90.9**	**90.7**	**87.5**	**85.9**	**83.3**	**77.2**	**73.6**	1	2
Biochemistry	4.7	4.5	4.2	4.1	4.0	4.0	3.9	4.0	3.8	3.7	3.7	4	2
Engineering	**91.8**	**88.3**	**86.4**	**78.2**	**74.4**	**70.1**	**67.2**	**64.3**	**64.4**	**62.9**	**64.6**	4	4
Chemical	7.0	7.2	7.4	6.9	6.3	5.9	5.4	5.2	5.1	5.1	4.9	−3	4
Metallurgical & materials	3.8	3.6	3.3	3.0	3.0	2.8	2.7	2.5	2.5	2.3	2.3	6	5
Petroleum	0.8	0.7	0.7	0.6	0.5	0.5	0.4	0.4	0.4	0.4	0.3	14	10
Environmental sciences	**14.3**	**14.3**	**14.3**	**13.8**	**13.1**	**12.8**	**12.6**	**12.2**	**12.3**	**11.7**	**11.0**	0	3
Mathematical and computer sciences	**39.0**	**35.4**	**33.2**	**30.3**	**27.1**	**25.0**	**22.7**	**21.5**	**21.1**	**21.7**	**21.3**	7	6
Psychology and social sciences	**102.8**	**104.5**	**105.4**	**107.3**	**108.7**	**109.7**	**105.8**	**101.2**	**100.6**	**99.8**	**98.7**	−2	0
TOTAL	**371.1**	**363.5**	**358.1**	**346.8**	**340.0**	**333.7**	**320.6**	**309.8**	**306.6**	**298.2**	**293.8**	2%	2%
ANNUAL CHANGE	2%	2%	3%	2%	2%	4%	3%	1%	3%	1%	—		

NOTE: Data for Ph.D.-granting institutions only. **Source:** National Science Foundation

Facts & Figures for Chemical R&D



Mettler photo

Rebecca L. Rawls, C&EN Washington

Research and development in the U.S. is growing modestly. Total expenditures for R&D are expected to top $122 billion in 1987, an increase of 6% over R&D spending from all sources last year. That's the smallest year-to-year change in the past decade, a decade that has seen R&D funding nearly triple, in current dollars, from 1977's $42.8 billion. For the decade as a whole, R&D spending in the U.S. has been growing 11% per year—nearly twice the rate at which it is growing now.

Still, although significantly more modest than in the recent past, the increase in R&D funding expected this year does represent real growth, outpacing anticipated inflation by some 2%. In keeping with the recent pattern, about half that money comes from the federal government—$60 billion in 1987—and almost all the rest from industry. Universities and other nonprofit institutions will kick in a relatively modest $4.2 billion, only 3% of the total, this year.

Government spending for R&D is actually growing a good deal

faster than federal spending as a whole. If Gramm-Rudman deficit reduction targets are to be met in this year's budget—an event that most observers consider unlikely—the overall federal budget probably will rise only a very modest 1% for the year ending Sept. 30. Federal R&D support, by contrast, is expected to be up 7% for 1987 as a whole. In general, the Reagan Administration and Congress have been relatively kind to R&D budgets during the past seven years, doubling federal support for R&D from its pre-Reagan level of $29.5 billion in 1980. Even when inflation is taken into account, federal R&D support has grown 46% since 1980.

Until recently, industrial support for R&D has kept pace with the federal effort. In 1986 and again in 1987, however, preliminary figures indicate that industry's support for R&D is lagging behind that of government. R&D spending by all industry is expected to rise 5% this year, following a 6% increase in 1986 and one of 7% in 1985. Federal support over the same period rose, on average, 10% per year.

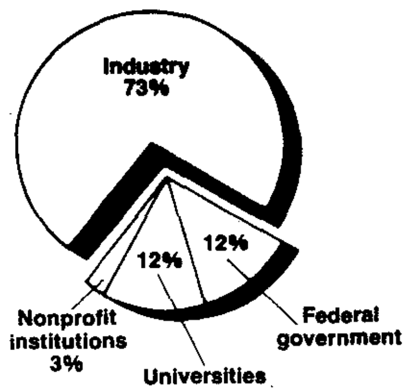
Considered in a broader context, however, current levels of support for R&D in the U.S. are quite high. R&D spending appears to be leveling off at about 2.7% of gross national product. For most of the past two decades it has been considerably lower than that, reaching its most recent nadir in 1978 at just above 2.1%. Not since the mid-1960s, when massive efforts in space and defense led the federal government to spend twice what industry did to support R&D, has such a large fraction of the nation's total output of goods and services, as measured by GNP, been devoted to supporting R&D. Though the rate of growth may be declining, overall support for R&D in the U.S. appears strong.

Chemical R&D, of course, is only a small piece of the total R&D picture. Just how much of the total national effort focuses on chemistry is never easy to measure, in part because the point where chemical R&D breaks off and R&D begins in some closely related field—materials science, say, or biotechnology—has never been clearly defined.

This year, separating out that part of the overall R&D effort that can reasonably be called chemical is even harder than usual. That's because some of the key data, particularly on the industrially financed half of the R&D picture, have yet to be compiled by the National Science Foundation. NSF is the chief source of statistical information on R&D in the U.S., and its data—collected in large part by the Census Bureau—form much of the basis of this special report. Recent reorganizations at both the Census Bureau and NSF's division of science resources studies have delayed the compilation of some of these data by three or four months. As a result, the most recent data available for many aspects of industrial R&D spending are based on information collected in 1983, too long ago to give a precise picture of the state of that R&D effort now.

Of the federally funded half of U.S. R&D, the biggest share—69% for the 1987 fiscal year—is funded by the Defense Department. Defense's share of the federal R&D budget has been climbing steadily in recent years, from a level of about 45% that prevailed throughout the late 1970s. That shift parallels another one that is taking place, name-

Almost three quarters of all R&D is by industry



1987 total R&D spending = $122.3 billion

Source: National Science Foundation

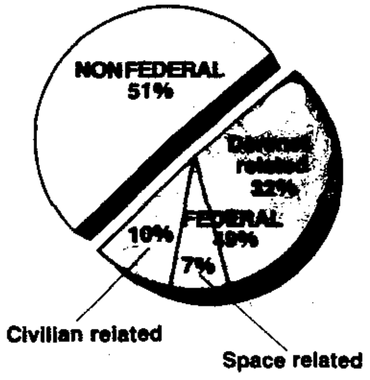
ly that more and more federal funds are going into the development part of R&D—72% in 1987, up from 64% five years ago. The Defense Department is the overwhelming source of federal development funds, supplying almost 90% in 1987.

Chemical research also finds its single largest federal patron in the Defense Department, which in the 1987 budget year is expected to spend $185 million for it. That's 28% of total federal chemical research support, which is estimated to reach $671 million. Defense Department support is up 10% from 1986 levels. Growing even faster is support from the National Science Foundation, which expects a 17% boost in its funding for chemical research in fiscal 1987. That would bring its support to $132 million, nearly to the level of the second largest supporter of chemical research in the federal government—the Department of Energy, which expects to spend $139 million on such research in fiscal 1987, down 6% from 1986. In fact, except for the Defense Department and NSF, all the major supporters of chemical research in the federal government will decrease their spending in this area in 1987. The net effect is a 3% rise overall for federal support for chemical research—no change at all when inflation is taken into account.

At universities, where half of the nation's basic research is performed, overall budgets for basic research were up a healthly 8% in 1986. Funds for applied R&D, which together account for only a third of total R&D spending at universities, also were up 8% in 1986. Spending at universities on chemical R&D reached $450 million in 1986, also an 8% hike from 1985. The federal government is the principal funder of university R&D—supplying nearly two thirds of the $11.1 billion universities expect to spend on R&D in 1987.

Though universities have a major role in performing basic research in the U.S., they trail far behind industry when it comes to carrying out applied research or development. In fact, industry will do 73% of the total R&D conducted in the U.S. this year, a fraction that has held essentially constant for the past decade. Universities and government-run R&D facilities each perform about equal shares of the remainder.

Federal funds account for half of all U.S. R&D



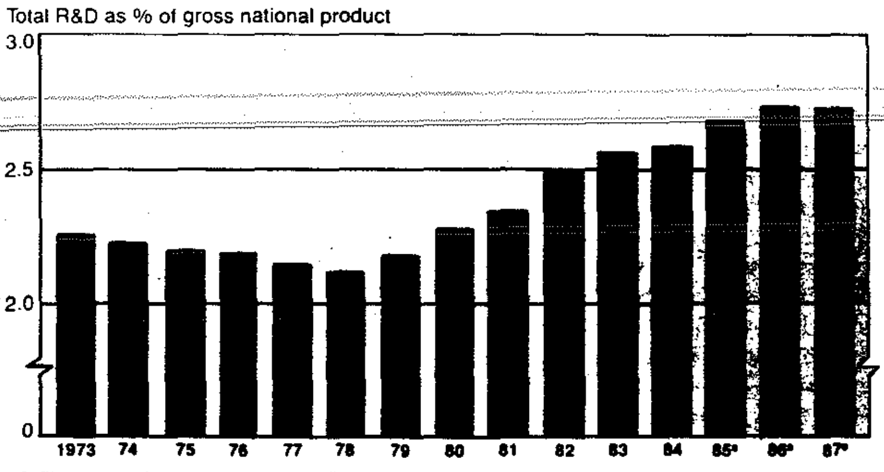
1987 total R&D spending = $122.3 billion

Source: National Science Foundation

Historically, the overall chemicals and allied products industry performs about 70% of all the applied R&D done on chemicals or drugs by industry. R&D performed by companies in the chemicals and allied products industry is estimated to have increased 10% in 1986 to $9.5 billion. That level of growth is off a bit from the 12% average annual rate of increase for the past decade. When adjusted for inflation, however, the real growth in spending for 1986, at 7%, is slightly better than the 6% annual rate for the decade as a whole.

Growth in R&D at major industrial chemical companies was not so high as that for the chemicals and allied products industry as a whole in 1986—up only 4%. Some of this difference comes about because drug companies, which are part of the chemicals and allied products industry, are increasing their R&D spending faster than are basic chemical companies. Another contributing factor is a major divestment that took place at Union Carbide in 1986. The company sold off nearly $2 billion of its assets, largely in consumer products fields. The much smaller Union Carbide spent less on R&D in 1986 than its predecessor company had in 1985. When this change is taken into account, major chemical company R&D spending rose 7% in 1986. □

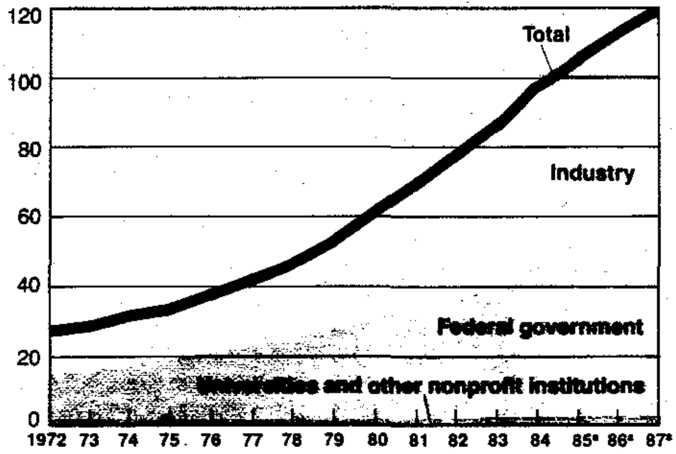
R&D share of U.S. GNP levels off after rise of early 1980s



a C&EN estimates. **Source:** National Science Foundation

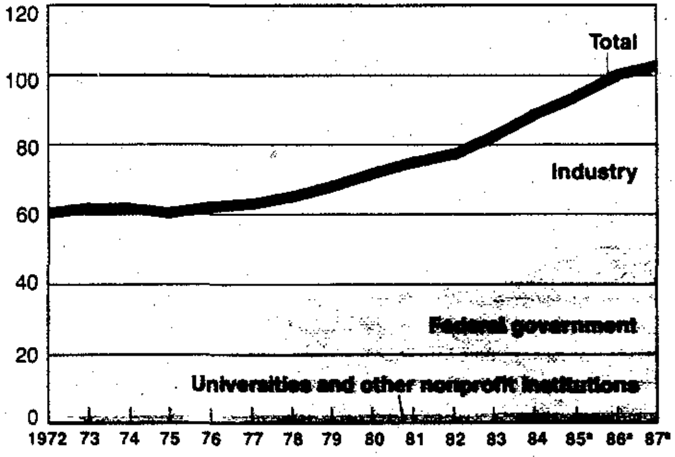
Although U.S. outlays for R&D are up fourfold in the past 15 years . . .

Sources of R&D funds, $ billions, current



. . . they are only two thirds higher if inflation is taken into account

Sources of R&D funds, $ billions, constant (1982)



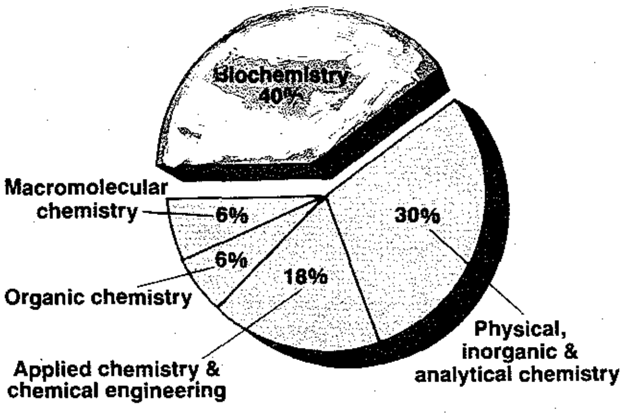
a C&EN estimates. Source: National Science Foundation

SOURCES OF R&D FUNDS: Industry and federal government each contribute nearly half

	$ Billions (current)											Annual change	
	1987a	1986a	1985a	1984	1983	1982	1981	1980	1979	1978	1977	1986–87	1977–87
Industry	$ 58.1	$ 55.3	$ 52.2	$48.8	$43.5	$40.1	$35.9	$30.9	$26.1	$22.5	$19.6	5%	11%
Federal government	60.0	56.0	51.8	45.6	40.7	36.5	33.4	29.5	26.8	23.9	21.6	7	11
Universities and colleges	2.7	2.5	2.3	2.0	1.9	1.7	1.5	1.3	1.2	1.0	0.9	8	12
Other nonprofit institutions	1.5	1.4	1.3	1.2	1.1	1.0	1.0	0.9	0.8	0.8	0.7	7	8
TOTAL	$122.3	$115.2	$107.5	$97.6	$87.2	$79.3	$71.8	$62.6	$54.9	$48.1	$42.8	6%	11%
ANNUAL CHANGE	6%	7%	10%	12%	10%	10%	15%	14%	14%	12%	10%		
	$ Billions (1982, constant)												
Industry	$ 48.8	$ 48.3	$46.8	$45.2	$41.9	$40.1	$38.3	$36.1	$33.2	$31.1	$29.2	1%	5%
Federal government	50.4	48.9	46.5	42.3	39.2	36.5	35.7	34.5	34.3	33.2	32.2	3	5
Universities and colleges	2.3	2.2	2.1	1.9	1.8	1.7	1.6	1.6	1.5	1.4	1.3	5	6
Other nonprofit institutions	1.3	1.2	1.2	1.1	1.1	1.0	1.0	1.1	1.1	1.1	1.0	8	3
TOTAL	$102.7	$100.6	$96.4	$90.5	$83.9	$79.3	$76.6	$73.2	$70.1	$66.8	$63.7	2%	5%
ANNUAL CHANGE	2%	4%	7%	8%	6%	4%	5%	4%	5%	5%	2%		

a C&EN estimates. Source: National Science Foundation

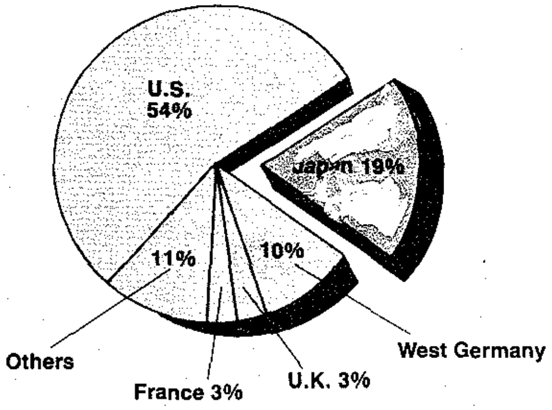
Two fifths of chemistry papers are in biochemistry



1986 total papers[a] = 474,429

[a] Number of abstracts of papers published in *Chemical Abstracts*.
Source: Chemical Abstracts Service

Japanese now receive nearly 20% of U.S. patents



1986 total U.S. patents issued = 70,860

Source: U.S. Patent & Trademark Office

PERFORMERS OF R&D: Industry's share is six times that of government

	$ Billions (current)											Annual change	
	1987[a]	1986[a]	1985[a]	1984	1983	1982	1981	1980	1979	1978	1977	1986–87	1977–87
Industry	$ 88.7	$ 84.4	$ 78.2	$71.5	$63.4	$58.0	$51.8	$44.5	$38.2	$33.3	$29.8	5%	12%
Federal government	15.1	13.4	13.0	11.6	10.6	9.1	8.4	7.6	7.4	6.8	6.0	13	10
Universities and colleges	10.7	10.3	9.5	8.5	7.8	7.3	6.8	6.1	5.4	4.6	4.1	4	10
University-associated FFRDCs[b]	4.0	3.8	3.5	3.1	2.7	2.5	2.5	2.2	1.9	1.7	1.4	5	11
Other nonprofit institutions	3.7	3.4	3.3	3.0	2.7	2.4	2.3	2.2	2.0	1.7	1.5	9	9
TOTAL	**$122.3**	**$115.2**	**$107.5**	**$97.6**	**$87.2**	**$79.3**	**$71.8**	**$62.6**	**$54.9**	**$48.1**	**$42.8**	6%	11%
	$ Billions (1982, constant)												
Industry	$ 74.5	$ 73.7	$70.1	$66.9	$61.0	$58.0	$55.1	$51.9	$48.7	$46.1	$44.3	1%	5%
Federal government	12.7	11.7	11.7	10.8	10.2	9.1	9.0	9.0	9.5	9.5	9.0	9	4
Universities and colleges	9.0	9.0	8.5	7.9	7.5	7.3	7.3	7.2	6.9	6.4	6.1	0	4
University-associated FFRDCs[b]	3.4	3.3	3.1	2.9	2.6	2.5	2.7	2.7	2.5	2.4	2.1	3	5
Other nonprofit institutions	3.1	3.0	3.0	2.8	2.6	2.4	2.4	2.5	2.5	2.3	2.2	3	3
TOTAL	**$102.7**	**$100.6**	**$96.4**	**$90.5**	**$83.9**	**$79.3**	**$76.6**	**$73.2**	**$70.1**	**$66.8**	**$63.7**	2%	5%

[a] C&EN estimates. [b] Federally funded R&D centers. Those administered by both industry and by nonprofit institutions are included in totals for their respective sectors.
Source: National Science Foundation

CHARACTER OF R&D: Uniform growth in all three sectors

	$ Billions (current)											Annual change	
	1987[a]	1986[a]	1985[a]	1984	1983	1982	1981	1980	1979	1978	1977	1986–87	1977–87
Basic research	$ 14.7	$ 13.8	$ 13.0	$12.1	$11.0	$ 9.9	$ 9.2	$ 8.1	$ 7.3	$ 6.4	$ 5.5	7%	10%
Applied research	26.4	24.7	23.4	22.3	20.4	18.5	16.9	14.1	12.3	10.8	9.7	7	11
Development	81.2	76.5	71.1	62.9	55.8	50.9	45.8	40.5	35.3	30.9	27.5	6	11
TOTAL	**$122.3**	**$115.2**	**$107.5**	**$97.6**	**$87.2**	**$79.3**	**$71.8**	**$62.6**	**$54.9**	**$48.1**	**$42.8**	6%	11%
	$ Billions (1982, constant)												
Basic research	$ 12.3	$ 12.1	$11.7	$11.2	$10.6	$ 9.9	$ 9.8	$ 9.5	$ 9.3	$ 8.9	$ 8.3	2%	4%
Applied research	22.2	21.6	21.0	20.7	19.6	18.5	18.0	16.5	15.8	15.1	14.5	3	4
Development	68.2	66.8	63.8	58.3	53.7	50.9	48.8	47.3	45.0	42.8	40.9	2	5
TOTAL	**$102.7**	**$100.6**	**$96.4**	**$90.5**	**$83.9**	**$79.3**	**$76.6**	**$73.2**	**$70.1**	**$66.8**	**$63.7**	2%	5%

[a] C&EN estimates. **Source:** National Science Foundation

PATENT ACTIVITY OF U.S. COMPANIES:[a] Significant decline for chemicals in 1986

Number of patents issued	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977	Total 1977–86
CHEMICAL COMPANIES											
Dow Chemical	371	335	328	246	276	260	249	217	334	297	**2,913**
Du Pont	329	342	348	326	283	343	289	227	386	431	**3,304**
Ciba-Geigy	244	305	290	244	281	345	309	248	347	354	**2,967**
Union Carbide	208	242	231	182	202	262	211	197	215	224	**2,174**
PPG Industries	124	128	137	137	177	189	166	118	190	196	**1,562**
Monsanto	110	100	138	136	131	211	205	144	264	192	**1,631**
American Cyanamid	92	115	111	128	129	188	205	143	225	215	**1,551**
Olin	81	117	112	85	80	80	106	82	99	91	**933**
Ethyl	77	105	76	44	31	43	51	25	41	46	**539**
International Flavors & Fragrances	76	104	95	87	87	96	76	60	80	52	**813**
Stauffer Chemical	75	104	95	81	87	94	93	80	132	116	**957**
Celanese	66	67	94	57	56	58	56	44	71	70	**639**
Hercules	43	41	39	37	30	52	23	24	49	51	**389**
W. R. Grace	42	45	57	52	49	68	72	56	76	63	**580**
Rohm & Haas	33	31	37	55	49	77	74	77	95	94	**622**
GAF	12	23	19	21	32	47	48	54	57	26	**339**
TOTAL[b]	**1983**	**2204**	**2207**	**1918**	**1980**	**2413**	**2233**	**1796**	**2661**	**2518**	**21,913**
ANNUAL CHANGE	**−10%**	**0%**	**15%**	**−3%**	**−18%**	**8%**	**24%**	**−33%**	**6%**	**−9%**	

a Includes U.S. chemical companies or U.S.-based subsidiaries of foreign companies that have received more than 999 U.S. patents since 1962. b These totals include patents issued to the chemical companies shown in this table only. **Source:** U.S. Patent & Trademark Office

U.S. PATENTS: Those of foreign origin rose 2% in 1986 as those of U.S. origin declined 4%

Number of patents issued	1986	1985	1984	1983	1982	1981	1980	1979[a]	1978	1977	Total 1977–86
U.S. origin	**38,124**	**39,554**	**38,365**	**32,871**	**33,896**	**39,223**	**37,356**	**30,079**	**41,254**	**41,485**	**372,207**
to U.S. corporations	27,324	28,944	28,002	24,038	24,085	27,623	25,967	21,145	29,421	29,566	**266,115**
to U.S. government	1,011	1,124	1,228	1,043	1,003	1,117	1,232	961	1,233	1,484	**11,436**
to individuals in the U.S.	9,461	9,243	8,887	7,562	8,539	10,241	9,940	7,804	10,399	10,249	**92,325**
to foreign-owned corporations in the U.S.	328	243	248	228	269	242	217	169	201	186	**2,331**
Foreign origin	**32,736**	**32,107**	**28,835**	**23,989**	**23,992**	**26,548**	**24,463**	**18,775**	**24,848**	**23,784**	**260,077**
to U.S.-owned corporations abroad	2,231	2,274	2,032	1,660	1,715	1,839	1,694	1,364	1,961	1,970	**18,740**
to foreign corporations	26,196	25,721	22,985	19,019	18,589	20.549	18,665	14,447	18,875	17,879	**202,925**
to foreign governments	471	483	440	336	368	249	253	186	249	215	**3,250**
to foreign individuals	3,838	3,629	3,378	2,974	3,320	3,911	3,851	2,778	3,763	3,720	**35,162**
TOTAL	**70,860**	**71,661**	**67,200**	**56,860**	**57,888**	**65,771**	**61,819**	**48,854**	**66,102**	**65,269**	**632,284**
% FOREIGN	**46.2%**	**44.8%**	**42.9%**	**42.2%**	**41.4%**	**40.4%**	**39.6%**	**38.4%**	**37.6%**	**36.4%**	**41.1%**

a Patent figures were low in 1979 because the U.S. Patent & Trademark Office was short of funds to print patents it might otherwise have issued. **Source:** U.S. Patent & Trademark Office

HOLDERS OF U.S. PATENTS: Japan's share doubles in past decade

% of patents	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977	Total 1977–86	Total 1963–76
U.S. origin	**54**	**55**	**57**	**58**	**59**	**60**	**60**	**62**	**62**	**64**	**59**	**73**
Foreign origin[a]	**46**	**45**	**43**	**42**	**41**	**40**	**40**	**38**	**38**	**36**	**41**	**27**
Japan	19	18	17	15	14	13	12	11	10	10	14	5
West Germany	10	9	9	10	9	10	9	9	9	8	9	7
U.K.	3	3	3	3	4	4	4	4	4	4	4	4
France	3	3	3	3	3	3	3	3	3	3	3	3
Switzerland	2	2	2	2	2	2	2	2	2	2	2	2
Canada	2	2	2	2	2	2	2	2	2	2	2	2
Sweden	1	1	1	1	1	1	1	1	1	1	1	1
Italy	1	1	1	1	1	1	1	1	1	1	1	1
Netherlands	1	1	1	1	1	1	1	1	1	1	1	1
U.S.S.R.	—	—	—	—	—	1	1	1	1	1	—	—
Others	2	—	—	—	—	—	—	—	—	—	3	2

a Data for individual countries may not equal this number because of rounding. **Source:** U.S. Patent & Trademark Office

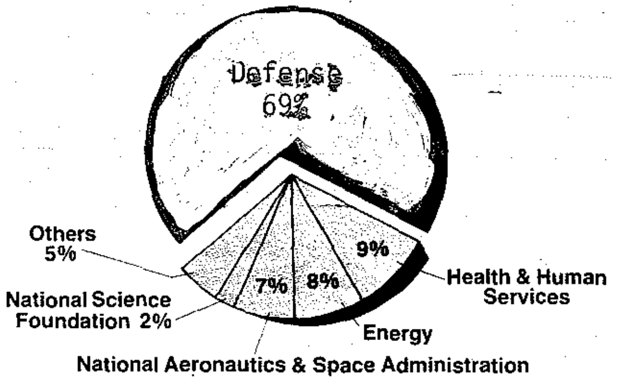
ABSTRACTS OF PAPERS IN *CHEMICAL ABSTRACTS:* Biochemistry's share holds steady at 40%

	1986	1985	1984	1983	1982	1981	1976	Percentage point change, 1976–86
BIOCHEMISTRY	40.4%	40.5%	40.5%	38.3%	39.5%	39.0%	38.8%	1.6%
	% of all biochemistry abstracts							
Mammalian hormones[a]	12.5%	12.3%	12.4%	12.9%	12.2%	6.8%	5.9%	6.6%
Pharmacology	12.2	12.3	11.6	11.8	12.0	12.4	12.0	0.2
Mammalian biochemistry[a]	10.8	11.1	11.3	11.1	11.6	15.6	16.3	−5.5
Toxicology	7.8	7.9	8.0	8.5	8.1	8.7	6.4	1.4
Immunochemistry	6.1	5.3	4.8	4.2	4.4	3.4	—	—
Biochemical genetics[b]	6.1	5.2	4.2	3.8	3.3	—	—	—
Microbial biochemistry[a]	5.7	5.7	5.2	5.1	5.3	5.6	5.0	0.7
Enzymes	5.6	5.6	5.8	6.1	5.9	5.9	6.4	−0.8
Plant biochemistry[a]	5.2	5.5	6.2	5.9	6.2	5.8	6.1	−0.9
Biochemical methods	5.0	4.9	4.9	4.9	4.6	5.7	—	—
General biochemistry	4.7	4.9	5.3	5.8	6.0	7.5	7.1	−2.4
Others	18.3	19.3	20.3	19.9	20.4	22.6	34.8	—
PHYSICAL, INORGANIC, AND ANALYTICAL CHEMISTRY	29.8	29.8	28.8	29.6	28.5	28.0	27.5	2.3
	% of all physical, inorganic, and analytical chemistry abstracts							
Spectra	20.0	18.4	18.0	17.6	17.2	18.0	17.8	2.2
Nuclear chemistry	19.9	21.8	22.2	22.5	22.6	21.6	19.7	0.2
Electric phenomena	10.8	10.8	10.8	10.0	10.5	11.0	10.5	0.3
Crystallography and liquid crystals	7.0	7.5	7.8	8.3	8.7	8.9	9.7	−2.7
General physical chemistry	7.0	6.9	6.9	7.3	7.3	7.2	7.0	0.0
Analytical chemistry	6.8	6.1	6.3	6.2	5.4	5.8	6.6	0.2
Others	28.5	28.5	28.0	28.1	28.3	27.5	28.7	−0.2
APPLIED CHEMISTRY AND CHEMICAL ENGINEERING	18.2	18.4	17.6	19.4	19.5	19.1	18.8	−0.6
	% of all applied chemistry and chemical engineering abstracts							
Water, wastes, and pollution	21.9	20.2	21.0	19.6	21.7	24.0	18.6	3.3
Metals and alloys	20.8	20.0	18.9	19.1	22.2	17.9	27.8	−7.0
Mineralogical and geological chemistry	12.0	12.5	14.6	14.1	13.6	14.1	17.6	−5.6
Fossil fuels, derivatives, and related products	9.0	10.1	10.1	10.3	9.4	9.4	6.0	3.0
Unit operations and processes	7.1	7.5	7.0	7.5	6.9	6.4	4.8	2.3
Others	29.2	29.7	28.4	29.4	26.2	28.2	25.2	4.0
ORGANIC CHEMISTRY	5.9	6.4	7.6	7.3	7.2	8.7	8.7	−2.8
	% of all organic chemistry abstracts							
Physical organic chemistry	27.3	30.6	32.0	30.5	31.5	37.0	38.4	−11.1
Organometallic and organometalloidal compounds	18.3	16.2	17.1	16.3	14.8	8.3	8.7	9.6
Heterocyclic compounds[a]	15.0	16.1	15.6	16.2	15.6	18.2	17.4	−2.4
Carbohydrates	7.8	5.7	5.7	5.8	5.8	5.4	5.1	2.7
Aromatic compounds[a]	7.3	6.3	6.3	7.1	7.2	8.7	8.0	−0.7
Biomolecules and their synthetic analogs[b]	5.0	4.9	4.4	4.5	3.7	—	—	—
Aliphatic compounds[a]	4.4	4.2	3.6	4.3	5.2	6.6	6.5	−2.1
Amino acids, peptides, and proteins[a]	3.9	4.6	4.8	4.5	4.4	4.2	4.3	−0.4
Others	11.0	11.4	10.5	10.8	11.8	11.6	11.6	—
MACROMOLECULAR CHEMISTRY	5.7	4.9	5.5	5.4	5.3	5.2	6.2	−0.5
	% of all macromolecular chemistry abstracts							
Synthetic high polymers	34.1	34.1	34.0	34.4	34.7	30.3	28.3	5.8
Plastics manufacture and uses	23.8	25.3	24.2	24.4	21.9	26.4	26.8	−3.0
Cellulose, lignin, paper, and other wood products	9.8	9.1	9.6	9.1	9.7	10.1	9.1	0.7
Textiles	8.8	8.2	7.3	7.9	8.9	9.9	11.1	−2.3
Coatings, inks, and related products	7.2	7.2	7.8	6.6	7.6	7.5	7.6	−0.4
Synthetic elastomers and natural rubber	6.7	6.8	7.3	7.5	7.8	7.9	8.6	−1.9
Others	9.6	9.3	9.8	10.1	9.4	7.9	8.5	1.1

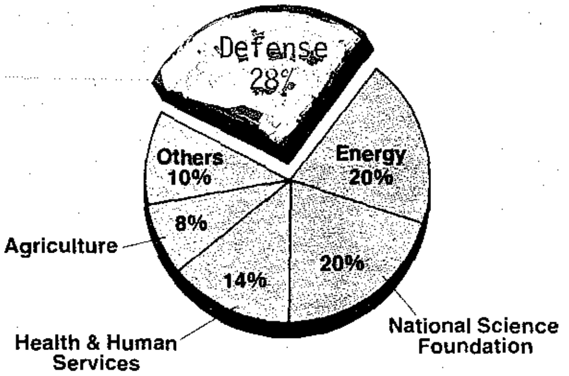
How to read this table: Using biochemistry as an example, 40.4% of all the papers abstracted by Chemical Abstracts Service in 1986 are in the various subdisciplines of biochemistry; 12.5% of all abstracts in biochemistry, in turn, are in the subdiscipline of mammalian hormones, 12.2% of biochemistry abstracts are in pharmacology, and so on. a Definition of section changed in 1982. b New section in 1982. **Source:** Chemical Abstracts Service

Defense's share of federal support grows

Defense gets nearly 70% of federal R&D funding but less than a third of funds for chemistry



Estimated fiscal 1987 total federal R&D obligations = $59.2 billion



Estimated fiscal 1987 federal chemistry research obligations = $671 million

Source: National Science Foundation

FEDERAL OBLIGATIONS FOR R&D: Up strongly thanks to big boost for military funds

$ Millions	1987[a]	1986[a]	1985	1984	1983	1982	Annual change	
							1986–87	1982–87
Defense	**$40,678.8**	**$33,646.3**	**$29,791.5**	**$25,372.9**	**$22,992.8**	**$20,622.6**	**21%**	**15%**
Air Force	17,356.5	13,757.5	13,260.9	12,091.6	10,812.6	9,357.9	26	13
Navy	10,700.8	10,137.3	9,127.4	7,605.6	6,068.2	5,845.1	6	13
Army	5,710.2	4,850.2	4,570.8	4,225.5	3,998.1	3,760.5	18	9
Defense agencies[b]	6,775.3	4,790.7	2,781.7	1,391.5	2,052.3	1,618.1	41	33
Health & Human Services	**5,270.8**	**5,611.3**	**5,451.0**	**4,830.7**	**4,352.5**	**3,940.7**	**−6**	**6**
National Institutes of Health	4,672.3	4,977.3	4,827.7[a]	4,257.4	3,789.2	3,433.1	−6	3
Alcohol, Drug Abuse & Mental Health Administration	383.1	396.2	377.6	337.2	302.2	248.1	−3	9
Energy	**4,770.7**	**4,691.6**	**4,996.0**	**4,673.6**	**4,536.7**	**4,708.2**	**2**	**0**
National Aeronautics & Space Administration	**3,926.0**	**3,478.4**	**3,327.2**	**2,821.9**	**2,661.6**	**3,077.9**	**13**	**5**
National Science Foundation	**1,508.3**	**1,333.5**	**1,345.6**	**1,202.8**	**1,062.0**	**975.3**	**13**	**9**
Agriculture	**909.2**	**923.0**	**943.0**	**866.2**	**847.6**	**797.3**	**−1**	**3**
Agricultural Research Service	497.0	463.1	469.7	451.3	443.4	404.9	7	4
Cooperative State Research Service	234.4	263.1	284.3	235.7	232.3	219.0	−11	1
Forest Service	111.5	120.1	113.1	108.4	107.7	112.1	−7	0
Interior	**350.6**	**388.3**	**391.7**	**410.9**	**382.5**	**381.1**	**−10**	**−2**
Geological Survey	207.6	218.6	214.9	208.9	157.0	152.6	−5	6
Environmental Protection Agency	**309.6**	**333.6**	**320.4**	**261.2**	**240.7**	**335.1**	**−7**	**−2**
Commerce	**300.9**	**391.1**	**398.8**	**358.2**	**335.0**	**336.3**	**−23**	**−2**
National Oceanic & Atmospheric Administration	196.3	268.1	269.8	244.3	222.0	222.0	−27	−2
National Bureau of Standards	91.4	99.3	100.5	95.5	95.0	88.8	−8	1
Others	**1,184.7**	**1,264.7**	**1,367.1**	**1,426.5**	**1,300.1**	**1,258.1**	**−6**	**−1**
TOTAL	**$59,209.6**	**$52,061.8**	**$48,332.3**	**$42,224.9**	**$38,711.5**	**$36,432.6**	**14%**	**10%**
ANNUAL CHANGE	**14%**	**8%**	**14%**	**9%**	**6%**	**4%**		

Note: Fiscal years. **a** Estimated. **b** Includes Defense Advanced Research Projects Agency, Defense Nuclear Agency, and others. **Source:** National Science Foundation

PERFORMERS OF FEDERALLY FUNDED RESEARCH: 54% is undertaken by industry

$ Millions	1987[a]	1986[a]	1985	1984	1983	1982	Annual change 1986–87	Annual change 1982–87
Industry	$31,787.9	$26,847.9	$23,774.3	$20,361.5	$18,649.0	$18,698.6	18%	11%
Federal intramural programs	15,396.7	13,533.4	12,998.4	11,572.3	10,581.9	9,141.0	14	11
Universities and colleges	6,558.7	6,554.7	6,299.0	5,565.1	4,966.4	4,605.5	0	7
University-associated FFRDCs[b]	2,712.8	2,446.2	2,534.5	2,324.9	2,265.8	1,976.7	11	7
Nonprofit institutions	2,451.3	2,318.1	2,365.0	2,094.4	1,822.9	1,612.3	6	9
Foreign	219.8	257.8	255.9	175.8	239.5	214.3	−15	1
State and local governments	82.4	103.6	105.2	130.9	186.0	184.3	−20	−15
TOTAL	**$59,209.6**	**$52,061.8**	**$48,332.3**	**$42,224.9**	**$38,711.5**	**$36,432.6**	**14%**	**10%**

Note: Fiscal years. a Estimated. **b Federally funded R&D centers.** Those administered by both industry and by nonprofit institutions are included in totals for their respective sectors. **Source:** National Science Foundation

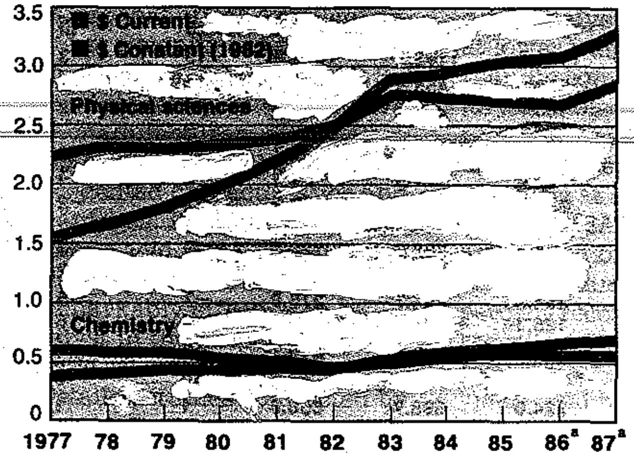
FEDERAL OBLIGATIONS FOR SCIENTIFIC DISCIPLINES: Slow growth for chemistry this year

$ Millions for research only	1987[a]	1986[a]	1985	1984	1983	1982	Annual change 1986–87	Annual change 1982–1987
Life sciences	**$ 6,289.2**	**$ 6,457.6**	**$ 6,366.2**	**$ 5,635.9**	**$ 5,177.9**	**$ 4,745.5**	**−3%**	**6%**
Engineering	**3,857.8**	**3,684.4**	**3,628.5**	**3,624.1**	**3,517.0**	**3,386.5**	**5**	**3**
Chemical	186.0	243.5	254.1	144.5	145.0	95.1	−24	14
Metallurgy and materials	465.5	464.1	439.1	341.1	332.5	309.1	0	9
Physical sciences	**3,300.3**	**3,071.8**	**3,044.0**	**2,969.0**	**2,891.4**	**2,500.4**	**7**	**6**
Chemistry	670.9	653.4	644.5	606.4	520.3	481.2	3	7
Physics	1,965.4	1,829.4	1,820.0	1,836.4	1,854.6	1,610.5	7	4
Environmental sciences	**1,483.4**	**1,458.2**	**1,403.6**	**1,275.9**	**1,251.2**	**1,148.3**	**2**	**5**
Mathematics and computer sciences	**759.0**	**665.0**	**577.5**	**440.3**	**419.4**	**350.1**	**14**	**17**
Other sciences	**1,151.4**	**1,117.7**	**1,110.3**	**1,033.6**	**996.6**	**891.4**	**3**	**5**
TOTAL	**$16,841.1**	**$16,454.7**	**$16,130.1**	**$14,978.8**	**$14,253.5**	**$13,022.2**	**2%**	**5%**
ANNUAL CHANGE	**2%**	**2%**	**8%**	**5%**	**9%**	**7%**		

a Estimated. **Source:** National Science Foundation

Federal support for physical science little changed since 1983 in real dollars

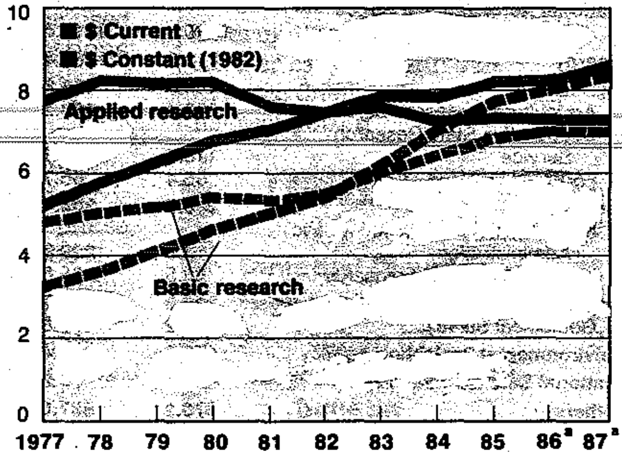
Federal obligations for research, $ billions



Note: Fiscal years. a Estimated. **Source:** National Science Foundation

Government funding of basic research catching up with applied research support

Federal obligations for research, $ billions



Note: Fiscal years. a Estimated. **Source:** National Science Foundation

FEDERAL OBLIGATIONS FOR BASIC RESEARCH: **Little growth this year**

$ Millions	1987ᵃ	1986ᵃ	1985	1984	1983	1982	Annual change 1986–87	1982–1987
Health & Human Services	**$3162.4**	**$3357.1**	**$3232.5**	**$2814.5**	**$2475.4**	**$2144.7**	**−6%**	**8%**
National Institutes of Health	2938.3	3133.6	3018.0ᵃ	2624.8	2313.0	2020.7	−6	8
Alcohol, Drug Abuse & Mental Health Administration	204.4	206.2	196.8	170.8	145.0	117.3	−1	12
National Science Foundation	**1422.6**	**1255.7**	**1261.8**	**1132.3**	**999.1**	**916.1**	**13**	**9**
Energy	**1063.1**	**945.9**	**942.6**	**830.4**	**767.7**	**642.2**	**12**	**11**
Defense	**995.9**	**994.3**	**861.4**	**847.9**	**785.6**	**686.7**	**0**	**8**
Navy	385.6	350.5	343.1	315.8	305.4	280.3	10	7
Air Force	284.5	234.4	198.3	192.4	164.2	145.8	21	14
Army	249.3	242.4	240.8	222.1	208.3	187.7	3	6
Defense agenciesᵇ	76.5	167.0	79.2	117.6	107.7	72.9	−54	1
National Aeronautics & Space Administration	**986.1**	**850.4**	**750.9**	**754.5**	**617.0**	**535.7**	**16**	**13**
Agriculture	**434.1**	**432.7**	**445.4**	**392.6**	**362.0**	**330.8**	**0**	**6**
Agricultural Research Service	267.2	247.6	250.2	240.6	215.3	192.9	8	7
Cooperative State Research Service	115.8	126.2	141.5	99.6	98.8	91.3	−8	5
Forest Service	43.1	50.5	44.1	41.2	38.8	38.7	−15	2
Interior	**115.7**	**137.6**	**138.3**	**125.9**	**103.0**	**76.5**	**−16**	**9**
Geological Survey	79.5	83.4	80.5	78.9	64.7	52.6	−3	9
Environmental Protection Agency	**37.0**	**39.3**	**38.6**	**29.6**	**22.2**	**32.7**	**−6**	**3**
Commerce	**19.5**	**22.1**	**23.2**	**20.6**	**19.2**	**16.9**	**−12**	**3**
National Bureau of Standards	19.1	21.2	22.1	20.2	18.4	16.5	−10	3
National Oceanic & Atmospheric Administration	0	0	0	0	0	0	—	—
Others	**111.3**	**110.0**	**124.0**	**119.1**	**108.9**	**99.3**	**1**	**2**
TOTAL	**$8347.7**	**$8145.1**	**$7818.7**	**$7067.4**	**$6260.1**	**$5481.6**	**2%**	**9%**
ANNUAL CHANGE	**2%**	**4%**	**11%**	**13%**	**14%**	**9%**		

Note: Fiscal years. **a** Estimated. **b** Includes Defense Advanced Projects Agency, Defense Nuclear Agency, and others. **Source:** National Science Foundation

FEDERAL OBLIGATIONS FOR APPLIED RESEARCH: **Increases for Defense, NASA, and NSF**

$ Millions	1987ᵃ	1986ᵃ	1985	1984	1983	1982	Annual change 1986–87	1982–1987
Defense	**$2636.1**	**$2364.8**	**$2306.9**	**$2200.7**	**$2437.0**	**$2266.1**	**11%**	**3%**
Army	719.4	551.3	582.6	486.7	485.3	451.6	30	10
Air Force	562.2	573.4	538.4	547.7	524.2	488.1	−2	3
Navy	464.6	463.9	448.2	449.6	521.6	498.4	0	−1
Defense agenciesᵇ	889.9	776.2	737.7	716.6	905.9	828.1	15	1
Health & Human Services	**1724.0**	**1834.0**	**1795.8**	**1651.5**	**1545.4**	**1460.9**	**−6**	**3**
National Institutes of Health	1368.2	1452.8	1410.1ᵃ	1285.6	1165.2	1103.8	−6	4
Alcohol, Drug Abuse & Mental Health Administration	177.5	188.8	179.7	165.2	155.4	128.7	−6	7
National Aeronautics & Space Administration	**1396.5**	**1114.4**	**1032.7**	**954.7**	**927.8**	**871.4**	**25**	**10**
Energy	**913.3**	**1080.4**	**1198.4**	**1194.5**	**1193.4**	**1053.9**	**−15**	**−3**
Agriculture	**444.0**	**458.8**	**465.6**	**442.2**	**455.5**	**435.7**	**−3**	**0**
Agricultural Research Service	202.4	188.1	191.8	183.7	202.6	186.2	8	2
Cooperative State Research Service	118.7	136.9	142.8	136.2	133.5	127.7	−13	−1
Forest Service	65.4	66.7	65.7	63.9	65.1	69.0	−2	−1
Commerce	**236.7**	**304.4**	**301.0**	**276.1**	**265.6**	**259.2**	**−22**	**−2**
National Oceanic & Atmospheric Administration	163.8	229.7	224.4	197.7	188.9	188.5	−29	−3
National Bureau of Standards	63.5	65.6	64.5	63.5	63.1	57.4	−3	2
Interior	**210.9**	**227.5**	**231.0**	**254.3**	**264.7**	**275.0**	**−7**	**−5**
Geological Survey	118.2	127.8	130.0	125.1	89.9	99.4	2	6
Environmental Protection Agency	**170.0**	**180.4**	**176.0**	**142.3**	**152.4**	**210.7**	**−6**	**−4**
National Science Foundation	**85.7**	**77.8**	**83.8**	**70.5**	**62.9**	**57.1**	**10**	**8**
Others	**676.2**	**667.0**	**720.3**	**724.6**	**688.7**	**650.6**	**1**	**1**
TOTAL	**$8493.4**	**$8309.5**	**$8311.5**	**$7911.4**	**$7993.4**	**$7540.6**	**2%**	**2%**
ANNUAL CHANGE	**2%**	**0%**	**5%**	**−1%**	**6%**	**5%**		

Note: Fiscal years. **a** Estimated. **b** Includes Defense Advanced Research Projects Agency, Defense Nuclear Agency, and others. **Source:** National Science Foundation

CIRCLE 31 ON READER SERVICE CARD →

FEDERAL OBLIGATIONS FOR DEVELOPMENT: **Nearly 90% goes for military work**

$ Millions	1987[a]	1986[a]	1985	1984	1983	1982	Annual change 1986–87	Annual change 1982–87
Defense	**$37,046.8**	**$30,287.2**	**$26,623.2**	**$22,324.3**	**$19,770.1**	**$17,669.8**	**22%**	**16%**
Air Force	16,509.8	12,949.7	12,524.3	11,351.5	10,124.2	8,724.0	27	14
Navy	9,850.6	9,322.9	8,336.1	6,840.2	5,241.2	5,066.4	6	14
Army	4,741.6	4,056.6	3,747.4	3,516.8	3,304.5	3,121.3	17	9
Defense agencies[b]	5,808.9	3,847.5	1,964.8	557.3	1,038.7	717.1	51	52
Energy	**2,794.4**	**2,665.3**	**2,825.0**	**2,648.7**	**2,575.6**	**3,012.1**	**5**	**−1**
National Aeronautics & Space Administration	**1,543.4**	**1,513.6**	**1,543.6**	**1,112.7**	**1,116.8**	**1,670.7**	**2**	**−2**
Health & Human Services	**384.3**	**420.2**	**422.7**	**364.7**	**331.7**	**335.2**	**−9**	**3**
National Institutes of Health	365.8	390.9	399.6[a]	347.0	311.0	308.7	−6	3
Alcohol, Drug Abuse & Mental Health Administration	1.2	1.2	1.1	1.2	1.8	2.1	0	−11
Environmental Protection Agency	**102.6**	**113.9**	**105.8**	**89.2**	**66.1**	**91.7**	**−10**	**2**
Commerce	**44.7**	**64.6**	**74.6**	**61.5**	**50.2**	**60.2**	**−31**	**−6**
National Oceanic & Atmospheric Administration	32.5	38.4	45.4	46.6	33.1	33.5	−15	−1
National Bureau of Standards	8.8	12.5	14.0	11.8	13.6	14.9	−30	−10
Agriculture	**31.1**	**31.5**	**32.0**	**31.3**	**30.0**	**30.8**	**−1**	**0**
Agricultural Research Service	27.4	27.4	27.7	27.0	25.5	25.8	0	1
Forest Service	3.0	2.9	3.3	3.3	3.8	4.5	3	−8
Cooperative State Research Service	0	0	0	0	0	0	—	—
Interior	**24.0**	**23.2**	**22.4**	**30.7**	**24.8**	**29.6**	**3**	**−4**
Geological Survey	9.9	7.4	4.4	4.9	2.3	0.5	34	82
National Science Foundation	**0**	**0**	**0**	**0**	**0**	**2.2**	**—**	**—**
Others	**397.2**	**487.6**	**552.8**	**583.0**	**492.7**	**508.1**	**−19**	**−5**
TOTAL	**$42,368.5**	**$35,607.1**	**$32,202.1**	**$27,246.1**	**$24,458.0**	**$23,410.4**	**19%**	**13%**
ANNUAL CHANGE	**19%**	**11%**	**18%**	**11%**	**4%**	**3%**		

Note: Fiscal years. a Estimated. b Includes Defense Advanced Research Projects Agency, Defense Nuclear Agency, and others. **Source:** National Science Foundation

UNIVERSITY RESEARCH: **Not much change in funding overall, but chemistry gets more**

Federal obligations, $ millions	1987[a]	1986[a]	1985	1984	1983	1982	Annual change 1986–87	Annual change 1982–87
Life sciences	**$3124.8**	**$3288.8**	**$3192.2**	**$2800.2**	**$2460.0**	**$2205.0**	**−5%**	**7%**
Physical sciences	**816.9**	**757.2**	**749.7**	**697.8**	**596.5**	**559.1**	**8**	**8**
Chemistry	287.0	259.7	266.8	242.3	205.7	189.6	11	9
Physics	429.8	406.5	401.8	375.2	328.8	306.0	6	7
Engineering	**577.8**	**559.0**	**507.1**	**474.2**	**408.7**	**361.5**	**3**	**10**
Chemical	43.7	48.8	45.6	51.2	23.6	19.4	−10	18
Metallurgy and materials	121.1	125.9	107.2	87.7	86.0	75.3	−4	10
Environmental sciences	**410.2**	**380.2**	**361.1**	**319.5**	**316.9**	**274.7**	**8**	**8**
Mathematics and computer sciences	**338.3**	**302.8**	**253.1**	**181.6**	**172.4**	**139.7**	**12**	**19**
Other sciences	**360.6**	**367.4**	**347.8**	**304.1**	**297.8**	**255.7**	**−2**	**7**
TOTAL	**$5628.6**	**$5655.4**	**$5411.0**	**$4777.4**	**$4252.3**	**$3795.7**	**0%**	**8%**
ANNUAL CHANGE	**0%**	**5%**	**13%**	**12%**	**12%**	**2%**		

Note: Fiscal years. a Estimated. **Source:** National Science Foundation

UNIVERSITY BASIC RESEARCH: **More than half goes for life sciences**

Federal obligations, $ millions	1987[a]	1986[a]	1985	1984	1983	1982	Annual change 1986–87	Annual change 1982–87
Life sciences	**$2267.5**	**$2379.2**	**$2306.8**	**$1979.6**	**$1701.7**	**$1483.7**	**−5%**	**9%**
Physical sciences	**714.1**	**646.7**	**628.8**	**581.9**	**502.2**	**455.3**	**10**	**9**
Chemistry	259.3	227.9	234.9	212.1	181.9	165.3	14	9
Physics	362.3	332.8	317.0	293.9	264.7	238.6	9	9
Engineering	**448.0**	**419.7**	**366.6**	**340.3**	**295.5**	**259.0**	**7**	**12**
Chemical	33.7	29.9	27.6	29.6	18.9	16.8	13	15
Metallurgy and materials	108.7	116.3	95.8	79.9	76.8	69.6	−7	9
Environmental sciences	**380.4**	**350.2**	**330.7**	**288.9**	**284.3**	**256.0**	**9**	**8**
Mathematics and computer sciences	**202.1**	**202.0**	**172.1**	**152.6**	**146.8**	**118.8**	**0**	**11**
Other sciences	**202.2**	**187.8**	**169.0**	**147.4**	**147.2**	**120.5**	**8**	**11**
TOTAL	**$4214.3**	**$4185.5**	**$3974.0**	**$3490.7**	**$3077.7**	**$2693.3**	**1%**	**9%**
ANNUAL CHANGE	**1%**	**5%**	**14%**	**13%**	**14%**	**9%**		

Note: Fiscal years. a Estimated. **Source:** National Science Foundation

← CIRCLE 31 ON READER SERVICE CARD

BASIC RESEARCH IN PHYSICAL SCIENCE: **NSF, Defense score biggest gains for chemistry**

Federal obligations, $ millions	1987[a]		1986[a]		1985		1984		1983	
	Physical sciences	Chemistry	Physical sciences	Chemistry	Physical sciences	Chemistry	Physical sciences	Chemistry	Physical sciences	Chemistry
Energy	$ 852.5	$112.1	$ 743.1	$108.5	$ 736.1	$102.3	$ 688.4	$108.4	$ 639.2	$104.3
National Aeronautics & Space Administration	535.6	7.8	437.7	5.1	377.9	10.2	338.7	5.4	329.5	7.7
National Science Foundation	380.7	128.9	340.6	109.9	347.9	112.7	330.2	106.8	283.5	88.5
Defense	213.2	82.1	212.7	73.9	185.5	70.1	212.2	60.0	198.4	55.6
Navy	87.5	30.3	84.8	26.1	73.9	26.7	100.4	20.7	98.0	18.7
Air Force	77.6	32.7	63.9	27.0	54.1	22.8	48.3	20.3	39.3	17.5
Army	46.2	19.0	51.7	20.8	54.3	20.6	59.8	19.1	58.7	19.4
Defense agencies[b]	1.8	0	12.3	0	3.2	0	3.7	0	2.5	0
Health & Human Services	81.4	73.4	86.8	78.3	83.6	75.4	72.0	65.0	61.8	55.0
National Institutes of Health	79.3	71.4	84.6	76.1	81.5[a]	73.3[a]	70.8	63.8	60.9	54.2
Alcohol, Drug Abuse & Mental Health Administration	2.1	2.0	2.2	2.1	2.1	2.1	1.2	1.2	0.9	0.9
Agriculture	33.5	33.3	35.6	33.5	35.6	33.6	45.4	43.5	40.0	38.2
Agricultural Research Service	26.9	25.5	25.0	23.7	25.2	23.9	37.4	36.0	33.5	32.2
Cooperative State Research Service	4.6	4.6	6.1	6.1	6.4	6.4	5.4	5.4	4.1	4.1
Forest Service	3.9	3.2	4.6	3.7	4.0	3.3	2.6	2.1	2.4	1.9
Commerce	15.9	5.2	18.1	6.7	19.7	7.2	16.3	4.8	15.7	4.7
National Bureau of Standards	15.9	5.2	17.6	6.3	18.9	6.4	16.3	4.8	15.7	4.6
Interior	7.0	5.5	7.9	6.3	7.6	6.0	7.1	5.6	2.9	1.8
Geological Survey	7.0	5.5	7.9	6.3	7.6	6.0	7.1	5.6	2.6	1.8
Environmental Protection Agency	3.4	2.9	3.6	3.1	3.5	3.0	3.0	3.0	2.3	1.9
Others	17.8	0.4	15.6	0.2	16.6	0.3	14.7	0.9	13.5	3.5
TOTAL	$2141.0	$451.3	$1901.7	$425.4	$1814.0	$420.8	$1728.0	$403.4	$1587.2	$362.2
ANNUAL CHANGE	13%	6%	5%	1%	5%	4%	9%	11%	14%	16%

Note: Fiscal years. a Estimated. b Includes Defense Advanced Research Projects Agency, Defense Nuclear Agency, and others. **Source:** National Science Foundation

ENGINEERING RESEARCH: **Support for chemical engineering drops sharply this year but is still twice th**

$ Millions	1987[a]			1986[a]			1985	
	Engineering	Chemical engineering	Metallurgy & materials	Engineering	Chemical engineering	Metallurgy & materials	Engineering	Chemical engineering
Defense	$1624.9	$ 54.5	$281.1	$1523.9	$ 50.3	$277.9	$1502.0	$ 53.3
Air Force	488.1	3.2	36.9	472.7	3.3	34.3	423.9	1.7
Army	434.9	23.5	41.3	336.1	20.9	37.7	344.3	26.7
Navy	409.9	27.8	120.1	408.5	26.1	121.1	421.2	24.8
Defense agencies[b]	292.1	0	82.8	306.6	0	84.8	312.6	0.1
National Aeronautics & Space Administration	1270.0	0.9	23.4	1021.6	0.8	17.7	931.6	0.6
Energy	322.0	58.8	73.6	463.6	126.2	68.7	511.3	136.6
National Science Foundation	231.3	41.2	47.6	195.6	34.4	42.1	193.3	32.6
Interior	69.6	4.4	25.4	94.9	4.9	40.9	100.2	4.8
Transportation	44.1	0.4	1.0	53.9	0.7	2.5	49.4	0.6
Environmental Protection Agency	43.7	17.5	2.5	45.6	18.1	2.7	44.6	18.0
Commerce	38.0	2.3	10.5	43.7	1.9	11.2	39.8	1.7
Agriculture	28.9	5.8	0	29.1	5.8	0	28.7	5.6
Others	185.3	0.3	0.5	212.5	0.4	0.4	227.4	0.4
TOTAL	$3857.8	$186.0	$465.5	$3684.4	$243.5	$464.1	$3628.5	$254.1
ANNUAL CHANGE	5%	−24%	0%	2%	−4%	6%	6%	76%

Note: Fiscal years. a Estimated. b Includes Defense Advanced Research Projects Agency, Defense Nuclear Agency, and others. **Source:** National Science Foundation

APPLIED RESEARCH IN PHYSICAL SCIENCE: **Chemical funding down slightly this year**

$ Millions[b]	1987[a] Physical sciences	1987[a] Chemistry	1986[a] Physical sciences	1986[a] Chemistry	1985 Physical sciences	1985 Chemistry	1984 Physical sciences	1984 Chemistry	1983 Physical sciences	1983 Chemistry
Energy	$ 511.6	$ 24.9	$ 538.7	$ 37.3	$ 606.1	$ 40.6	$ 603.5	$ 32.0	$ 584.8	$ 13.3
Defense	434.8	102.7	415.1	93.4	412.0	86.3	477.2	79.8	562.0	66.3
Army	129.7	71.0	116.4	62.1	124.2	57.5	77.4	47.2	86.9	39.9
Air Force	59.0	17.0	60.2	17.3	57.5	16.7	58.6	16.4	54.5	13.7
Navy	55.6	13.9	53.9	13.4	50.7	11.6	69.2	15.9	135.2	12.3
Defense agencies[c]	190.5	0.8	184.6	0.6	179.6	0.4	272.1	0.3	285.4	0.3
National Aeronautics & Space Administration	81.9	6.0	79.9	6.0	76.3	6.1	25.6	1.9	40.4	1.7
Commerce	34.0	9.8	35.1	10.4	35.2	10.5	36.9	10.5	33.9	9.3
National Bureau of Standards	25.1	8.5	25.0	8.4	25.3	9.0	28.1	9.3	26.7	8.1
National Oceanic & Atmospheric Administration	8.9	1.3	10.1	2.0	9.9	1.4	8.9	1.3	7.2	1.2
Health & Human Services	26.5	23.0	28.4	24.6	27.3	23.6	24.7	21.3	22.6	19.2
National Institutes of Health	24.6	21.1	26.1	22.4	25.4[a]	21.8[a]	23.6	20.3	21.5	18.1
Alcohol, Drug Abuse & Mental Health Administration	1.9	1.9	2.3	2.2	1.9	1.9	1.1	1.1	1.2	1.1
Agriculture	24.2	22.2	25.8	23.8	26.4	24.4	27.3	25.5	27.6	25.6
Agricultural Research Service	13.9	12.9	12.9	12.0	13.1	12.2	16.9	15.6	18.6	17.2
Cooperative State Research Service	6.8	6.8	9.3	9.3	9.7	9.7	8.1	8.1	6.7	6.7
Forest Service	3.5	2.4	3.6	2.5	3.5	2.4	2.4	1.8	2.3	1.7
Environmental Protection Agency	15.4	14.1	16.1	14.9	15.7	14.5	13.8	12.9	13.9	12.8
Interior	14.5	12.5	16.2	13.9	15.5	13.3	15.7	13.6	5.5	4.4
Geological Survey	14.5	12.5	16.2	13.9	15.5	13.3	14.9	12.8	4.7	3.8
National Science Foundation	12.5	3.1	11.3	2.7	11.8	2.9	10.9	3.1	9.4	3.9
Others	3.9	1.3	3.3	1.0	3.8	1.4	5.4	2.4	4.2	1.6
TOTAL	$1159.3	$219.6	$1170.0	$228.0	$1230.1	$223.6	$1241.0	$203.0	$1304.3	$158.1
ANNUAL CHANGE	−1%	−4%	−5%	2%	−1%	10%	−5%	28%	1%	−7%

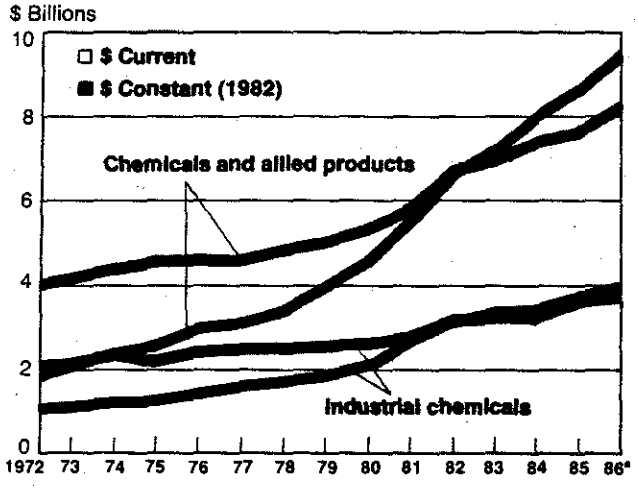
Note: Fiscal years. a Estimated. b Obligations. c Includes Defense Advanced Research Projects Agency, Defense Nuclear Agency, and others. **Source:** National Science Foundation

the level of five years ago

1985	1984			1983			1982		
Metallurgy & materials	Engineering	Chemical engineering	Metallurgy & materials	Engineering	Chemical engineering	Metallurgy & materials	Engineering	Chemical engineering	Metallurgy & materials
$260.9	$1488.4	$ 38.4	$180.3	$1573.9	$ 44.9	$179.3	$1473.3	$39.0	$159.3
28.6	439.5	3.5	30.3	419.3	3.1	38.2	387.3	2.9	35.1
42.2	324.8	23.5	35.5	318.9	29.3	28.4	297.2	24.4	31.7
121.1	398.4	11.3	53.9	395.5	11.9	50.0	378.0	11.6	49.3
69.0	325.7	0.2	60.6	440.2	0.6	62.8	410.8	0.2	43.1
15.8	967.8	0.3	14.2	799.6	1.0	19.1	771.7	0.4	16.2
68.4	439.0	46.1	68.7	440.2	51.9	62.6	420.8	1.1	61.2
42.7	164.9	27.7	27.3	142.5	21.5	27.3	129.9	18.8	26.4
39.8	111.4	4.5	42.2	91.4	0.4	31.5	87.1	1.4	32.8
1.5	51.1	1.2	1.9	56.1	1.0	1.4	48.3	0.5	1.0
2.6	37.8	17.8	0	47.8	16.7	3.5	76.4	26.0	5.2
6.9	35.3	1.8	6.4	37.4	1.3	7.8	32.0	2.0	7.1
0	56.7	6.4	0	54.7	6.2	0	51.2	5.8	0
0.5	271.7	0.3	0.1	273.4	0.1	0	295.8	0.1	0
$439.1	$3624.1	$144.5	$341.1	$3517.0	$145.0	$332.5	$3386.5	$95.1	$309.1
29%	3%	0%	3%	4%	53%	8%	10%	38%	21%

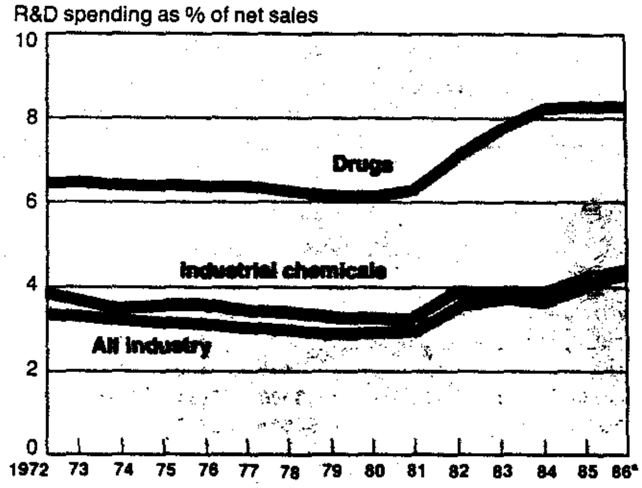
Industrial support for R&D up only 5%

With inflation low, chemical companies' R&D outlays rise smartly in real terms



a C&EN estimates. Source: National Science Foundation

Outlays for industrial R&D are rising at slightly faster rate than industrial sales



a C&EN estimates. Source: National Science Foundation

TOTAL FUNDS FOR INDUSTRIAL R&D: Drug producers continue to set a fast pace

$ Millions	1986ª	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976	Annual change 1985–86	Annual change 1976–86
Chemicals and allied products	$ 9,500	$ 8,667	$ 8,028	$ 7,293	$ 6,659	$ 5,625	$ 4,636	$ 4,038	$ 3,580	$ 3,202	$ 3,017	10%	12%
Industrial chemicals	4,150	3,915	3,512	3,411	3,301	2,802	2,197	1,962	1,798	1,668	1,524	6	11
Drugs	4,070	3,548	4,516	3,882	3,358	2,823	1,777	1,517	1,308	1,117	1,091	15	14
Other chemicals	1,280	1,204					662	559	474	417	401	6	12
Other industries	74,900	69,512	63,442	56,110	51,337	46,185	39,869	34,188	29,724	26,623	23,980	8	12
TOTAL	$84,400	$78,179	$71,470	$63,403	$57,996	$51,810	$44,505	$38,226	$33,304	$29,825	$26,997	8%	12%

a C&EN estimates Source: National Science Foundation

COMPANY FUNDS FOR INDUSTRIAL R&D: Chemical industry spends about a sixth of the total

$ Millions	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976	1975	Annual change 1984–85	Annual change 1975–85
Chemicals and allied products	$ 8,352	$ 7,797	$ 6,845	$ 6,226	$ 5,205	$ 4,264	$ 3,692	$ 3,250	$ 2,907	$ 2,751	$ 2,490	7%	13%
Industrial chemicals	3,618	3,289	2,970	2,879	2,393	1,856	1,617	1,473	1,387	1,275	1,173	10	12
Drugs	3,545	3,381	2,937	2,490	2,064	1,756	2,075	1,777	1,520	1,476	1,317	5	14
Other chemicals	1,189	1,126	938	856	747	653						6	
Other industries	43,344	40,511	36,016	33,286	30,223	26,212	22,016	18,865	16,433	14,685	13,092	7	13
TOTAL	$51,696	$48,308	$42,861	$39,512	$35,428	$30,476	$25,708	$22,115	$19,340	$17,436	$15,582	7%	13%

Source: National Science Foundation

FEDERAL FUNDS FOR INDUSTRIAL R&D: Of little significance for the chemical industry

												Annual change	
$ Millions	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976	1975	1984–85	1975–85
Chemicals and allied products	$ 316	$ 232	$ 448	$ 434	$ 421	$ 372	$ 346	$ 330	$ 295	$ 266	$ 236	36%	3%
Industrial chemicals	298	223	440	423	409	341	345	325	281	249	218	34	3
Drugs and other chemicals	18	9	8	11	12	31	1	5	14	17	18	100	0
Other industries	**26,168**	**22,930**	**20,094**	**18,049**	**15,961**	**13,657**	**12,172**	**10,859**	**10,190**	**9295**	**8369**	**14**	**12**
TOTAL	**$26,484**	**$23,162**	**$20,542**	**$18,483**	**$16,382**	**$14,029**	**$12,518**	**$11,189**	**$10,485**	**$9561**	**$8605**	**14%**	**12%**

Source: National Science Foundation

R&D BY U.S. COMPANIES ABROAD: Relatively small but expanding steadily

												Annual change	
$ Millions	1986[a]	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976	1985–86	1976–86
Chemicals and allied products	**$ 900**	**$ 816**	**$ 793**	**$ 732**	**$ 684**	**$ 715**	**$ 603**	**$ 500**	**$ 395**	**$ 332**	**$ 312**	**10%**	**11%**
Industrial and other chemicals	440	409	363	354	313	287	245	199	151	133	108	8	15
Drugs	460	406	430	378	371	428	357	301	244	199	204	13	8
Other industries	**3100**	**2931**	**2786**	**2544**	**2413**	**2679**	**2562**	**2254**	**1814**	**1545**	**1347**	**6**	**9**
TOTAL	**$4000**	**$3747**	**$3579**	**$3276**	**$3097**	**$3393**	**$3165**	**$2754**	**$2209**	**$1877**	**$1659**	**7%**	**9%**

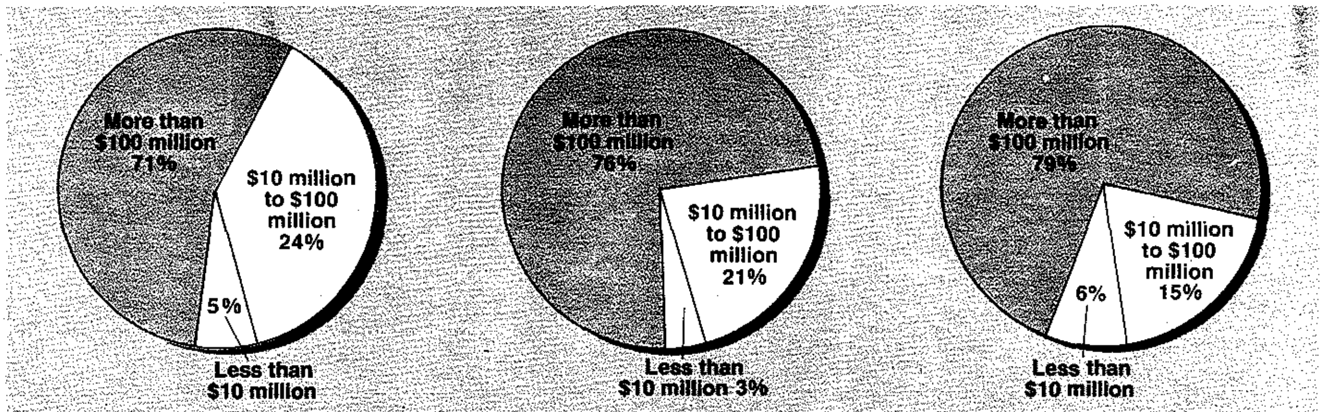
a C&EN estimates. **Source:** National Science Foundation

CHEMICAL R&D SPENDING: Slight rise last year largely reflects Carbide's major divestments

$ Millions	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976	1986 R&D spending as % of sales
Air Products	$ 61	$ 51	$ 44	$ 40	$ 37	$ 32	$ 30	$ 24	$ 23	$ 24	$ 19	3.1%
American Cyanamid	278	251	232	208	185	166	148	130	108	96	83	7.3
Dow Chemical	605	547	507	492	460	404	314	269	232	203	188	5.4
Du Pont[a]	1070	1080	1000	875	775	647	591	509	461	367	353	9.0
Ethyl	47	47	40	39	39	37	34	29	25	28	25	3.0
W. R. Grace	94	92	81	73	64	57	45	42	37	32	28	2.5
Hercules	71	76	72	74	74	65	57	50	43	40	37	2.7
International Flavors	39	34	32	32	31	30	29	27	24	20	16	6.3
Lubrizol	51	44	33	37	36	33	28	23	21	19	17	5.2
Monsanto	596	470	370	290	264	233	208	161	136	132	114	8.7
Nalco Chemical	33	32	32	30	33	30	28	21	17	14	12	4.5
Olin	56	53	52	49	45	38	31	26	25	25	23	3.3
Pennwalt	45	39	36	33	31	27	24	22	23	21	19	4.1
Petrolite	12	12	12	13	10	8	7	6	5	5	4	4.3
PPG Industries	204	176	150	127	127	119	103	83	70	61	56	4.3
Rohm & Haas	133	124	109	100	92	77	67	54	49	45	43	6.4
Union Carbide[b]	148	275	265	245	240	207	166	161	156	156	143	2.4
TOTAL	**$3543**	**$3403**	**$3067**	**$2757**	**$2543**	**$2210**	**$1910**	**$1637**	**$1455**	**$1288**	**$1180**	**5.7%**
ANNUAL CHANGE	**4%**	**11%**	**11%**	**8%**	**15%**	**16%**	**17%**	**13%**	**13%**	**9%**	**8%**	

a Figures exclude petroleum and coal segments. b Union Carbide divested a substantial part of its businesses in 1986; on a pro forma basis, R&D spending was $181 million in 1985 and $178 million in 1984. **Source:** Company data

Companies whose annual R&D budgets top $100 million do more than 70% of all R&D



1985 chemicals and allied products R&D funds = $8.7 billion

1985 industrial chemicals R&D funds = $3.9 billion

1985 industry R&D funds = $78.2 billion

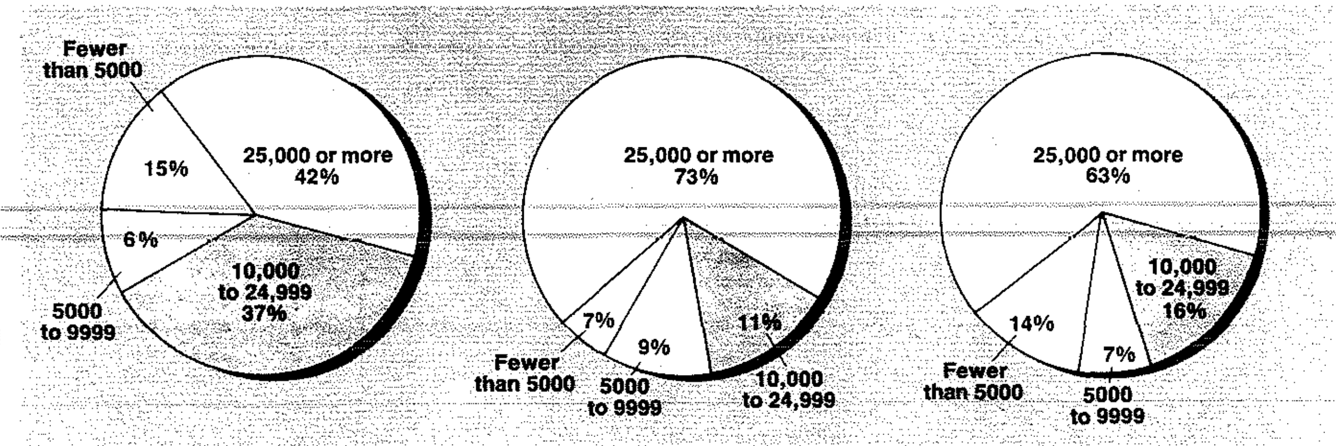
Note: Ranges indicate size of companies' 1985 R&D program. **Source:** National Science Foundation

R&D SCIENTISTS AND ENGINEERS IN INDUSTRY: **Increasing faster for chemicals**

Thousands[a]	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976	Annual change 1985–86	Annual change 1976–86
Chemicals and allied products	**71.3**	**67.0**	**67.1**	**66.0**	**61.6**	**54.7**	**51.4**	**50.0**	**48.3**	**46.4**	**44.4**	6%	5%
Industrial chemicals	26.8	25.0	26.7	27.2	25.9	21.6	20.9	21.4	21.3	20.6	20.1	7	3
Drugs	33.3	30.7	30.1	28.2	25.6	23.3	21.6	20.8	19.5	17.8	16.6	8	7
Other chemicals	11.2	11.3	10.3	10.6	10.1	9.8	8.9	7.8	7.5	8.0	7.8	−1	4
Other industries	**509.0**	**493.2**	**477.4**	**456.1**	**448.2**	**433.1**	**399.2**	**373.9**	**356.1**	**336.4**	**320.0**	3	5
TOTAL	**580.3**	**560.2**	**544.5**	**522.1**	**509.8**	**487.8**	**450.6**	**423.9**	**404.4**	**382.8**	**364.4**	4%	5%

Note: Data as of January of each year. a Full-time equivalent. **Source:** National Science Foundation

Chemical companies with 10,000 to 25,000 employees perform more than a third of R&D



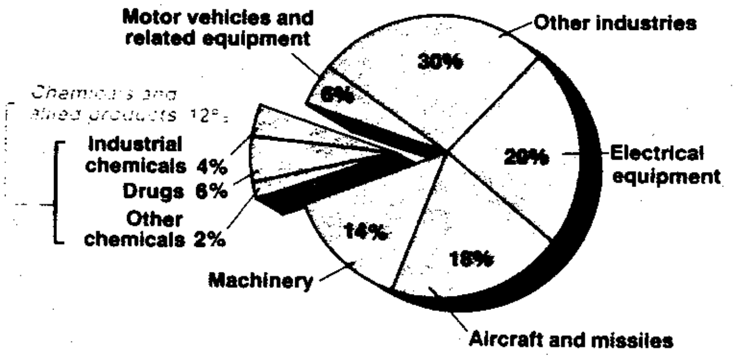
1985 chemicals and allied products R&D funds = $8.4 billion[a]

1985 industrial chemicals R&D funds = $3.6 billion[a]

1985 industry R&D funds = $51.7 billion[a]

Note: Ranges indicate companies' number of employees in 1985. a Excludes federal funding. **Source:** National Science Foundation

Chemical and drug companies provide jobs for 12% of all industrial scientists and engineers



1986 total industrial R&D scientists and engineers[a] = 580,300

a Full-time equivalent, as of January 1986. **Source:** National Science Foundation

R&D SCIENTISTS AND ENGINEERS PER 1000 EMPLOYEES: At new high in chemical industry

	1986	1984	1983	1982	1981	1980	1979	1978	1977	1976	1975
Chemicals and allied products	55	54	54	51	44	42	42	43	42	40	41
Industrial chemicals	42	44	45	44	37	36	36	38	38	36	38
Drugs	93	88	82	74	66	60	62	65	62	64	59
Other chemicals	38	37	36	36	33	30	27	27	29	28	29
All industry	36	38	35	33	29	27	27	27	27	27	26

Source: National Science Foundation

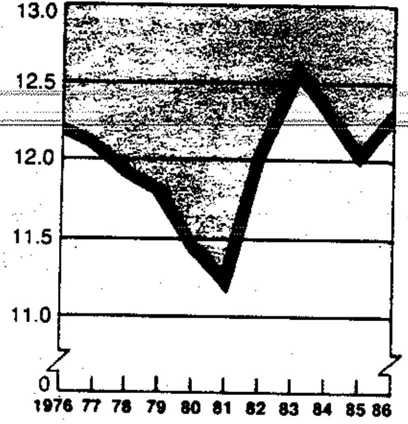
COST PER INDUSTRIAL R&D SCIENTIST OR ENGINEER: More than doubled in past decade

$ Thousands	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976	1975
Chemicals and allied products	$125.2	$119.1	$109.6	$104.4	$ 96.6	$ 87.4	$79.6	$72.8	$67.6	$66.5	$60.9
Industrial chemicals	151.1	135.1	126.6	124.3	118.0	103.4	92.8	84.2	79.6	74.7	67.5
Drugs	a	111.2	100.7	a	a	79.2	71.4	64.8	59.9	63.4	60.9
Other chemicals	a	a	a	a	a	66.5	66.5	61.6	53.8	50.8	43.2
All industry	$137.0	$129.7	$118.9	$112.4	$103.9	$ 94.9	$87.4	$80.4	$75.8	$72.2	$66.5

a Not separately available but included in chemicals and allied products. **Source:** National Science Foundation

Chemical firms' share of R&D personnel up in 1986

% of total industrial R&D scientists and engineers in the chemical industry[a]



a Full-time equivalent, as of January of each year
Source: National Science Foundation

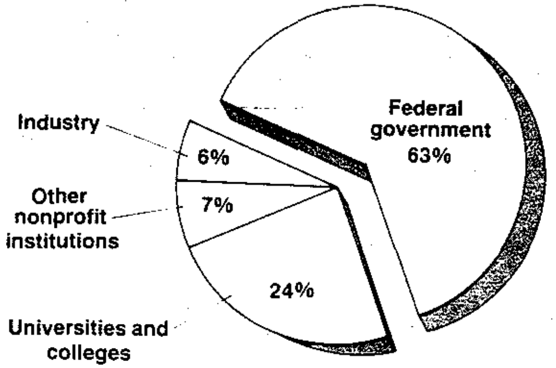
CHEMISTS IN INDUSTRY: Drugs biggest employer

Industry	% of industrial chemists				Mean salary ($ thousands)[a]		
	All chemists	B.S.	M.S.	Ph.D.	B.S.	M.S.	Ph.D.
Pharmaceuticals[b]	18%	17%	20%	17%	$40.3	$42.4	$57.2
Specialty chemicals	15	13	12	16	41.8	45.7	53.3
Basic chemicals	7	4	5	9	40.8	43.8	58.2
Plastics	5	5	6	6	42.3	47.6	56.6
Petroleum and natural gas	5	3	4	6	45.1	49.4	63.6
Agricultural chemicals	4	2	4	5	37.8	46.0	54.4
Coatings	4	5	4	3	41.6	47.7	50.6
Electronics	4	3	4	4	41.2	46.2	56.9
Food	3	5	4	2	39.8	46.2	56.5
Metals and minerals	2	4	2	1	40.2	38.8	47.0
Rubber	2	3	2	2	40.7	37.8	54.7
Biochemical products	2	1	2	2	35.1	35.5	57.5
Soaps and detergents	1	1	1	2	36.3	47.2	59.8
Paper	1	1	1	1	37.2	37.8	54.8
Other manufacturing	17	20	17	16	41.2	44.1	55.1
Nonmanufacturing	10	13	12	7	40.7	41.0	50.1

a As of March 1, 1987; to facilitate comparison, mean salaries are adjusted for differences in average length of experience for each group. b Includes personal care products. **Source:** ACS survey

University R&D increased 8% last year

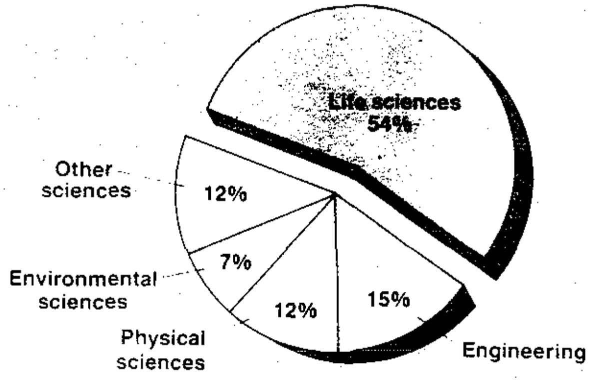
Nearly two thirds of academic R&D funding comes from federal government



Estimated fiscal 1986 academic R&D expenditures = $10.25 billion

Source: National Science Foundation

More than half of academic R&D is in the life sciences



Estimated fiscal 1986 academic R&D expenditures = $10.25 billion

Source: National Science Foundation

CHARACTER OF UNIVERSITY R&D SPENDING: Basic research gets two thirds

$ Millions	1986[a]	1985	1984	1983	1982	1981	1980	1979	1978[b]	1977	1976	Annual change 1985–86	Annual change 1976–86
Basic research	$ 6,900	$6377	$5638	$5269	$4857	$4576	$4026	$3612	$3176	$2800	$2549	8%	10%
Applied research	2,760	2580[a]	2370[a]	2101	2004	1866	1691	1465	1213	1067	1015	7	11
Development	590	517[a]	495[a]	437	415	377	343	284	236	200	164	8	14
TOTAL	**$10,250**	**$9504**	**$8503**	**$7807**	**$7276**	**$6819**	**$6060**	**$5361**	**$4625**	**$4067**	**$3729**	**8%**	**11%**
ANNUAL CHANGE	**8%**	**12%**	**9%**	**7%**	**7%**	**13%**	**13%**	**16%**	**14%**	**9%**	**9%**		

Note: Data for institutional fiscal years. a C&EN estimates. b Estimated, based on data from Ph.D.-granting institutions only. **Source:** National Science Foundation

SOURCE OF UNIVERSITY R&D FUNDS: Federal share is largest, but it is falling

$ Millions	1986[a]	1985	1984	1983	1982	1981	1980	1979	1978[b]	1977	1976	Annual change 1985–86	Annual change 1976–86
Federal government	$ 6,400	$6003	$5388	$4960	$4752	$4562	$4096	$3595	$3059	$2726	$2512	7%	10%
Industry	580	538	458	379	334	291	237	194	170	139	123	8	17
Universities	2,500	2258	2024	1881	1690	1520	1319	1198	1037	888	810	11	12
Other sources	770	704	633	587	500	446	409	374	359	314	284	9	10
TOTAL	**$10,250**	**$9504**	**$8503**	**$7807**	**$7276**	**$6819**	**$6060**	**$5361**	**$4625**	**$4067**	**$3729**	8%	11%

Note: Data for institutional fiscal years. a C&EN estimates. b Estimated, based on data from Ph.D.-granting institutions only. **Source:** National Science Foundation

FIELDS OF UNIVERSITY R&D SPENDING: Biggest growth for computers and math

$ Millions	1986[a]	1985	1984	1983	1982	1981	1980	1979	1978[b]	1977	1976	Annual change 1985–86	Annual change 1976–86
All sciences	**$ 8,730**	**$8120.5**	**$7296.5**	**$6695.5**	**$6250.2**	**$5857.6**	**$5195.4**	**$4593.0**	**$4023.6**	**$3568.5**	**$3297.3**	**8%**	**10%**
Life	5,510	5138.5	4607.3	4233.0	3972.4	3673.1	3216.9	2832.5	2538.0	2258.8	2101.7	7	10
Physical	1,230	1136.6	996.9	898.9	824.3	766.3	677.4	601.9	469.4	423.5	379.4	8	12
Physics	600	549.9	470.8	414.4	366.2	357.2	322.2	292.0	235.1	201.7	183.1	9	13
Chemistry	435	414.5	371.2	336.0	309.4	285.1	244.0	206.4	183.1	159.4	140.1	5	12
Environmental	755	707.0	649.5	620.5	559.3	550.3	509.1	452.9	379.4	319.4	288.5	7	10
Computer	340	277.7	222.7	175.5	149.5	113.1	114.2	97.9	67.4	55.6	44.5	22	23
Mathematical	145	129.4	124.4	108.4	98.9	89.1	78.6	78.5	58.8	52.3	42.5	12	13
Others	750	731.3	635.7	659.1	645.8	645.8	599.1	539.3	483.7	458.9	440.7	3	5
Engineering	**1,520**	**1383.2**	**1206.4**	**1111.3**	**1025.8**	**961.0**	**864.9**	**768.4**	**601.1**	**498.5**	**431.7**	**10**	**13**
Chemical	115	109.0	96.2	90.8	83.6	83.2	67.6	na	na	na	na	6	na
TOTAL	**$10,250**	**$9503.7**	**$8503.0**	**$7806.8**	**$7276.1**	**$6818.6**	**$6060.3**	**$5361.4**	**$4624.7**	**$4067.0**	**$3729.0**	**8%**	**11%**
ANNUAL CHANGE	**8%**	**12%**	**9%**	**7%**	**7%**	**13%**	**13%**	**16%**	**14%**	**9%**	**9%**		

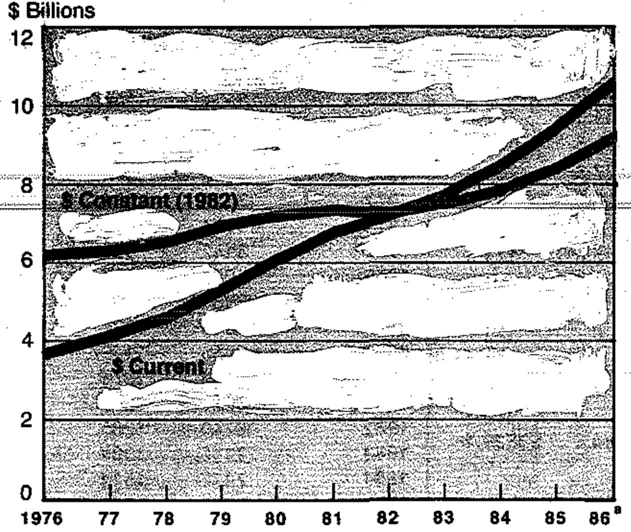
Note: Data for institutional fiscal years. a C&EN estimates. b NSF estimates, based on data from Ph.D.-granting institutions only. na = not available. **Source:** National Science Foundation

FEDERALLY FINANCED R&D SPENDING AT UNIVERSITIES: Growth slows in physical science

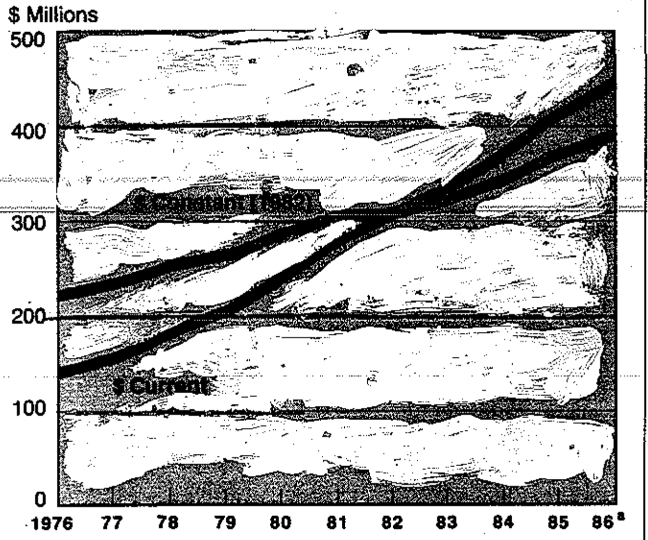
$ Millions	1986[a]	1985	1984	1983	1982	1981	1980	1979	1978[b]	1977	1976	Annual change 1985–86	Annual change 1976–86
All sciences	**$5420**	**$5145.0**	**$4609.4**	**$4221.8**	**$4054.0**	**$3899.3**	**$3500.6**	**$3068.9**	**$2651.2**	**$2389.4**	**$2221.3**	**5%**	**9%**
Life	3290	3138.7	2793.9	2565.3	2494.4	2364.2	2094.0	1818.8	1626.4	1474.0	1380.8	5	9
Physical	920	883.3	779.3	698.5	650.0	619.0	554.8	490.7	392.3	338.8	305.4	4	12
Physics	480	454.7	387.9	340.0	306.2	308.7	279.9	252.5	199.2	171.9	156.1	6	12
Chemistry	320	308.4	278.9	248.6	231.1	216.8	189.4	156.5	138.0	121.5	107.9	4	11
Environmental	500	480.7	451.5	427.9	392.2	392.7	372.5	329.2	275.1	238.6	211.8	4	9
Computer	230	193.1	161.6	127.8	107.0	93.5	77.0	69.2	41.2	37.5	32.9	19	21
Mathematical	115	96.1	91.3	76.7	72.1	67.9	61.1	60.4	44.1	40.6	32.9	20	13
Others	365	353.1	331.8	325.5	338.4	361.9	341.2	300.6	272.0	259.9	257.4	3	4
Engineering	**980**	**857.5**	**778.6**	**737.9**	**698.2**	**662.5**	**595.4**	**526.4**	**407.5**	**336.7**	**290.5**	**14**	**13**
Chemical	65	57.9	54.4	52.1	49.6	55.2	46.1	na	na	na	na	12	na
TOTAL	**$6400**	**$6002.6**	**$5388.0**	**$4959.7**	**$4752.2**	**$4561.8**	**$4096.0**	**$3595.3**	**$3058.7**	**$2726.1**	**$2511.9**	**7%**	**10%**
ANNUAL CHANGE	**7%**	**11%**	**9%**	**4%**	**4%**	**11%**	**14%**	**18%**	**12%**	**9%**	**10%**		

Note: Data for institutional fiscal years. a C&EN estimates. b NSF estimates, based on data from Ph.D.-granting institutions only. na = not available. **Source:** National Science Foundation.

Money for academic R&D, in constant dollars, is growing strongly . . .



. . . and funding for R&D in chemistry also forges higher in real terms



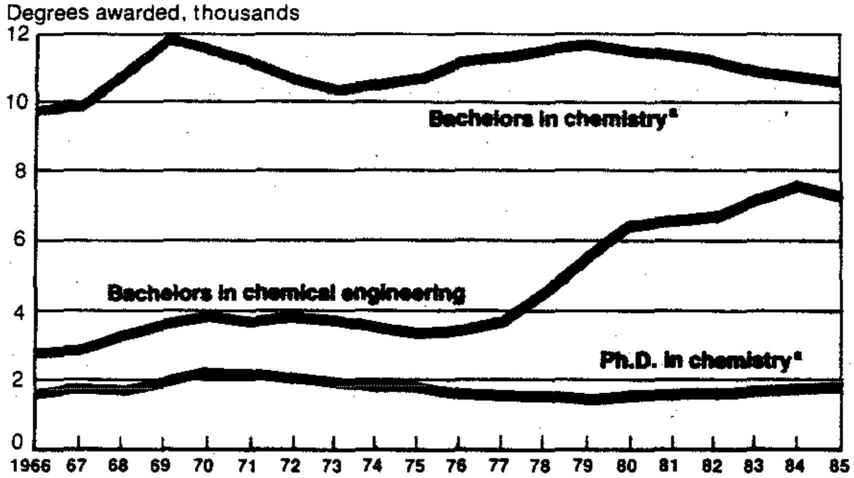
Note: Data for institutional fiscal years. a C&EN estimates. **Source:** National Science Foundation

TOP 10 UNIVERSITIES IN R&D SPENDING: 21% of total goes to top 10 institutions

$ Millions, fiscal 1985	Physical sciences	Chemistry[a]	Engineering	Environmental sciences	Life sciences	Math and computer sciences	Other sciences[b]	Total
1 Johns Hopkins U	$ 58.3	$ 4.2	$ 116.8	$ 28.3	$ 99.6	$ 71.7	$ 13.9	**$ 388.6**
2 Massachusetts Inst. of Technology	70.7	12.4	103.8	12.5	31.1	13.4	11.5	**243.0**
3 U of Wisconsin, Madison	23.7	5.2	21.8	17.8	115.8	7.4	21.9	**208.4**
4 Cornell U	36.2	6.3	30.6	5.2	114.5	6.6	10.1	**203.2**
5 Stanford U	35.2	7.1	58.3	3.2	83.1	14.1	5.3	**199.2**
6 U of Minnesota	11.2	3.3	18.1	3.7	127.2	3.4	9.7	**173.3**
7 U of Washington	11.6	2.0	11.9	18.0	99.8	3.8	18.9	**164.0**
8 U of Michigan	11.4	2.3	23.0	9.6	79.3	3.7	36.7	**163.7**
9 U of California, Berkeley	31.8	9.9	31.9	2.4	62.6	2.8	18.4	**149.9**
10 U of California, Los Angeles	15.5	6.7	18.5	8.8	93.3	1.2	12.4	**149.7**
TOTAL, TOP 10 INSTITUTIONS	$ 305.7	$ 59.4	$ 434.7	$109.4	$ 906.4	$128.1	$158.7	$2043.0
TOTAL, ALL INSTITUTIONS	$1136.6	$308.4	$1383.2	$707.0	$5138.5	$407.1	$731.3	$9503.7

a Included in physical sciences. b Includes social sciences, psychology, and other sciences not listed separately. **Source:** National Science Foundation

Fewer degrees awarded at undergraduate level



Note: Academic fiscal years. a Excludes biochemistry and geochemistry.
Source: National Center for Education Statistics

TOP 10 UNIVERSITY R&D CENTERS: 40% of funding goes to support work in physical sciences

$ Millions, fiscal 1985	Physical sciences	Engineering	Environmental sciences	Math and computer sciences	Total[a]
1 Lawrence Livermore Lab	$ 230.5	$ 432.2	$ 26.4	$ 95.0	$ 805.3
2 Los Alamos National Lab	335.8	233.0	16.9	64.1	704.0
3 Jet Propulsion Lab	72.7	295.2	61.8	236.5	666.2
4 Lincoln Lab	50.3[b]	186.2[b]	0	27.8[b]	264.5
5 Argonne National Lab	69.3	116.5	24.5	2.3	223.7
6 Brookhaven National Lab	134.7	29.5	9.4	0.7	199.0
7 Lawrence Berkeley Lab	103.6[b]	16.5[b]	17.6[b]	5.5[b]	174.6
8 Fermi National Accelerator Lab	151.3	0	0	0	151.3
9 Plasma Physics Lab	131.7	0	0	0	131.7
10 Stanford Linear Accelerator Center	79.7	0	0	0	79.7
All others	70.2	3.3	45.8	2.4	129.1
TOTAL, ALL FEDERALLY FUNDED R&D CENTERS	$1429.8	$1312.4	$202.4	$434.3	$3529.1

Note: Data for university-administered, federally funded R&D centers. a Includes life sciences and other sciences not listed separately. b Estimated. **Source:** National Science Foundation

CHEMICAL DEGREES: Doctorates increase

Academic fiscal year	Bachelors	Masters	Ph.D.s
DEGREES IN CHEMISTRY			
1966	9,735	1839	1571
1967	9,872	1831	1744
1968	10,847	2014	1757
1969	11,807	2070	1941
1970	11,617	2146	2208
1971	11,183	2284	2160
1972	10,721	2259	1971
1973	10,226	2230	1882
1974	10,525	2138	1828
1975	10,649	2006	1824
1976	11,107	1796	1623
1977	11,322	1775	1571
1978	11,474	1892	1525
1979	11,643	1765	1518
1980	11,446	1733	1551
1981	11,347	1654	1622
1982	11,062	1751	1722
1983	10,746	1604	1746
1984	10,704	1667	1744
1985	10,482	1719	1789
DEGREES IN CHEMICAL ENGINEERING			
1966	2848	994	354
1967	2869	949	305
1968	3211	1156	367
1969	3557	1136	409
1970	3720	1045	438
1971	3615	1100	406
1972	3663	1154	394
1973	3636	1051	397
1974	3454	1045	400
1975	3142	990	346
1976	3203	1031	308
1977	3581	1086	291
1978	4615	1237	259
1979	5655	1149	304
1980	6383	1271	284
1981	6527	1267	300
1982	6740	1285	311
1983	7145	1304	319
1984	7475	1514	330
1985	7146	1544	418

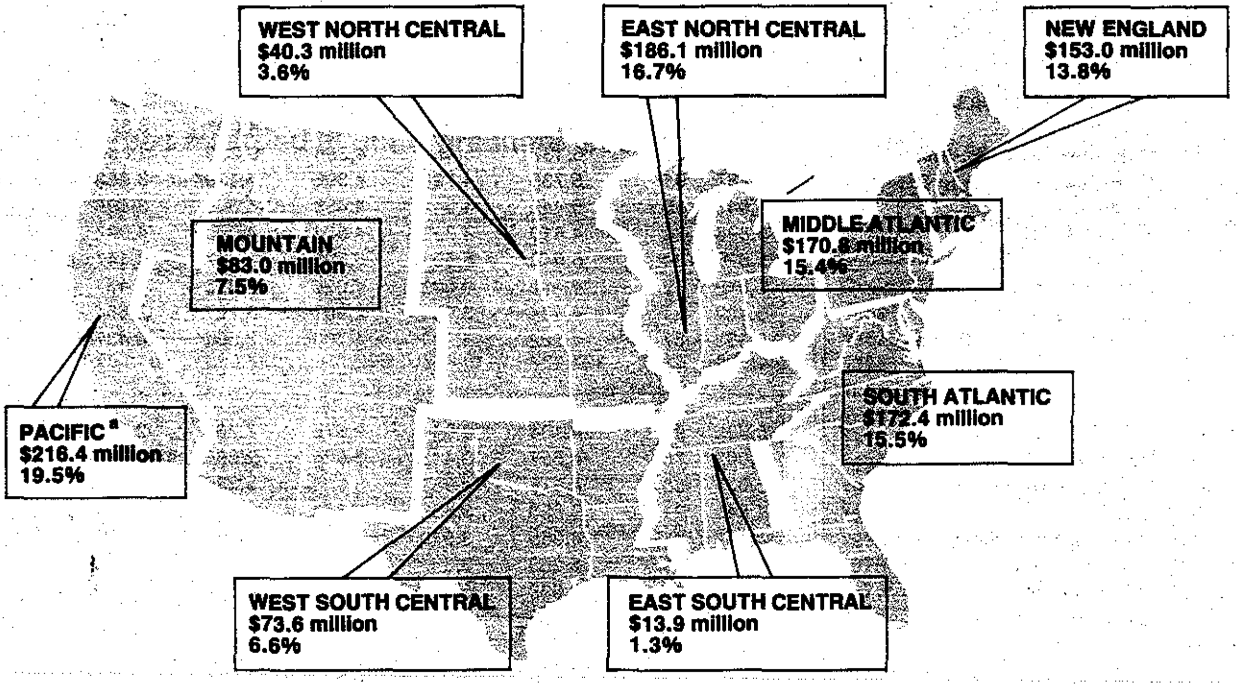
a Excludes biochemistry and geochemistry.
Source: National Center for Education Statistics

SCHOOLS SPENDING MOST ON CHEMICAL R&D: More than 20 spent at least $5 million in 1985

Rank			1985							Annual change	
1985	1984		Total spending ($ thousands)	% federal funds	1984	1983	1982 ($ thousands)	1981	1980	1984–85	1980–85
1	1	**Massachusetts Inst. of Technology**	$ 13,221	94%	$ 11,741	$ 8,914	$ 9,792	$ 8,222	$ 6,764	13%	14%
2	3	**U of California, Berkeley**	10,804	92	7,850	7,945	6,283	6,553	6,022	38	12
3	2	**Harvard U**	8,663	76	8,327[a]	6,898[a]	5,512[a]	6,123[a]	4,797[a]	4	13
4	5	**Stanford U**	8,354	85	6,809	6,375	6,116	5,564	4,788	23	12
5	6	**Cornell U**	7,962	79	6,710	5,717[a]	6,239[a]	4,618	3,808	19	16
6	8	**California Inst. of Technology**	7,605	92	6,446	6,994	6,136	6,901	6,328	18	4
7	12	**U of Wisconsin, Madison**	7,350	70	6,076	5,310	4,567	4,122	3,976	21	13
8	9	**U of Maryland, College Park**	7,289	46	6,324	6,333[a]	4,718[a]	3,109	2,766	15	21
9	4	**U of California, Los Angeles**	7,243	93	7,219	5,496	5,187	4,420	4,159	0	12
10	10	**U of Illinois, Urbana**	7,079	76	6,284	5,886	6,422	5,239	4,261	13	11
		Total, first 10 institutions	85,570	82%	73,786	65,868	60,972	54,871	47,669	16%	12%
11	16	**Pennsylvania State U**	6,509	90	5,124	4,729	3,564	3,413	2,973	27	17
12	26	**U of Colorado**	6,360	85	4,134	3,302	3,492	4,047	3,332	54	14
13	11	**U of Massachusetts, Amherst**	6,291	63	6,137	5,162	4,364	3,230	1,889	3	27
14	13	**U of Chicago**	6,287	91	5,735	4,798[a]	4,396	4,139[a]	3,958[a]	10	10
15	15	**Purdue U**	6,018	90	5,443	4,542	4,459	4,600	3,596	11	11
16	19	**Texas A&M U**	5,896	71	4,610	4,963	4,521	4,069	4,097	28	8
17	14	**Indiana U**	5,820	84	5,642	5,551	5,341	3,637	3,147	3	13
18	17	**U of Notre Dame**	5,549	92	4,760	4,022	4,020	3,855	3,457	17	10
19	27	**Ohio State U**	5,422	71	4,104	3,739	2,907	3,227	2,654	32	15
20	18	**Columbia U, main division**	5,188	87	4,662	4,281	4,700	3,564	4,437	11	3
		Total, first 20 institutions	144,910	82%	124,137	110,957	102,736	92,652	81,209	17%	12%
21	25	**Yale U**	5,096	90	4,134	3,341	2,875	2,781	2,023	23	20
22	20	**Northwestern U**	5,062	78	4,557	3,413	3,026	2,995	2,367	11	16
23	21	**U of Pennsylvania**	5,025	88	4,375	4,982	3,068	3,386	3,688	15	6
24	34	**U of Utah**	4,840	91	3,830	3,638	3,364	3,076	2,811	26	11
25	22	**U of California, San Diego**	4,642	87	4,355	3,910	3,894	4,430	4,425[a]	7	1
26	23	**U of Oregon, main campus**	4,640	85	4,255	3,351	2,971	1,389	1,119	9	33
27	7	**U of Texas, Austin**	4,588	47	6,639	5,938	4,843	4,779	3,970	−31	3
28	31	**U of Pittsburgh**	4,580	84	3,965	3,267	2,714	2,039	1,641	16	23
29	29	**Johns Hopkins U**	4,466	93	4,030	4,592[a]	4,721	4,066	4,652	11	−1
30	30	**U of Florida**	4,380	53	4,024	2,347	2,248	2,302	2,283[a]	9	14
		Total, first 30 institutions	192,229	81%	168,301	149,736	136,460	123,895	110,188	14%	12%
31	28	**U of Minnesota**	4,167	79	4,067	4,047	4,297	4,260	2,642	2	10
32	36	**Princeton U**	3,963	78	3,670	3,509	3,062	2,513	2,065	8	14
33	37	**U of South Carolina**	3,729	75	3,423	2,721	2,483	1,087[b]	970[a]	9	31
34	33	**Georgia Inst. of Technology**	3,684	56	3,846	3,401	3,327	3,660	3,655	−4	0
35	40	**State U of New York, Stony Brook**	3,481	67	3,084	2,607	2,783	2,691	1,966	13	12
36	38	**Lehigh U**	3,456	39	3,361	3,664	2,584	1,680	1,066	3	27
37	24	**U of Connecticut**	3,429	44	4,135	2,720	2,049	1,748	1,300	−17	21
38	44	**Virginia Polytechnic Inst. & State U**	3,339	59	2,633	2,206	1,740	1,581	1,612	27	16
39	39	**Florida State U**	3,276	32	3,137	2,500	2,959	3,012	2,791	4	3
40	—	**Howard U**	3,269	91	3,672	2,336	982	1,406	1,287	−11	20
		Total, first 40 institutions	228,022	79%	203,329	179,447	162,726	147,533	129,542	12%	12%
41	44	**Michigan State U**	3,222	60	2,869[b]	2,714	2,493	2,178	1,638	12	14
42	41	**U of North Carolina, Chapel Hill**	3,201	90	2,945	2,397	2,240	2,016	1,789	9	12
43	32	**U of Rochester**	3,196	90	3,858	3,167	3,123	2,966	2,089	−17	9
44	—	**U of California, Irvine**	3,142	97	2,177	1,777	1,661	1,915	1,398	44	18
45	—	**U of California, Santa Barbara**	3,060	89	2,172	1,902	1,698	1,834	1,434	41	16
46	—	**U of Virginia**	3,046	71	2,516	2,069	1,778	1,781	1,203	21	20
47	—	**Iowa State U**	2,988	41	2,239	1,903	1,462	1,272	1,159	33	21
48	—	**U of Washington**	2,964	68	2,340	2,162	2,276	1,500	1,326	27	17
49	40	**Wayne State U**	2,093	99	3,071	2,645	2,656	2,261	2,163	−32	−1
50	—	**Syracuse U**	2,900	52	2,110	2,171	2,868	2,259	764	37	31
		Total, first 50 institutions	**$258,644**	**78%**	**$229,626**	**$202,354**	**$184,981**	**$167,515**	**$144,505**	**13%**	**12%**
		NATIONAL TOTAL	**$414,529**	**74%**	**$371,182**	**$336,025**	**$309,371**	**$285,520**	**$244,454**	**12%**	**11%**

Note: Data for institutional fiscal years. a Estimated. b Imputed. Source: National Science Foundation

East and West Coast schools account for 64% of R&D spending in physical sciences



Key to map: Using the Middle Atlantic states as an example, $170.8 million, or 15.4%, of all R&D expenditures in the physical sciences by all Ph.D.-granting universities and colleges are made in this geographical area. **Note:** Data are based on R&D expenditures of $1.11 billion in the physical sciences during the 1985 fiscal year.
[a] Includes Alaska, Hawaii, and outlying areas. **Source:** National Science Foundation

GRADUATE SCIENCE STUDENTS: **Chemistry, biochemistry, chemical engineering total 8%**

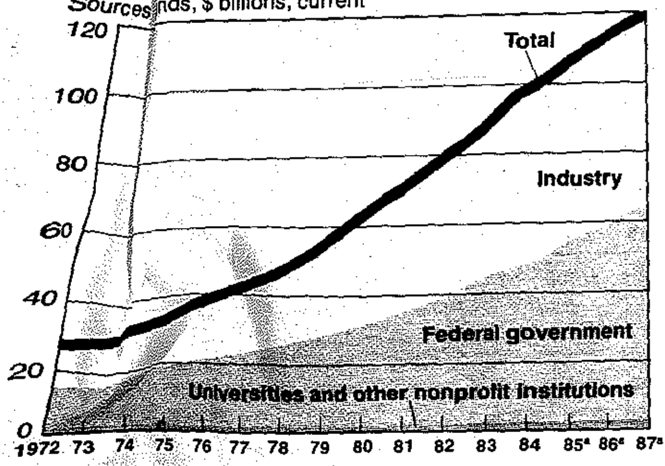
											Annual change	
Thousands	**1985**	**1984**	**1983**	**1982**	**1981**	**1980**	**1979**	**1978**	**1977**	**1976**	**1975**	**1984–85**	**1975–85**
Physical sciences	**29.4**	**28.4**	**27.7**	**26.5**	**25.8**	**25.4**	**24.9**	**24.7**	**24.8**	**24.8**	**24.5**	4%	2%
Chemistry	17.3	16.6	16.5	15.8	15.2	15.1	14.9	14.8	14.6	14.4	14.1	4	2
Physics	11.3	11.0	10.5	10.0	9.9	9.6	9.3	9.2	9.5	9.6	9.6	3	2
Life sciences	**93.8**	**92.5**	**91.2**	**90.7**	**90.9**	**90.7**	**87.5**	**85.9**	**83.3**	**77.2**	**73.6**	1	2
Biochemistry	4.7	4.5	4.2	4.1	4.0	4.0	3.9	4.0	3.8	3.7	3.7	4	2
Engineering	**91.8**	**88.3**	**86.4**	**78.2**	**74.4**	**70.1**	**67.2**	**64.3**	**64.4**	**62.9**	**64.6**	4	4
Chemical	7.0	7.2	7.4	6.9	6.3	5.9	5.4	5.2	5.1	5.1	4.9	−3	4
Metallurgical & materials	3.8	3.6	3.3	3.0	3.0	2.8	2.7	2.5	2.5	2.3	2.3	6	5
Petroleum	0.8	0.7	0.7	0.6	0.5	0.5	0.4	0.4	0.4	0.4	0.3	14	10
Environmental sciences	**14.3**	**14.3**	**14.3**	**13.8**	**13.1**	**12.8**	**12.6**	**12.2**	**12.3**	**11.7**	**11.0**	0	3
Mathematical and computer sciences	**39.0**	**35.4**	**33.2**	**30.3**	**27.1**	**25.0**	**22.7**	**21.5**	**21.1**	**21.7**	**21.3**	7	6
Psychology and social sciences	**102.8**	**104.5**	**105.4**	**107.3**	**108.7**	**109.7**	**105.8**	**101.2**	**100.6**	**99.8**	**98.7**	−2	0
TOTAL	**371.1**	**363.5**	**358.1**	**346.8**	**340.0**	**333.7**	**320.8**	**309.8**	**306.6**	**298.2**	**293.8**	**2%**	**2%**
ANNUAL CHANGE	**2%**	**2%**	**3%**	**2%**	**2%**	**4%**	**3%**	**1%**	**3%**	**1%**	**—**		

NOTE: Data for Ph.D.-granting institutions only. **Source:** National Science Foundation

) • Overview

Altho S. outlays for R&D are up fourf he past 15 years . . .

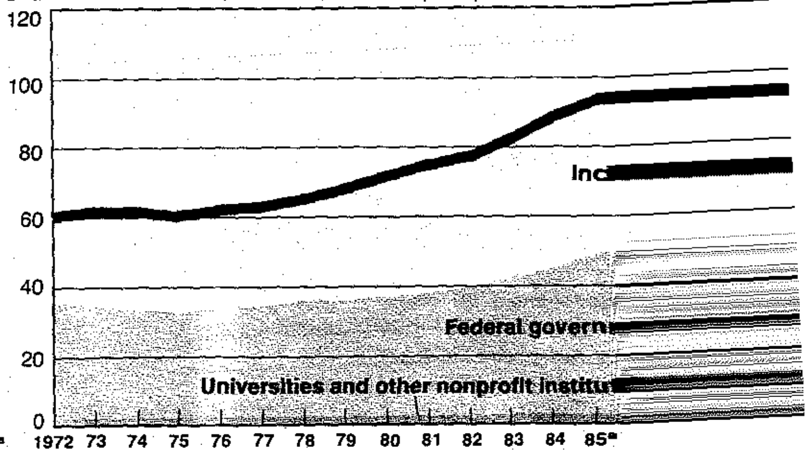
Sources nds, $ billions, current



a C&EN estimates. Source: National Science Foundation

. . . they are only two thirds higher if inflation is taken into account

Sources of R&D funds, $ billions, constant (1982)



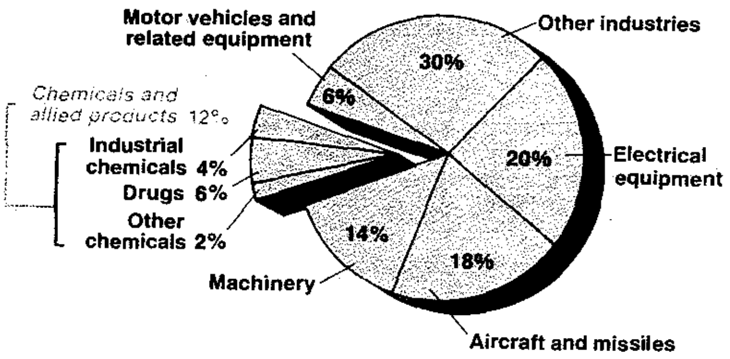
SOURCES OF R&D FUNDS: Industry and federal government each contribute nearly half

	$ Billions (current)											Annual ch	
	1987ᵃ	1986ᵃ	1985ᵃ	1984	1983	1982	1981	1980	1979	1978	1977	1986–87	1
Industry	$ 58.1	$ 55.3	$ 52.2	$48.8	$43.5	$40.1	$35.9	$30.9	$26.1	$22.5	$19.6	5%	
Federal government	60.0	56.0	51.8	45.6	40.7	36.5	33.4	29.5	26.8	23.9	21.6	7	
Universities and colleges	2.7	2.5	2.3	2.0	1.9	1.7	1.5	1.3	1.2	1.0	0.9	8	1
Other nonprofit institutions	1.5	1.4	1.3	1.2	1.1	1.0	1.0	0.9	0.8	0.8	0.7	7	
TOTAL	$122.3	$115.2	$107.5	$97.6	$87.2	$79.3	$71.8	$62.6	$54.9	$48.1	$42.8	6%	1
ANNUAL CHANGE	6%	7%	10%	12%	10%	10%	15%	14%	14%	12%	10%		

	$ Billions (1982, constant)												
Industry	$ 48.8	$ 48.3	$46.8	$45.2	$41.9	$40.1	$38.3	$36.1	$33.2	$31.1	$29.2	1%	5
Federal government	50.4	48.9	46.5	42.3	39.2	36.5	35.7	34.5	34.3	33.2	32.2	3	5
Universities and colleges	2.3	2.2	2.1	1.9	1.8	1.7	1.6	1.6	1.5	1.4	1.3	5	6
Other nonprofit institutions	1.3	1.2	1.2	1.1	1.1	1.0	1.0	1.1	1.1	1.1	1.0	8	3
TOTAL	$102.7	$100.6	$96.4	$90.5	$83.9	$79.3	$76.6	$73.2	$70.1	$66.8	$63.7	2%	5
ANNUAL CHANGE	2%	4%	7%	8%	6%	4%	5%	4%	5%	5%	2%		

a C&EN estimates. Source: National Science Foundation

Chemical and drug companies provide jobs for 12% of all industrial scientists and engineers



1986 total industrial R&D scientists and engineers[a] = 580,300

a Full-time equivalent, as of January 1986. **Source:** National Science Foundation

R&D SCIENTISTS AND ENGINEERS PER 1000 EMPLOYEES: At new high in chemical industry

	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976	1975
Chemicals and allied products	**55**	**54**	**54**	**51**	**44**	**42**	**42**	**43**	**42**	**40**	**41**
Industrial chemicals	42	44	45	44	37	36	36	38	38	36	38
Drugs	93	88	82	74	66	60	62	65	62	64	59
Other chemicals	38	37	36	36	33	30	27	27	29	28	29
All industry	**36**	**38**	**35**	**33**	**29**	**27**	**27**	**27**	**27**	**27**	**26**

Source: National Science Foundation

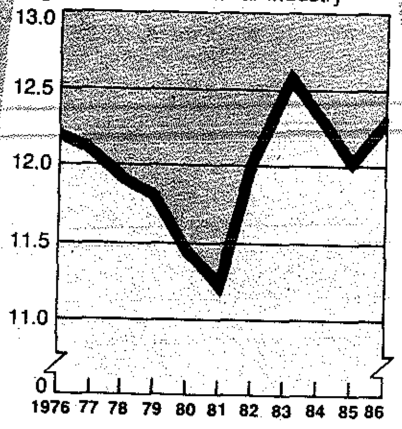
COST PER INDUSTRIAL R&D SCIENTIST OR ENGINEER: More than doubled in past decade

$ Thousands	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976	1975
Chemicals and allied products	**$125.2**	**$119.1**	**$109.6**	**$104.4**	**$ 96.6**	**$ 87.4**	**$79.6**	**$72.8**	**$67.6**	**$66.5**	**$60.9**
Industrial chemicals	151.1	135.1	126.6	124.3	118.0	103.4	92.8	84.2	79.6	74.7	67.5
Drugs	a	111.2	100.7	a	a	79.2	71.4	64.8	59.9	63.4	60.9
Other chemicals	a	a	a	a	a	66.5	66.5	61.6	53.8	50.8	43.2
All industry	**$137.0**	**$129.7**	**$118.9**	**$112.4**	**$103.9**	**$ 94.9**	**$87.4**	**$80.4**	**$75.8**	**$72.2**	**$66.5**

a Not separately available but included in chemicals and allied products. **Source:** National Science Foundation

Chemical firms' share of R&D personnel up in 1986

% of total industrial R&D scientists and engineers in the chemical industry[a]



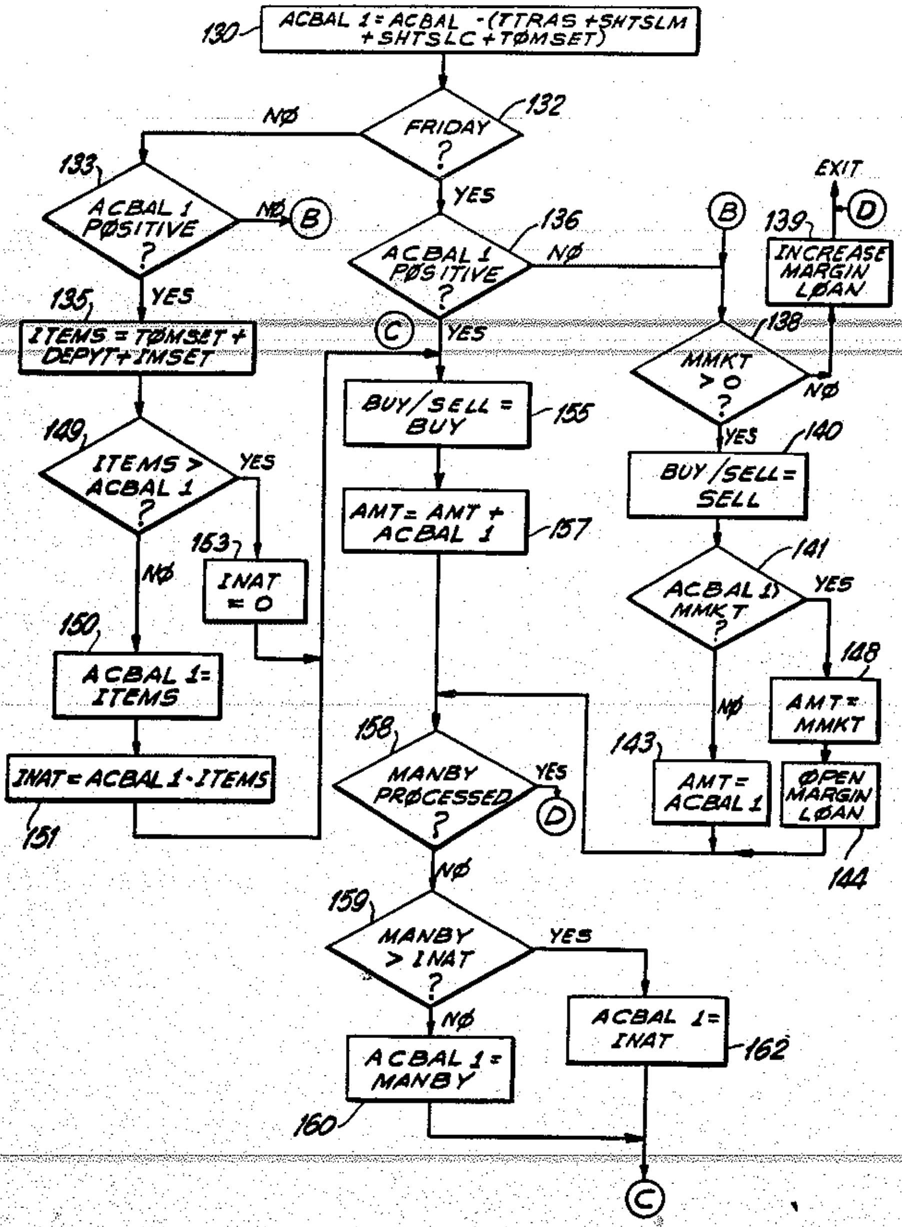
a Full-time equivalent, as of January of each year.
Source: National Science Foundation

CHEMISTS IN INDUSTRY: Drugs biggest employer

Industry	% of industrial chemists				Mean salary ($ thousands)[a]		
	All chemists	B.S.	M.S.	Ph.D.	B.S.	M.S.	Ph.D.
Pharmaceuticals[b]	18%	17%	20%	17%	$40.3	$42.4	$57.2
Specialty chemicals	15	13	12	16	41.8	45.7	53.3
Basic chemicals	7	4	5	9	40.8	43.8	58.2
Plastics	5	5	6	6	42.3	47.6	56.6
Petroleum and natural gas	5	3	4	6	45.1	49.4	63.6
Agricultural chemicals	4	2	4	5	37.8	46.0	54.4
Coatings	4	5	4	3	41.6	47.7	50.6
Electronics	4	3	4	4	41.2	46.2	56.9
Food	3	5	4	2	39.8	46.2	56.5
Metals and minerals	2	4	2	1	40.2	38.8	47.0
Rubber	2	3	2	2	40.7	37.8	54.7
Biochemical products	2	1	2	2	35.1	35.5	57.5
Soaps and detergents	1	1	1	2	36.3	47.2	59.8
Paper	1	1	1	1	37.2	37.8	54.8
Other manufacturing	17	20	17	16	41.2	44.1	55.1
Nonmanufacturing	10	13	12	7	40.7	41.0	50.1

a As of March 1, 1987; to facilitate comparison, mean salaries are adjusted for differences in average length of experience for each group. b Includes personal care products. **Source:** ACS survey

NEXT


130
ACBAL 1 = ACBAL - (TTRAS + SHTSLM + SHTSLC + TOMSET)
132
FRIDAY ?
NO
YES
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ACBAL 1 POSITIVE ?
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ITEMS = TOMSET + DEPYT + IMSET
136
ACBAL 1 POSITIVE ?
NO
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139
INCREASE MARGIN LOAN
138
MMKT > 0 ?
NO
YES
BUY/SELL = BUY
155
140
BUY/SELL = SELL
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ITEMS > ACBAL 1 ?
YES
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153
INAT = 0
AMT = AMT + ACBAL 1
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141
ACBAL 1 > MMKT ?
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ACBAL 1 = ITEMS
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AMT = ACBAL 1
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INAT = ACBAL 1 - ITEMS
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MANBY PROCESSED ?
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Software Protection—Integrating Patent, Copyright and Trade Secret Law

*Gregory J. Maier**

In intellectual property terms, software is a true hybrid. Although software has its origin in writing, it also possesses functionality, a property that clearly distinguishes it from ordinary writings. To write software is to formulate instructions for reconfiguring a collection of electronic logic gates and memory cells into a virtual structure capable of accomplishing a predetermined objective. Thus what begins intellectually as a form of coded writing ultimately operates as an electronic network. The same, certainly, cannot be said of other types of writings, which are simply not capable of reconfiguring logic gates, but only of expressing intellectual concepts. Similarly, other types of electronic networks are not capable of existing entirely in the form of writings. Software is a hybrid because it both expresses intellectual concepts and has the power to physically implement them with the aid of a computer.

It is the hybrid nature of software that causes its failure to fit neatly into any one existing category of intellectual property, resulting in seemingly endless confusion as to how it may best be protected. The purpose of this article is not to place software into any particular category of intellectual property protection, but rather to identify the hybrid nature of software and to demonstrate that the very different intellectual property concepts embodied within software can be coextensively protected by patent, copyright, and trade secret. This article advocates a prospectively straightforward approach to protecting the various types of intellectual property found in software: an approach in which patents protect functioning implementations of concepts, copyrights protect modes of expression, and trade secrets protect functional aspects when patent protection is unavailable or undesirable.

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*Oblon, Fisher, Spivak, McClelland & Maier, P.C. The author gratefully acknowledges the assistance of Donna L. Angotti, a law review student at Georgetown University Law Center.

As patent protection for software has experienced a more troubled legal history than copyright or trade secret protection, somewhat more emphasis is placed on historical development in this area than in the other areas.

PATENT PROTECTION

Misinformation concerning patent protection for software is widespread. Many programmers still believe that software cannot be protected by patent.[1] Pamphlets and publications make erroneous statements such as: "There is little chance in obtaining a patent for software"[2] and "[T]he great majority of software does not qualify for patent protection."[3] The academic community also misperceives the utility of patent protection. A recent law review comment states that case law "suggests that processes that use computers may be patented, but that protection does not extend to software programs themselves,"[4] and that "there continues to be no protection under current patent law for the large number of computer programs that are neither embodied in firmware nor related to a process of production."[5]

Confusion regarding the nonpatentability of software is not the fault of academic writers, but has its origin in case law.

The most troubling aspect of the case law is the part played in its development by the Patent and Trademark Office (PTO) because one would think that the PTO, the nation's only agency empowered to issue patents, would have had an interest in encouraging, rather than discouraging, the patenting of new technology. Early decisions of the Court of Custom and Patent Appeals (the predecessor of the Court of Appeals for the Federal Circuit) strongly suggested that the CCPA judged software patentable by the same standards as any other technology.[6] It was the PTO that originated the theory that software did not fall within the broad statutory classes of patentable technology set forth in 35 U.S.C. 101.[7] Sadly, this theory had its origins in bureau-

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[1] ABA Comm. On Computer Software, Res. 406-3, discussion (1986)).

[2] *Id.* (quoting How to Copyright Software and Secure Trademarks (Sofprotex ed. n.d.)).

[3] *Id.* (quoting Salone, How to Copyright Software (1984)).

[4] Comment, *Combating Software Piracy: A Statutory Proposal to Strengthen Software Copyright*, 34 De Paul L. Rev. (1985), at 1005.

[5] *Id.* at 1006.

[6] *See In re* Benson, 441 F.2d 682 (C.C.P.A. 1971), *rev'd sub nom.* Gottschalk v. Benson, 409 U.S. 63 (1972); *In re* Flook, 559 F.2d 21 (C.C.P.A. 1977), *rev'd sub nom.* Parker v. Flook, 437 U.S. 584 (1978).

[7] *See* Parker v. Flook, 437 U.S. 584, 587–588 (1978), *rev'g In re* Flook, 559 F.2d 21 (C.C.P.A. 1977).

cratic concerns over workload, rather than in careful theoretical analysis.[8] In the early 1970's, the PTO anticipated a deluge of software applications at a time when it did not have the resources to hire skilled software examiners.[9] Worry about workload and backlog motivated the PTO to lead the fight against software patentability.

The fight was against the respected logic of the CCPA and led to several rather tentative Supreme Court decisions.[10]

The first such decision was *Gottschalk v. Benson*,[11] which involved a method for converting binary coded decimal numerals directly into binary numerals for use with a general purpose digital computer. The court stated that, since the mathematical formulas in the claimed process involved had no application except in connection with a computer, any patent "would wholly preempt the mathematical formula and in practical effect would be a patent on the algorithm itself."[12] Despite the courts' noble attempt at a theoretical explanation of its preemption theory, its conclusion was influenced more by the cry for help from the PTO[13] than by sound principles of intellectual property law. In its opinion, the court cited the PTO's lack of classification techniques and search files to handle the supposed burden of examining software applications.[14] The court, persuaded by the PTO, felt that there was sufficient growth in the software industry without need for patent protection.[15] Thus the Supreme Court, instigated by the PTO, relied as much upon bureaucratic economic arguments as legal principles in foreclosing one of the fastest growing areas of technology from adequate patent protection.

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[8] *See id.*

[9] *See id.*

[10] *See, e.g.*, Gottschalk v. Benson, 409 U.S. 63 (1972), *rev'g In re* Benson, 441 F.2d 682 (C.C.P.A. 1971); Dann v. Johnston, 425 U.S. 219 (1976), *rev'g In re* Johnston, 502 F.2d 765 (C.C.P.A. 1974) (finding obvious claims to a machine system for automatic recording of bank checks and deposits under which checks and deposits are customer labeled with code categories which are processed by a data processor and permitting a bank to furnish a customer with a categorized breakdown of his transactions, despite the fact that the prior art did not possess the ability to allow a large number of small users to get the benefit of a large scale computer and still use individual bookkeeping methods); *Flook*, 437 U.S. 584.

[11] *Benson*, 409 U.S. 63.

[12] *Id.* at 72.

[13] *See id* at 72–73 (quoting Report of the President's Commission on the Patent System (1966)).

[14] *Id.*

[15] *See id.* at 72. Without reviewing the scope or desirability of copyright protection, the court concluded that it was available.

The CCPA resisted the Supreme Court's questionable logic and there ensued a further conflict between the courts.[16] Subsequently in *Parker v. Flook,* involving a method for updating alarm limits during catalytic conversion processes, the Supreme Court set forth its "point of novelty test" that a claim was directed to unpatentable subject matter if the point of novelty lay in the formula or algorithm recited in the claims.[17] Conventional or obvious post-solution activity was not sufficient to transform an unpatentable principle into a patentable process.[18] The court again considered the PTO's interest in not having to process "thousands of additional patent applications."[19]

This case truely marks the low point for patent protection of software inventions. The court's approach improperly imported into its analysis of eligibility of subject matter for patent protection (under § 101) the considerations of novelty and "inventiveness" which are the proper concerns of §§ 102 and 103.[20] The point of novelty test is wholly inconsistent with the conventional view that a patent claim must be considered as a whole.

Just prior to *Flook,* the CCPA had expressed its opinion that the "point of novelty" approach was inappropriate,[21] and had set forth its two step *(Freeman)* analysis for determining whether a claim preempts nonstatutory subject matter as a whole:

> First, it must be determined whether the claim directly or indirectly recites an algorithm in the *Benson* sense of that term, for a claim which fails even to recite an algorithm clearly cannot wholly preempt an algorithm. Second, the claim must be further analyzed to ascertain whether in its entirety it wholly preempts that algorithm.[22]

The *Freeman* court addressed the confusion regarding the word "algorithm." The *Benson* court had defined an algorithm as "A procedure for solving a given type of mathematical problem."[23] In *Free-*

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[16] Meyer, *Patentability of Business Methods Implemented by Computer*, 2 Computer Law. 12, 14 (Feb. 1985); *see* Diamond v. Diehr, 450 U.S. 175, 205 (1981) (Stevens, J., dissenting), *aff'g In re* Diehr, 602 F.2d 982 (C.C.P.A. 1979).

[17] *See Flook*, 437 U.S. at 594.

[18] *See id.* at 590.

[19] *Id.* at 587–588.

[20] *Id.* at 600 (Stewart, J., dissenting).

[21] *In re* Freeman, 573 F.2d 1237–1243 (C.C.P.A. 1978) (involving a system for typesetting alphanumeric information which positions mathematical symbols in an expression in accordance with their appearance while maintaining the mathematical integrity of the expression).

[22] *Id.* at 1245.

[23] *Benson*, 409 U.S. at 65.

man, the CCPA rejected a broader definition of an algorithm as "a step-by-step procedure for solving a problem or accomplishing some end."[24] Such a definition, said the court, is "unnecessarily detrimental to our patent system and leads to reading the word 'process' out of the statute."[25] The CCPA interpreted *Benson* as concerned only with mathematical algorithms.[26]

Following *Flook*, the CCPA once again rejected the "point of novelty" approach.[27] The CCPA did not read *Flook* as adopting a "point of novelty" test (despite the fact that this is exactly what the Supreme Court had done) because it could not believe that "the Supreme Court has acted in a manner so potentially destructive."[28] The CCPA restated the second step of the *Freeman* test:

> If it appears that the mathematical algorithm is implemented in a specific manner to define structural relationships between the physical elements of the claim (in apparatus claims) or to refine or limit claim steps (in process claims), the claim being otherwise statutory, the claim passes muster under § 101.[29]

Finally, in *Diamond v. Diehr*, the Supreme Court changed direction and upheld the eligibility for patent protection for claims drawn to a process for curing synthetic rubber.[30] The *Diehr* Court rejected the "point of novelty" approach by saying,

> In determining the eligibility . . . for patent protection[,] . . . claims must be considered as a whole. It is inappropriate to dissect the claims into old and new elements and then to ignore the presence of the old elements in the analysis. . . . The question therefore of whether a particular invention is novel is wholly apart from whether the invention falls into a category of statutory subject matter.[31]

The confusion between the requirements of § 101 and those of §§ 102 and 103 was at last resolved. The court also addressed the confusion

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[24] *Freeman*, 573 F.2d at 1245–1246.
[25] *Id.* at 1246.
[26] *Id.*
[27] *See In re* Walter, 618 F.2d 758, 766 (C.C.P.A. 1980) (involving a method and apparatus for cross-correlating return jumbled signals with the original signal which was transmitted into the earth in seismic prospecting and surveying).
[28] *Id.*
[29] *Id.* at 767.
[30] *Diehr*, 450 U.S. 175.
[31] *Id.* at 188–189.

regarding the term "algorithm," rejecting the broad definition espoused by the PTO[32] and affirming the narrow definition set forth in *Benson*.[33]

Though the majority in *Diehr* attempted to distinguish *Diehr* from *Flook* on the grounds that Flook's claimed invention contained insignificant post-solution activity while Diehr's claimed invention transformed or reduced an article to a different state or thing,[34] this distinction is questionable in technical terms. Stevens' dissent in *Diehr* provides an excellent analysis of the striking similarity in the method of updating the curing time calculation in *Diehr* and the method of updating the alarm limit in *Flook*.[35] His analysis concludes that the most significant difference between the cases was not in the characteristics of the inventions, but rather the manner in which the claims were drafted.[36] If this analysis is accepted as accurate, it is clear that the *Flook* and *Diehr* cases should have been decided the same way,[37] in favor of eligibility for patent.

Later in *Diamond v. Bradley*, the Supreme Court affirmed the CCPA in holding that there was no "algorithm" in an invention relating to a firmware module which directs data transfers between registers and memory.[38] This solidified the narrow definition of the term "algorithm" adopted in *Benson*.

The CCPA further clarified the meaning of the term "algorithm," holding in *In re Pardo* that the applicants' use of the term "algorithm" to describe the invention is not an admission of nonstatutory subject matter.[39] The court found no mathematical formula or calculation present in the claims in the case.[40]

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[32] *Id.* at note 9. The PTO defined the term "algorithm" as:

> 1. A fixed step-by-step procedure for accomplishing a given result; usually a simplified procedure for solving a complex problem, also a full statement of a finite number of steps. 2. A defined process or set of rules that leads [sic] and assures development of a desired output from a given input. A sequence of formulas and/or algebraic/logical steps to calculate or determine a given task; processing rules.

[33] *Id.* at 186 (algorithm defined as a procedure for solving a given type of mathematical problem).

[34] *Id.* at 191–193.

[35] *Id.* at 209–210 (Stevens, J., dissenting).

[36] *Id.* at note 32 (Stevens, J., dissenting).

[37] The reasoning in Stevens' dissent goes astray in analyzing the requirements of §101 and §102. The dissent would further the confusion regarding the term "algorithm" by presenting yet another definition of the term:

> "the term algorithm . . . is synonymous with the term computer program." *Id.* at (Stevens, J., dissenting).

Furthermore, the dissent considers the burden on the PTO in deciding the case. *Id.* at 219.

[38] Diamond v. Bradley, 450 U.S. 381 (1981), *aff'g In re* Bradley, 600 F.2d 807 (C.C.P.A. 1979).

[39] *In re* Pardo, 684 F.2d 912 (C.C.P.A. 1982).

[40] *Id.* at 916.

The CCPA again refined and finalized the *Freeman* software patentability test in the case *In re Abele*[41] stating: "Thus, if the claims would be 'otherwise statutory,' id., albeit inoperative or less useful without the algorithm, the claim likewise presents statutory subject matter when the algorithm is included."[42] The court found some claims ineligible for patent protection because they were "no more than the calculation of a number and display of the result, albeit in a particular format,"[43] while other similar claims were deemed eligible for patent protection.

The inescapable conclusion to be drawn from this case law is that all software claims are eligible for patent protection unless they simply involve the use of a mathematical formula to calculate and display a number.[44]

Software patentability is a *de facto* reality today, as the PTO now commonly issues patents for software inventions. Examples of patented software inventions include a process for a management control system for multiprogrammed data processing,[45] a method of constructing a task program for operating a word processing system,[46] a program that checks for spelling errors,[47] and a program that converts one programming language into another (an RPG to COBOL compiler).[48]

A patent for an AC current control system is an example of how close claims can come to reciting calculations and still be accepted by the Patent Office.[49] Patents for software systems involving artificial intelligence have also been granted.[50]

Perhaps the best known software patent was issued to Merrill Lynch for a Securities Brokerage and Cash Management System.[51] This patent was the subject of a court action which resulted in an opinion denying a motion for summary judgment of invalidity under

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[41] *In re* Abele, 684 F.2d 902 (C.C.P.A. 1982).

[42] *Id.* at 907.

[43] *Id.* at 909.

[44] Sumner, *The Versatility of Software Patent Protection: From Subroutines to Look and Feel*, 3 Computer Law. 1, 3 (June 1986). An approach treating patent claims directed to subject matter implemented at least in part with software the same as other inventions has been adopted by the ABA. ABA Comm. on Computer Software, Res. 406-3 (1986).

[45] U.S. Patent 3,618,045.

[46] U.S. Patent 4,308,582.

[47] U.S. Patent 4,355,371.

[48] U.S. Patent 4,374,408.

[49] U.S. Patent 4,555,755.

[50] U.S. Patents 4,593,367 and 4,599,693.

[51] U.S. Patent 4,346,442.

35 U.S.C. § 101 for not claiming patentable subject matter.[52] The decision, following earlier CCPA precedent, rejected the contention that a computer program is inherently an algorithm[53] and found no direct or indirect recitation of a procedure for solving a mathematical problem.[54]

This initially favorable court action, together with the issuance of software patents by the PTO, lends considerable support to the premise that software is now generally patentable subject matter.

Stating that software is "patentable" is somewhat misleading because, as has been explained, software is a complex hybrid in terms of the intellectual property concepts it embodies. More accurately, the intellectual property embodied in the functional aspects of the software is protected by patent. The mode of expression embodied in the code that comprises the software is not specifically protected by patent, but the basic organization of the software and the manner in which it operates are in principle protectable by patent—assuming all other standard requirements for patentability are met. Thus, while a patent may not protect against copying the mode of expression found in a software code, it would provide the legal right to prevent others from making, using, or selling the claimed software invention. On the other hand, it is difficult to imagine a situation in which copying a software code would not also result in patent infringement.[55]

One of the important advantages of patents over copyrights is that patents protect against independent development, while copyrights only protect against derivation from protected works. Thus, a broadly claimed software patent could provide protection against a range of independently developed software, including programs achieving similar results with differing code structures, while copyright would provide no protection.

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[52] Paine, Webber, Jackson and Curtis, Inc. v. Merrill Lynch, Pierce, Fenner and Smith, Inc.; 564 F. Supp. 1358 (D. Del. 1983).

[53] *See id.* at 1367, 1368.

[54] *Id.* at 1368. The court then addressed the issue of whether the claims were drawn to nonstatutory subject matter for claiming a method of doing business. The court held that the claims effectuating a useful business method would be unpatentable if done by hand but pass the requirements of § 101 since they teach a method of operation on a computer to effectuate a business activity. *Id.* at 1369. For a discussion of the effect of the definition of "algorithm" on the issue of patent eligibility for methods of doing business, see Meyer, *supra* note 16, at 15, 16.

[55] A discussion of the manner of enforcing by an infringement suit a method or system-apparatus claim for a software invention, against producers and distributors of software as well as against users, is beyond the scope of this article. It is noted that legal theories such as contributory infringement and inducement may be explored.

The patent's advantage in broader protection is, to an extent, offset by the significantly higher cost and levels of difficulty in securing protection relative to the simplicity and low cost of obtaining a copyright. When basic or valuable software concepts are at stake, however, the cost and effort involved in obtaining patent protection are minor compared to the insurance value of the rights obtained.

COPYRIGHT PROTECTION

Copyright protects original works of authorship,[56] meaning the intellectual property embodied in the mode of expression by which intellectual concepts are conveyed.[57] The copyright law expressly prohibits copyright protection of any idea, procedure, process, system, method of operation, concept, principle, or discovery, regardless of the form in which it is described.[58] A Copyright therefore, as applied to software, would appear to protect only the intellectual property embodied in software as a mode of expression.[59] Copyright arms its owner with the legal right to prevent copying of the protected work, to prevent the distribution of copies, and to prevent the preparation of derivative works;[60] all of which are valuable rights, since software is easily copied.

The originality and creativity of a computer program may lie in the appearance and presentation of software, known as the "look and feel."[61] Many have favored extending copyright to protect the mode of expression embodied in the "look and feel"[62] as well as the literal text of software.

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[56] 17 U.S.C. § 102(a).

[57] *See* Baker v. Selden, 101 U.S. 99 (1880) (setting forth the distinction between the description of the art which may be secured by copyright and the art itself which may only be secured by patent).

[58] 17 U.S.C. § 102(b).

[59] Applying the idea/expression dichotomy to computer programs, the court in Apple Computer, Inc. v. Franklin Computer Corp., 714 F.2d 1240, 1252 (3d Cir. 1983), identified the expression adopted by the programmer as the copyrightable element in a computer program.

[60] 17 U.S.C. § 106.

[61] Russo and Derwin, *Copyright in the "Look and Feel" of Computer Software*, 2 Computer Law. 1 (Feb. 1985).

[62] *Id.* at 11; *see* Whelan Assocs. v. Jaslow Dental Lab., Inc., 797 F.2d 1222 (3d Cir. 1986), *aff'g*, 609 F. Supp. 1307 (E.D. Pa. 1985) (discussed in following text), SAS Inst., Inc. v. S & H Computer Sys., Inc., 605 F. Supp. 816 (M.D. Tenn. 1985) (applying a broad test for substantial similarity and finding infringement in adopting the organizational scheme of another's code even though this code was independently written), Comment, *supra*, note 4, at 1019–1022. The court in Williams v. Arndt, 626 F. Supp. 571 (D. Mass 1985) extended the scope of copyright protection by finding liability in translating a prose work into computer language. See Gesmer, *Developments in the Law of Computer Software Copyright Infringement*, 26 Jurimetrics 224 (Spring 1986) for a discussion of the role of facts amounting to misconduct in *Whelan*, *SAS*, and *Arndt*.

To constitute copyright infringement, there must be substantial similarity between the accused work and the work copyrighted, and that similarity must have been caused by the infringer "copying" the copyright owner's work.[63] Those in favor of protecting the "look and feel" of software by copyright adopt the position that two works are substantially similar if the "total concept and feel" of the works are alike.[64]

The farthest extension of copyright protection of computer programs can be found in *Whelan Associates, Inc. v. Jaslow Dental Lab.*,[65] a recent landmark decision holding that copyright protection of computer programs may extend beyond the programs' literal code to their structure, sequence, and organization. The court of appeals affirmed a holding which broadly defined the expression of an idea in a computer program as "the manner in which the program operates, controls and regulates the computer in receiving, assembling, calculating, retaining, correlating, and producing information either on a screen, print-out or by audio communication."[66] This case is very significant in extending the scope of copyright protection to methods of operation, procedures, and processes which would appear to have been expressly excluded from copyright protection under 17 U.S.C. 102(b) and which are perhaps better protected by patent.[67]

The rationale relied upon in favor of extending copyright protection for computer programs includes: 1) the belief that computer programmers deserve some form of protection for the intellectual property they create, and 2) the assumption that there exists no other adequate means of protection.[68] In *Whelan* the court was concerned with providing the "proper incentive for programmers by protecting

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[63] Roth Greeting Cards v. United Card Co., 429 F.2d 1106 (9th Cir. 1970) (finding infringement of the association of elements of a greeting card despite the lack of infringement of any of the individual elements).

[64] *See* Comment, *supra*, note 4, at 1019. The "total concept and feel" test originated in *Roth*, 429 F.2d at 1106. *Roth* is criticized for finding the whole work greater than the sum of its parts. *Id.* at 1110.

[65] *Whelan*, 797 F.2d 1222.

[66] Whelan Assocs. v. Jaslow Dental Lab. Inc., 609 F. Supp. 1307, 1320 (E.D. Pa. 1985), *aff'd*, 797 F.2d 1222 (3d Cir. 1986).

[67] Patents are meant to protect utilitarian creations. Patent protection can be viewed as stronger than copyright protection in that there is no defense of independent development against a claim of patent infringement.

[68] *See* Comment, *supra*, note 4; Final Report of National Commission on New Technological Uses of Copyrighted Works (1978), *reprinted in* A. Latman, Copyright for the 80's 129 (1985).

their most valuable efforts."[69] (Since patent protection was not considered applicable at the time the software was created.)

The expansive definition of "expression" in *Whelan* could be interpreted as extending copyright protection to the internal workings of a computer, not the traditional subject of copyright,[70] and suggesting a substantial area of overlap between patent and copyright protection.

In effect, copyright protection has been stretched in *Whelan* to fill the gap left when the courts denied software inventions patent protection. Stretching copyright protection is understandable, from an equitable point of view, to protect software authors/inventors who were discouraged from seeking patent protection due to the changing status of the law regarding the patentability of software inventions. The equities are particularly important in cases involving misconduct. Prospectively, however, as the intellectual property community accepts the notion that software is patentable, there may ultimately be little need to so stretch the bounds of copyright protection.

It should be noted further that there is no central appeals court for copyrights as there is for patents. Thus, the scope of copyright law in protecting software may vary among the circuit courts of appeals. This fact, and the unusual circumstances of *Whelan*, suggest that it may not be prudent to conclude that copyright protection will be applied with the same breadth as in *Whelan* by other courts faced with other factual circumstances. Nonetheless, *Whelan* is an important precedent when one must rely exclusively upon copyright in software litigation.

One must not suppose that copyright and patent protection are in any way at odds. Copyright protection can mesh very neatly with patent protection to provide a unique continuum of intellectual property protection in the software environment. Copyright protects against literal copying and against slavish imitation of code or mode of expression.[71] Patent protects against infringing use, whether through derivation or independent development, of the broader functional aspects of software. Thus the combination of available copyright and patent protection would appear to make software the most protectable of all technology—a far cry from its position a decade ago.

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[69] *Whelan*, 797 F.2d at 1236.

[70] *Copyright in the Look and "Feel" of Computer Software*, 309 Copyright and New Technology 181 (1985).

[71] *See supra*, notes 57–59 and accompanying text. *But see supra*, notes 65–69 and accompanying text.

TRADE SECRET PROTECTION

Trade Secret law has also been relied upon to partially fill the void left when software was denied patent protection by the courts. The Uniform Trade Secret Act presents the following definition of a trade secret:

> Trade secret means information, including but not limited to, a formula, pattern, compilation, program, device, method, technique, or process, that:
>
> 1. Derives independent economic value, actual or potential, from not being generally known to, and not being readily ascertainable by proper means by, other persons who can obtain economic value from its disclosure or use, and
> 2. Is the subject of efforts that are reasonable under the circumstances to maintain its secrecy.[72]

Under this basic definition of trade secret, it is clear that a computer program including logic, structure, and organization can qualify for trade secret protection as long as it is not generally known.[73] Where major software is developed by corporations for internal use, or where a very limited distribution of software is anticipated, the traditionally required level of secrecy is easily maintained. Similarly, if software is developed for sale on a limited basis, contractual or licensing provisions can easily be provided to maintain trade secret protection. But in mass marketing software to over-the-counter customers, it is certainly questionable as to whether an adequate degree of secrecy can be maintained,[74] or whether any contractual trade secrecy provisions can be enforced to the extent traditionally required for trade secret protection.[75]

The concept of "shrink-wrap licensing" was developed in an intriguing attempt to accommodate the situation. Due to the dubious common law basis for enforcing shrink-wrap trade secret clauses,[76]

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[72] Unif. Trade Secret Act.

[73] Rice, *Trade Secret Clauses in Shrink-Wrap Licenses*, 2 Computer Law. 17 (Feb. 1985).

[74] *See id.* at 18.

[75] *See id.* at 18, 19.

[76] A non-disclosure clause in a shrink-wrap license neither evidences nor creates a confidential relationship since special facts are required to transform an arms-length market transaction to a confidential one. *Id.* Furthermore, the remoteness of the parties precludes a finding of negotiated terms, and consequently, it would be difficult to enforce the clauses on contract theory. *Id.* at 19.

states such as Louisiana have enacted laws to give these clauses legal effect.[77]

Just as in the area of copyrights, the "shrink-wrap" extension of trade secret law to protect mass marketed software might be interpreted as a response to a perceived lack of adequate protection by patent. Given that many software authors/inventors have been discouraged from seeking patent protection, it is understandable that techniques such as shrink-wrap licenses including trade secret clauses would be developed in order to obtain at least a modicum of intellectual property protection. Indeed, in some circumstances such as low cost, short life span or unpatentable software, such inexpensive protection may be all that is economically justified or available. But for more valuable, more unique software where patent protection is available, shrink-wrap licenses may be needed only while patents are pending, or not at all.

TRADE SECRETS AND PATENT DISCLOSURE

Patent protection may, of course, coexist with trade secret protection.[78] Trade secret protection may be important during the pendency of a patent application, and may even protect undisclosed details of an invention during the term of, or after the expiration of, the patent. As trade secret protection is relinquished to the extent an invention is disclosed in a patent application, there is sometimes motivation to minimize the disclosure made in a patent application in order to obtain broad patent protection and yet retain significant trade secret protection. In software terms, this can mean a patent disclosure that does not reveal any code.

Under 35 U.S.C. § 112, first paragraph, one must disclose the invention "in such full, clear, concise and exact terms as to enable any person skilled in the art to which it pertains . . . to make and use" it.[79] The best mode of carrying out the invention must also be disclosed.[80] A present issue of controversy is whether a program listing or other detailed code disclosure must be made in order to satisfy

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[77] *Id.* at 20. Such laws might perhaps be challenged on constitutional grounds for giving patent-like protection in perpetuity, which violates the basic policy central to federal patent law. There are also possible conflicts with federal antitrust laws. Due to the uncertain theoretical basis of shrink-wrap trade secret clauses, any protection provided is fraught with doubt. *Id.*

[78] Sumner, *supra,* note 44 at 4.

[79] 35 U.S.C. § 112.

[80] *Id.*

these statutory requirements. In the case of *In re Sherwood*,[81] disclosure of the listing of the program was found unnecessary to satisfy the best mode requirement because an outline of the methodology used was provided, and detail of the code was considered to be within the ability of typical programmers. On the other hand, in *White Consolidated*[82] a patent was invalidated for failure to comply with the disclosure requirements under 35 U.S.C. § 112 because key software was not disclosed. However, in *White Consolidated* no effort was made to disclose the missing software, other than an attempt to incorporate it into the patent by reference. Since the software in question was considered a trade secret and was not publicly available, the court correctly concluded that the patent was invalid. Had the patent included a software disclosure of the level found in the *Sherwood* case, it may be assumed that the patent in *White Consolidated* would have been found valid.

Regarding this disclosure question, it is well established law that there is no need to describe any invention in the detail needed for direct production.[83] Reasonable experimentation may be required to make and use an invention disclosed in a patent specification. To require an applicant for a software patent to provide a complete program listing would raise the standard of disclosure for software inventions far above that for any other technology.[84] Such a requirement would require that an invention be disclosed so that a person of virtually no programming experience would be able to make and use it. Furthermore, all trade secrets in the program listing would be lost through publication. In general, therefore, it is consistent with well established law that complete program listings should not be required to satisfy statutory disclosure requirements in software patent applications. Disclosure of algorithms and techniques of attaining results sought must be described, but nothing further, as long as an ordinary skilled programmer could be expected to draft a workable code with no more than a reasonable degree of difficulty based upon the disclosure.

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[81] *In re* Sherwood, 613 F.2d 809 (C.C.P.A. 1980), *cert. denied*, 450 U.S. 994 (1981).

[82] *White Consol. Indus. v. Vega Servo-Control, Inc.*, 713 F.2d 788 (Fed. Cir. 1983).

[83] Ill. Tool Works, Inc. v. Foster Grant Co., Inc., 547 F.2d 1300 (7th Cir. 1976), *cert. denied*, 431 U.S. 929; *aff'g*, 395 F. Supp. 234 (N.D. Ill. 1974) (exact identity of description is not required by the enablement requirement).

[84] *But see* Comment; *The Disclosure Requirements of 35 U.S.C. § 112 and Software-Related Patent Applications: Debugging the System*, Conn. L. Rev. 1.

Block diagrams, flow charts and top-down diagrams are presently considered the preferable means of disclosing a program, as a person does not have to understand any particular computer language to understand such diagrams.[85] Whether or not a program listing is provided, a detailed and clearly written narrative of the program is required, since most patents examiners are not enthusiastic about disecting computer listings and normally will not issue patents on inventions they don't understand.[86]

Happily, the disclosure questions for software inventions appear to be resolving themselves to a degree. Disclosure must be sufficient for one of ordinary skill in the art, at the time of the invention, to make and use the invention without "undue experimentation."[87] What is considered "undue experimentation" depends upon the nature of the invention and the level of "ordinary skill" in the art.[88] As the experience of nearly all technically educated people with software is increasing rapidly, it becomes apparent that "ordinary skill" today is nearly as common as it was rare a decade ago. Furthermore, today's rapid spread of computer technology in schools and even homes will assure continued growth in the level of sophistication among those of "ordinary skill." As a result, issues concerning fulfillment of the statutory disclosure requirements for software inventions should become less significant in the future.

CONCLUSION

Now that the courts and PTO have abandoned their excessive concern over the job of examining software applications, patent protection is presently available for virtually all software inventions. As software authors/inventors come to understand this, extensions of copyright and trade secret law to protect functionality will be less necessary. Patent, copyright, and trade secret law will again be able to resume their traditional scopes and continue their complementary relationships, particularly in protecting intellectual property embodied in software.

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[85] *See* Hirschfeld v. Banner, 462 F. Supp. 135, 141–142 (D.D.C. 1978) (Markey, C. J., C.C.P.A., sitting by designation), *aff'd mem.*, 615 F.2d 1368 (D.C. Cir. 1980), *cert. denied*, 450 U.S. 994 (1981).

[86] *But see* Comment, *supra*, note 84 at 18–19.

[87] *Hirschfeld*, 462 F. Supp. at 142.

[88] *See White Consol.*, 713 F.2d at 791, (where the details of a program were required to be disclosed since no suitable substitutes were known or available and could not be obtained without 1½ to 2 years of effort).

Reexamination—
At Issue with Mr. Neff

Dear Gregor:

Your article in the December 1986 JPTOS is excellent but I must disagree with the conclusion you reached. The survey which you quoted in your article is flawed to some extent because I received four copies of the questionnaire and no one else in my law firm received any copies.

Having been involved in four reexamination matters, I agree with your observation that reexamination is most favorable to the patent owner and isn't being used very much by third parties. Is this bad? It is my opinion that this is what we expected when the act was passed. The legislative history will reflect that the PTO and many patent lawyers felt that there should be some inexpensive way for later discovered prior art to be considered by the Examiner in the PTO. What Examiner could possibly be better qualified to do this than the examiner who examined the original application. Thus, the law is functioning the way it was intended and I personally believe we should let it alone for a while.

My concern is that if we create more of an inter partes proceeding in reexaminations, we would soon have it more complicated and much more expensive. An example to consider is our "legal tinkering" with interference practice. Most of us believe that interference law is now breathing its last gasps and I am one who believes this is unfortunate.

Sincerely yours,
Herbert B. Roberts
HAVERSTOCK, GARRETT & ROBERTS
St. Louis, Missouri

NEXT

FORM CD-183
(REV 2-60)
FORMERLY SEC-356

U.S. DEPARTMENT OF COMMERCE

ABSTRACT OF SECRETARIAL CORRESPONDENCE

TO:	☐	The Secretary	☒	The Deputy Secretary

INFORMATION MEMORANDUM

From: Director, National Bureau of Standards

Prepared by: K.F. Gordon/NBS/PBF/975-2664

Subject: Report of Coordinating Committee on Emerging Technologies

Attached is a report from the Coordinating Committee on Emerging Technologies you created in April 1986, for which I served as Chairman.

As requested, it presents a consensus of the Committee on what the important emerging technologies will be over the next decade or two. In addition, the Committee ranked these technologies based on expected economic impact, and also identified the major barriers to the commercialization of these technologies.

Although discussing the barriers quickly raises the issue of formulating policies or actions aimed at removing them, we judged the operating units of Commerce had the more appropriate expertise and mandate for that task.

I would like to brief you on the results of our activities at your convenience.

I suggest the next step after your briefing might be to arrange a presentation to Department officials on these results, perhaps at one of your monthly staff meetings. I think this could be important for two reasons. First, to obtain their concurrence, and second, so that they can make sure the policy formulation and programmatic actions of their agencies are focused upon removing the barriers identified.

	PREPARED BY	CLEARED BY	CLEARED BY	CLEARED BY	CLEARED BY	CLEARED BY
SURNAME AND ORGANIZATION *(Typed)*	Director, NBS	ExSec				
INITIALS AND DATE	JAN 8 1987 [illegible] Signed [illegible]					

USCOMM-DC 1030-P60

FINAL REPORT

THE STATUS OF EMERGING TECHNOLOGIES: AN ECONOMIC/TECHNOLOGICAL ASSESSMENT TO THE YEAR 2000

COORDINATING COMMITTEE ON EMERGING TECHNOLOGIES

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FINAL REPORT

THE STATUS OF EMERGING TECHNOLOGIES: AN ECONOMIC/TECHNOLOGICAL ASSESSMENT TO THE YEAR 2000

COORDINATING COMMITTEE ON EMERGING TECHNOLOGIES

INTRODUCTION

The Coordinating Committee on Emerging Technologies was established by Deputy Secretary Clarence Brown in April 1986. The Committee was chaired by Dr. Ernest Ambler, Director of the National Bureau of Standards, with participating members appointed by the head of the bureaus of the Department concerned with technology or technology policy. Appendix C lists the members.

The mandate of the Committee was: 1) to identify major technologies that are likely to have large impacts on future economic growth of the U.S., 2) to analyze the relative economic and technological importance of these new areas, and 3) to identify the primary barriers to their commercialization. The recommended approach was to formulate a consensus among knowledgeable units of Commerce, and in the process to share information and judgments among the participating Commerce units.

This is a report arrived at through deliberations at eight Committee meetings from June 1986 to January 1987. It is based on individual assessments of scientific/industrial plans and the existing and/or required policies involved in fostering the successful commercialization of new and innovative technologies.

IDENTIFICATION OF EMERGING TECHNOLOGIES

As its initial task, the Committee focused upon identifying the major emerging technologies of interest to U.S. industry and government.[1] By emerging technologies we mean new or significantly modified technologies expected to lead to improved industrial processes or innovative products. Such technologies are usually derived from new scientific knowledge or new applications of existing scientific knowledge.

Using a Delphi approach involving several iterations and discussions, the Committee agreed upon the list of emerging technologies shown in Table 1 of Appendix A. There are 17

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[1] Use of the term "industry" is meant to include the full economic spectrum of manufacturing, agriculture, services, mining, and construction.

separate technologies grouped into 7 categories. For each technology, the multi-page table provides brief descriptive information, describes what it does new or better, what products or processes it might be applied to, and what industries might use it. Although details could not be shown, interactions and synergistic effects among technologies are also expected.

A high level of aggregation was desired for this study, since a reasonably short list of technologies was wanted that would be useful to policymakers. Thus we expect that all items on our final list will have a major impact in the future, and many will be of the "breakthrough" type.

A necessary part of each technology is the inherent scientific information, technical data, standards, and measurement methods (often produced by Government agencies) that industry needs to design and produce products in a reliable and efficient way. Therefore, the technology descriptions and barriers to commercialization do not separately identify these factors.

The list presented probably will not include many surprises to anyone active in monitoring technological trends or science policy. Its intended value comes from the consensus of the knowledgeable people involved (and the agencies they represent), and the comprehensive coverage that may be broader than any one expert.

RELATIVE IMPORTANCE

Anyone concerned with allocation of resources would want to know which emerging technologies are expected to bring the most benefits to the nation, as well as those which might result in benefits greater than currently projected if given added support.

The emerging technologies were categorized by their relative importance to our nation's economy using the criterion <u>contribution to U.S. gross national product (GNP) by the year 2000.</u> While this is an imprecise measure requiring highly qualitative forecasts, it is probably the best proxy to judging relative importance. It is important to stress the criterion should be economic in nature, not scientific sophistication or engineering uniqueness.

The year 2000 is somewhat arbitrary. Since a decade or more is usually needed for new scientific understanding to be converted into commercial products (and probably another decade to reach its full market penetration), that means we are discussing technologies for which the underlying science is already understood.

Using the economic contribution criterion defined above, the Committee ranked the technologies listed in Table 1. The rankings should be recognized to be highly qualitative and aggregative; they did not attempt to extend into employment displacement and other second-order effects. They also assume U.S. firms are aggressive in applying new technologies in both domestic and foreign markets, and that firms from Japan or other nations do not overwhelm emerging markets.

While the exact ranking of each is probably not significant, a grouping into categories having similar scores provides useful information. Such a grouping is presented in Table 2 of Appendix A, with group A having the highest economic impact. Calling them high, moderate, and low, would not be appropriate because no one would be listed at all unless it was thought to have significant industrial applications.

BARRIERS

The Committee thought it should go beyond just identifying emerging technologies with potential economic benefits and also identify the barriers or impediments that could prevent or slow the U.S. from achieving these benefits in its domestic or international commerce. In these very competitive times, the ability to <u>rapidly</u> offer new commercial products will determine if any market success is obtained. Removing or reducing the barrier should have the important effect of accelerating the economic benefits or beating out a competitor to those benefits. Particular barriers may have a stronger effect for one technology versus another.

Table 3 of Appendix A lists the impediments the Committee judged would be significant barriers to achieving the maximum economic benefits from many or all of the emerging technologies. Because these short titles for the barriers represent complex issues, Appendix B presents detailed descriptions that elaborate on the background and significance of each barrier.

The Committee members wanted to emphasize that <u>uncertainty</u> about the interpretation or future changes of each barrier can be an equally important impediment to meaningful action. Businessmen are hesitant to make investments in developing new technology in the face of uncertainty, particularly when long time horizons are involved.

While the ten barriers listed are limited to those the Committee judged important, it also felt that barrier No. 1 (Inadequate strategic planning and execution by U.S. firms) stands out as the most critical factor.

CONCLUSIONS

There are a significant number of emerging technologies that can have an important economic impact to individual firms and for the overall competitive position of the nation. There is general agreement on these technologies within the Department and within U.S. industry (and within Japan and Europe). In other words, identifying the technological opportunities is not the main problem. Even judging the areas of greatest economic potential is not difficult.

The real problem is converting these opportunities into real economic success. Many U.S firms have not adopted new technology fast enough or marketed superior products compared to Japanese competitors in recent years.

The more important task in improving the use of emerging technologies appears to be understanding the barriers to implementation and possibly initiating policy or other actions that will reduce them. Our Committee did agree on ten important barriers to achieving maximum economic benefits from emerging technologies. Several of these barriers cannot be overcome by the Federal government, although it can actively encourage private sector action. Others are outside the mission of the Commerce Department. Because it is primarily technologically oriented, this Committee felt it is not the best place to pursue remedial activities. However, several of the operating units of the Commerce Department do have the necessary policy analysis capabilities, and some are already active in these areas.

RECOMMENDATIONS

The Committee recommends sharing the results of this study among the operating units of Commerce so they can benefit from the consensus aspect of our results. While not new information to officials already dealing with competitiveness problems, it may represent useful confirmation for some and trigger ideas for others. One alternative is for the Deputy Secretary to arrange a briefing for agency heads and staff to see if they agree with the conclusions of the Committee and to discuss subsequent actions.

Identifying possible legislative or policy initiatives and taking actions in those directions is outside the expertise or charter of this Committee. We recommend the operating units that have policy formulation responsibilities be asked to take appropriate follow-up actions. In at least some barrier areas, we know this is already being done. However, coordination by the Deputy Secretary's office would serve to ensure complete and prompt coverage.

APPENDICES

APPENDIX A - DESCRIPTIVE TABLES

Table 1 - Emerging Technologies (4 pages)

Table 2 - Emerging Technologies Ranked by Economic Impact

Table 3 - Generic Barriers to Achieving Maximum Benefits From Emerging Technologies

APPENDIX B - DETAILED DESCRIPTIONS OF BARRIERS

APPENDIX C - REPRESENTATIVES PARTICIPATING IN COMMITTEE ACTIVITIES

Appendix A

Table 1

EMERGING TECHNOLOGIES

Technology	What does it do new or better?	Applied to what products or processes?	Used by What Major Industries?
1. Advanced Materials			
A. Ceramics	Better high temperature strength-to-weight properties	Heat engine components, turbine blades, heat shields	Automotive & aircraft engines
(high performance structural and electronic ceramics)	Better dielectric & optical properties	Electronic substrates, integrated optics	Electronic components
B. Polymer Composites	Higher strength-to-weight ratio	Structural components	Aerospace, automotive, ind. const.
(high strength fiber reinforced plastic resin)	Design flexibility because of spatial asymmetry	Structural components	Aerospace, automotive, ind. const.
C. Metals	Improved strength & high-temp performance	Structural components Super conducting components	Manufactured components
(rapid solidification, & metal matrix composites)	Improved magnetic properties	Electro-magnetic equipment	Electrical machinery
2. Electronics			
A. Advanced Microelectronics	Improved performance in speed, size	Semiconductor devices	Electronic & optical components & systems
(enhanced VLSI and VHSIC chips)	Improved magnetic properties	Information storage	Information processing
	Higher efficiency photovoltaic conversion	Solar cells	Energy generation

Technology	What does it do new or better?	Applied to what products or processes?	Used by What Major Industries?
B. Optoelectronics (optical fiber and light wave processing)	Improved performance in speed, size, capacity, and security Higher density information storage	Electronic equipment, information processing Computer systems of all sizes	Communications & computers Computers
C. Millimeter Wave Technology	When replacing radio systems it frees RF spectrum for other uses	Voice & data communication systems	Telecommunications carriers & corporate use for private circuits
3. Automation			
A. Manufacturing (computer integrated and flexible systems)	Flexible reconfiguration of production processes Integrated control of all production operations	All manufacturing processes	All manufacturing
B. Business and Office Systems (computer applications within an organization)	Efficient information storage, retrieval, & exchange	Networking, word processing, & data base management	All organizations
C. Technical Services (computer applications in the provision of commercial services)	Efficient high-volume information storage, retrieval & exchange	Information retrieval and distribution, data base management, education and training	Financial services, electronic mail, telecommunications, professional service

Technology	What does it do new or better?	Applied to what products or processes?	Used by What Major Industries?
4. Biotechnology			
A. Genetic Engineering	Improved diagnostic and therapeutic drugs	Health Services	Medicine, Pharmaceuticals
(design & production of highly selective agents)	Improved plants, pesticides, & animal supplements	Foods and pesticides	Agriculture Food processing
	Neutralize pollutants	Environmental control processes	Chemical manufacturing & treatment
B. Biochemical Processing	Improved control of chemical processes, outputs, and yields	Chemical separations and reactions, biosensors	Chemical manufacturing
5. Computing			
A. Computing Equipment	Faster, lower-cost computing	Information processing and computer control	Potentially all
(supercomputers, parallel processing, computer arch.)			
B. Artificial Intelligence Techniques	Improved computer replication of human judgment	Information processing and computer control	All applications using computers
(includes expert systems, natural language, and robotic control)			

Technology	What does it do new or better?	Applied to what products or processes?	Used by What Major Industries?
6. **Medical Technology**			
A. Drugs (other drugs are included in category 4 - Biotechnology)	Improved immunology and treatment	Health Services	Medicine, Pharmaceuticals
B. Instruments & Devices	Improved diagnostic and therapeutic systems	Magnetic Resonance Imaging & CAT scanning, radiation treatment	Medicine
7. **Thin Layer Technology** (semiconductor applications also are included in Electronics)			
A. Surfaces & Interfaces	Improved control and yield of chemical reactions	Chemical catalysis	Chemical manufacturing, food processing
	New electronic & optical properties	Semiconductor devices, surface modification and coatings	Electronic components, computers
B. Membranes	New chemical properties, better chemical separation techniques	Chemical separations	Chemical manufacturing, food processing

NBS/Gordon/1/7/87

Appendix A (Continued)

Table 2

EMERGING TECHNOLOGIES RANKED BY ECONOMIC IMPACT

Group A (Highest)	Advanced Materials; Composites Biotechnology; Genetic Engineering Electronics; Optoelectronics Electronics; Advanced Microelectronics Computing; Computing equipment Automation; Manufacturing
Group B	Automation; Business and Office Systems Biotechnology; Biochemical Processing Medical Technology; Drugs Advanced Materials; Ceramics Automation; Technical Services Computing; Artificial Intelligence Tech. Medical Technology; Devices
Group C	Thin Layer Technology; Membranes Advanced Materials; Metals Thin Layer Tech.; Surfaces & Interfaces Electronics; Millimeter Wave Technology

Appendix A (Continued)

Table 3

GENERIC BARRIERS TO ACHIEVING MAXIMUM ECONOMIC BENEFITS FROM EMERGING TECHNOLOGIES

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1. Inadequate long-range strategic planning by U.S. firms, and/or failure to execute long-range strategic plans, often because of excessive importance attached to short-range financial statements and concomitant managerial incentives.

2. Restrictive trade policies in foreign markets.

3. High costs of capital funds in the U.S. relative to foreign competitors.

4. Inadequate laws, regulations, and enforcement protecting intellectual property rights in the U.S. or overseas.

5. Restraints and uncertainty caused by product liability and tort laws.

6. Export controls on advanced technologies and high-technology products.

7. Federal or State regulations on corporate activities intended to protect the public health and safety (e.g., building codes, environmental laws, drug approval regulations, and occupational health regulations).

8. Poor integration of manufacturing, design, and R&D functions.

9. Inadquate tax incentives for U.S. companies relative to foreign competitors to deploy emerging technologies (including the instability of tax regulations).

10. Anti-trust restrictions against cooperative ventures for marketing or production. There may still be perceived barriers against cooperative R&D, but legal restrictions against procompetitive R&D were eased by legislation in 1984.

APPENDIX B

DETAILED DESCRIPTIONS OF GENERIC BARRIERS TO ACHIEVING MAXIMUM ECONOMIC BENEFITS FROM EMERGING TECHNOLOGIES

1. Inadequate long-range strategic planning by U.S. firms, and/or failure to execute long-range strategic plans, often because of excessive importance attached to short-range financial statements and concomitant managerial incentives.

U.S. firms have often not taken the actions or made decisions needed for strategic effectiveness. That is, they have been "out managed" by their Japanese competitors. In tight competitive markets, it is important to have a well developed strategy that continues to offer customers products or services with comparative advantages over other alternatives in the market. Firms must aggressively move to develop new products with superior features, automate manufacturing to lower costs, capitalize on new technologies, and improve quality/service. In contrast to Japanese competitors, many U.S. companies do not think of technology as a strategic variable and using it to gain market advantage. Often Japanese firms introduce new products in U.S. markets, even though the technology it uses was developed in American laboratories. U.S. firms have shown very little initiative to jointly address generic or structural challenges of a long-term nature.

Many factors contribute to this barrier. Many managers had become complacent with their successes during the last three decades, were not sensitive to foreign competition in domestic markets, and not interested in exports even though almost all markets had become worldwide. They were reluctant to take risk, and slow to react to change when rates of change were accelerating.

Perhaps the most pervasive cause is the strong pressure on U.S. managers toward short-term actions and results. The financial markets, SEC reporting requirements, and the necessity of raising capital (plus the accompanying managerial rewards and incentives) force managers of public corporations to give priority to showing short-term profits over long-term investments. Recent U.S. activities in mergers, leveraged buy outs, and hostile takeovers make these pressures even stronger.

2. Restrictive Trade Policies in Foreign Markets

Restrictive trade policies take many forms -- laws, regulations and practices -- with an overriding consequence of protecting a home market from foreign products. Although most of these policies are sponsored by governments, business practices and social mores may also act as significant trade barriers.

Direct Government Practices are one type of policy affecting trade. Included here are:

- Tariffs and other import duties designed to protect a domestic market rather than to raise revenues.
- Import licensing designed to create uncertainty, delays, and discrimination for foreign products.
- Government procurement (i.e., buy national products)
- Product development and export subsidies programs.

Indirect Government Practices are a second type of policy. Included here are:

- Standards codes, testing, labeling, and certification requirements which interfere with market availability and acceptance of foreign products.
- Local or domestic content (e.g. rules or origin) requirements on foreign products which adversely affect technology and process innovations.
- Market reserve policies that designate certain markets for domestic products only.
- Disregard of intellectual property rights by foreign governments which undermine the ability to exploit markets with new products.

Non-trade and Non-government Measures and Practices are a third type. Included here are:

- Public health and safety laws that indirectly restrict the importation of foreign products.
- Local and national distribution systems that discriminate against foreign products through interlocking relationships among manufacturers, wholesalers, and financial institutions.

3. High costs of capital funds in the U.S. relative to foreign competitors.

Higher interest rates, lower debt-equity ratios, cultural practices, and tax laws combine to make the effective cost of capital funds for U.S. firms up to twice as high as their Japanese competitors. For example, U.S. savings rates, as a percentage of GNP, have historically been, and continue to be, among the lowest of developed countries (and about half that of Japan). Recent declines in the value of the dollar relative to foreign currencies have reduced some capital cost differentials, but the above factors combine to keep that differential high.

4. Inadequate laws, regulations, and enforcement protecting intellectual property rights in the U.S. or overseas.

U.S. businesses rely upon strong intellectual property protection to realize the benefits of emerging technologies. In fact, the rate of development of emerging technologies may well depend upon patents as incentives and security for R&D or marketing investment, and upon trademarks to build and protect reputations for quality. Barriers exist where laws, regulations or enforcement procedures are inadequate. When innovation is neither rewarded nor encouraged, markets are either forfeited, left untapped, or are underdeveloped. Examples of domestic barriers include (1) the inadequacy of the statutory 17-year patent term for certain agricultural and pharmaceutical products which are subject to extensive premarket testing, and (2) the absence of effective protection for process patent holders against imports of products made abroad under the patented process.

On the international front, it is well recognized that many countries do not offer adequate intellectual property protection and, in some cases, actually sanction abuse of intellectual property rights. This would include, for example, a nation's outright appropriation of foreign-owned technologies or of creative and artistic works. This robs the inventor or creator and, of course, the associated business concern of any possibilities of realization of world market potential.

5. Restraints and uncertainty caused by product liability and tort laws.

With increasing frequency, claims are made that innovation and ability to compete are retarded in the U.S. by product liability and tort laws. The resulting uncertainty and instability have brought about a need for reform. Reasons include:

-- A patchwork of 50 different state laws on product liability. Cases based on similar facts, but tried in different states, can produce strikingly different and contradictory results.

-- The enormous transaction costs for all parties involved in litigation.

-- The high costs of insurance for product-liability related protection.

Over the past 20 years our product liability law has moved away from fault as its basic guiding principle. The Commerce Department has taken the position that as a matter of fairness to manufacturers and as an incentive to them to construct new and safe products, businesses should generally be held liable only for behavior based on fault.

6. Export controls on advanced technologies and high-technology products.

While the need for control of the export of technology for purposes of U.S. national security has been clearly established, the costs attributable to "over-control" are also now becoming more apparent. That is, the Executive Branch's inability to decontrol goods and technology -- that are no longer strategic or are available from foreign competitors--is now seen as inhibiting our ability to remain technologically superior to our international competitors as well as contributing to the erosion of our defense industrial base . The Department of Commerce is trying to establish interagency procedures that will facilitate the decontrol to take place as Congress intended.

7. Federal or State regulations on corporate activities intended to protect the public health and safety (e.g., building codes, environmental laws, occupational health regulations, and drug approvals).

Emerging technologies generally require, somewhere in their development and production, some form of environmental and/or health clearance or regulation. This will occur on the Federal or State levels depending on which of the Federal regulation(s) apply.

Those technologies involving large-scale use of new materials, particularly in the broader electronics categories, will have to continue to meet the existing water, air and disposal requirements. In the case of new and exotic materials, such as the new semiconductor compounds (e.g. Gallium Arsenide), OSHA regulations are constantly being revised to protect against potential hazards, while EPA has control of various emissions through clean air and clean water legislation.

Solid waste reclamation also will enter into the cost of using new technologies. Disposal of new composite materials as scrap in products that have reached the end of their useful life, will impose a new set of costs and possible barriers. The present case of what to do with worn-out lead storage batteries is a good example of what might happen to a higher technology material with end-of-cycle toxicity.

For those technologies involved in medical and health care, regulations covering production, product certification, standards, OSHA considerations and disposal add to the burden of time/testing, as well as to the cost of meeting stringent health and environmental standards. The current issues surrounding the regulation and testing of genetically-altered naturally occurring organisms is a prime example of an emerging technology in the early stages of development.

The costs and time delays involved are further exacerbated if competing countries have less stringent certification and environmental requirements. Technologies in those countries are often put into production faster, thus putting U.S. suppliers at a competitive disadvantage. There are several recent examples in the pharmaceutical industry of the effect of these differences.

8. Poor integration of manufacturing, design, and R&D functions.

For rapid movement of new technologies through the functions of R&D, design, product development, and production, it is necessary to have effective communication among these functions. Lack of willingness and opportunity of key technical staff to move with the emerging technology from R&D into manufacturing, for example, has been common in U.S. organizations, although much improvement has occurred in recent years. A contributing factor in the U.S. has been the lower status, reflected in lower salaries and recognition, given to manufacturing relative to other branches of engineering.

Lack of cooperation and integration <u>among institutions</u> in the U.S. is just as important a barrier as among functions within a firm. For example, more rapid application of new technologies could be the result of closer coupling of firms to technical activities in Universities and Federal laboratories, and from intercompany cooperation to jointly address generic or structural technical problems of a longer-term nature. In this category would fall the classic Government research (carried out by NBS, NOAA, and NTIA) to provide technical data and standards that industry needs to design reliable new products/processes, but single firms do not have the incentive, expertise, or funds to develop themselves.

The Japanese are said to be particularly strong in integrating functions; this may partly account for the rapid speed with which their firms introduce new products into the market. Rotation of staff among these functions in Japan also helps this integration process.

9. Tax incentives for U.S. companies relative to foreign competitors to deploy emerging technologies (including the stability of tax regulations).

Foreign countries continue to employ a variety of incentives to encourage the growth of new technologies. These range from subsidies for the conduct of R&D to import protection of the products derived from the new technologies, at least in their early marketing stages. U.S. firms receive few such subsidies. Some predict that recent changes in the tax law will have a stultifying effect upon venture capital, thus denying U.S. firms access to a previously major source of funding for new high-technology firms.

Frequent changes have made it difficult for U.S. businessmen. Drafting of regulations often lag behind legislation significantly. These changes and delays have created an air of uncertainty in business planning: uncertainty is always an anathema to the businessman.

10. Anti-trust restrictions against cooperative ventures for marketing or production. There may still be perceived barriers against cooperative R&D, but legal restrictions against procompetitive R&D were eased by legislation in 1984.

Many U.S. anti-trust restrictions have been in place, substantially unchanged, for over 75 years. In these times of strong foreign competition and worldwide markets, U.S. firms are at a disadvantage when compared to foreign firms not subject to such strong, legal strictures. Production economies not envisaged when the original laws were enacted are now possible. These economics permit firms jointly to build and operate facilities at lower cost, thus improving world-competitive positions. Facilities housing flexible auomated manufacturing systems are one example, but other shared facilities are also possible. Joint production by large firms, joint marketing of the products, and mergers of such large firms are subject to close scrutiny by U.S. Federal agencies, even though they may increase efficiency. This is viewed as an anachronism, particularly in the light of foreign practice.

Cooperative funding of procompetitive R&D was eased by changes enacted in 1984 which, among other things, reduced damages to be assessed to losses actually incurred. These changes are still not as widely known as they might be, with the result that some cooperative U.S. ventures are not being undertaken in fear of anti-trust prosecution.

APPENDIX C

REPRESENTATIVES PARTICIPATING IN COMMITTEE ACTIVITIES

Agency	Name
Office of the Secretary	Otto Wolff Andrew Cochran
National Bureau of Standards	Ernest Ambler, Chairman Kenneth Gordon Helmut Hellwig Ray Kammer
International Trade Administration	Edwin Shykind Philip Marcus John McPhee Jack Clifford
Patent & Trademark Office	Donald Peterson Anne Kelly Donald Kelly
Office of Productivity, Technology & Innovation	Bruce Merrifield Jack Williams Philip Goodman
National Technical & Information Service	Joe Caponio David Mowry
National Telecommunications & Information Administration	Carol Emery Harold Kimball David Macuk Jack Gleason
Bureau of Economic Analysis	Frank deLeeuw
National Oceanic & Atmospheric Administration	Robert Hausenfluck

UNITED STATES DEPARTMENT OF COMMERCE
The Assistant Secretary for Administration
Washington, D.C. 20230

JAN 06 1987

MEMORANDUM FOR Ernest Ambler, Chairman
Emerging Technologies Coordinating Committee

From: Kay Bulow Kay Bulow
Assistant Secretary for Administration

Subject: Long-Range Planning Process

The Department is now beginning its formal, long-range planning process for fiscal years 1989-1991. We will be revising our goal-oriented policy framework, at the subgoal level, to establish new policy directions for the next two years and each organizational unit will be preparing planning documents that identify both short-range and long-range strategies for achieving our goals. To complement this process of organizational planning, the Deputy Secretary has requested that special, crosscutting long-range plans be developed for the five policy goal areas where the Department has established formal coordinating committees.

I am requesting that you, as Chairman, ask the Department's Coordinating Committee on Emerging Technologies to assess our current and proposed goals, plans and strategies for this area and prepare a crosscutting, Departmentwide plan by February 16. Operating Unit plans are due by February 2, and should be available for your use shortly thereafter. However, we are not expecting the Committee to simply consolidate or "package" these plans. Our main objective is to obtain from your Committee a Departmentwide perspective on what our goals, policies, strategies and program priorities should be, both for the next two years and for 1989 and beyond.

The Committee's plans should provide the vehicle for a broader-based policy discussion of crosscutting issues and strategies than can be obtained from individual Operating Unit plans. To that end, we sould especially welcome the Committee's views and recommendations on:

- Program and policy priorities for this area from a Departmentwide viewpoint;
- The adequacy of the Department's existing policy goals and program objectives in this area; and

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- Major issues that need to be resolved or legislation that should be considered by the Department to further these goals.

I have asked each Operating Unit to cooperate fully with your Committee in providing you with the information and assistance you will need to prepare your plans (see attached memo). Additional details on next year's planning process are being provided to Departmental planning and budget officers by my staff. If you need additional information or assistance, please call Cora Beebe on 377-3490.

Attachment

Proposed Remarks for Deputy Secretary Brown
News Briefing on Emerging Technologies
June 9, 1987

Good morning. It is no secret that this country has a trade problem. Likewise, it is no secret that at least part of the problem has been our inability to take full commercial advantage of scientific and technological developments made in the U.S. Time and time again we have seen foreign competitors, most notably, but not exclusively, the Japanese, turn our technological developments into their commercial product successes.

I think it is fair to say that the country has awakened to this dilemma. The national attention to the general subject of competitiveness is evidence of our awakening. The President has put forward a comprehensive package of proposals to deal with this problem, and the Administration is taking a series of steps to improve our situation.

This morning, I want to take a longer view of our trade and technology position. I want to draw attention to the future and to the technologies that just now are emerging from the laboratory and seem particularly promising in both a scientific and commercial context.

I am firmly convinced that America's ability to exploit a new set of emerging technologies with huge market potential in the year 2000 and beyond will play a big role in determining the country's economic successes or failures well into the next century.

Recognizing the importance of these technologies, I asked a group of technical experts and top officials from Commerce Department agencies to examine the latest scientific and technological advancements and to report to me on which technologies seemed especially important, what barriers stood in the way of their commercialization within the United States, and what steps could be taken to remove those obstacles.

This group, headed by Dr. Ernest Ambler, director of the National Bureau of Standards, who is with us this morning, studied scientific and industrial plans and the commercialization process here and abroad.

They identified 17 emerging technologies in 7 major groups which are expected to lead to new products or processes in the future. Among other things, the review panel considered the expected contribution of each technology to the gross national product.

Here is the list the group came up with:

SHOW POSTERBOARD WITH EMERGING TECHNOLOGIES LIST

Advanced materials. These include high performance ceramics, polymer composites, and advanced metals. They will bring improvements in automotive and aircraft engines, electronic components, electrical machinery, and manufactured components.

Electronics. Here the panel singled out advanced microelectronics critical to semiconductor devices, optoelectronics -- which covers optical fiber and lightwave processing vital to advances in communications and computers -- and millimeter wave technology, which can be used in voice and data communication systems.

Automation. Computer-integrated and flexible systems for manufacturing are on the list, as are computer applications in business and office systems as well as applications for commercial services such as financial transactions and electronic mail.

Biotechnology. Both genetic engineering -- for improved diagnostic and therapeutic drugs and agricultural and food applications -- as well as biochemical processing for chemical manufacturing, are critical technologies.

But all you have to do is to look at one possible application for these superconductors, the transmission of electrical energy, to realize the enormity of their promise. We now spend $160 billion a year on electrical power in this country, and we waste a full 20 percent of that power due to losses in transmissions. If high-temperature superconductors can be developed to the point where they can be substituted for conventional electrical transmission wires, we could save more than $30 billion a year.

When I talk about the potential of emerging technologies, that is what I am talking about, a revolution that could affect every industry in America and around the globe.

But there are barriers.

SHOW POSTERBOARD WITH GENERIC BARRIERS

This list of generic barriers to achieving maximum economic benefits from emerging technologies should look familiar.

The relatively high costs of capital funds and the less favorable tax incentives in the United States compared to foreign competitors top the list.

Management's focus on short-term, rather than longer range, goals for returns on investments, poor integration of manufacturing, design and research and development functions within U.S. firms, and the lack of cooperation among American institutions, hurt our chances of exploiting emerging technologies.

So do inadequate laws, regulations, and enforcement protecting intellectual property rights in the United States or overseas.

Complacency and a dependence on the domestic market -- the lack of awareness of the need to compete with Japan and other countries head-to-head in the international marketplace -- are a basic stumbling block.

Restrictive trade policies in foreign markets,

Federal or state regulations on corporate activities,
Export controls on advanced technologies and high-technology products,

Restraints and uncertainty caused by product liability and tort laws, and

Anti-trust restrictions -- real and perceived -- against cooperative ventures for R&D, marketing or production.

All are formidable barriers to the commercialization of these emerging technologies.

Now, what do we do about breaking down these barriers? You have a description of the recommendations in your press kits. They include:

- continued vigilance to reduce federal budget deficits and to avoid high interest rates which affect the cost of capital
- creation of venture capital pools at the state and local levels
- additional tax incentives and other actions to increase aggregate savings
- a commitment to making future changes in the tax laws focus on the incentives available for modernization investment in all stages of production, marketing, and distribution
- fostering participative management by employees
- training managers in the production process and updating business school curricula

- -- eliminating provisions in foreign tax laws and regulations that discriminate against U.S. products, and
- -- improving export controls, reforming product liability and tort laws, and lifting antitrust restrictions.

In a recent hearing before his Committee on Commerce, Science and Transportation, Senator Fritz Hollings complained, "America may still invest enough in research to win most of the Nobel Prizes, but the Japanese make all the profits on them." Well, we cannot let that continue to happen. As you can see by looking at the barriers and recommendations for commercializing emerging technologies, the government has an important role to play. But the private sector - the people who work in and run America's factories and board rooms - must take the lead.

This country has done enough looking back and talking about how many different areas of technology we have already lost to the commercial competition. Our look ahead at critical emerging technologies should be a warning that unless we pull together and take swift action now to break down the barriers to the commercialization of new technologies, we are going to be facing the same international trade problems we confront today right on into the next century.

We have made some progress. Although we neither talk nor read enough about them, this country has some wonderful success stories and some good things happening to show that businesses and even entire industrial sectors can and are taking decisive actions to improve the situation. We have firms joining together in research consortia, corporations cutting down on excessive managerial positions, companies finding new market niches overseas.

We simply must be vigilant and make additional changes now if the country's economic future is to be bright when the new century arrives.

Now, I'd be happy to take any questions you may have.

FINAL REPORT

THE STATUS OF EMERGING TECHNOLOGIES:
AN ECONOMIC/TECHNOLOGICAL ASSESSMENT TO THE YEAR 2000

The Department of Commerce has concluded, in a review of emerging technologies and their future impact on the economy, that American businesses lag behind many of their foreign competitors, especially the Japanese, in exploiting technological breakthroughs.

The review was ordered by Deputy Secretary Clarence J. Brown in April 1986 to identify the new technologies that will lead to new products or processes, analyze their commercialization, and recommend means of reducing the barriers. It is based on an assessment by technical experts and agency heads within the Department. They studied scientific and industrial plans and the commercialization process here and abroad.

Once the list of technologies was determined, the experts determined their probable contribution to the gross national product by the year 2000. While recognizing this as an imprecise measure requiring some subjective forecasting, the Department believes it to be the best proxy to judge economic impact. Although the technologies are ranked in terms of high, moderate or low impact, the terms are relative; all are expected to play a significant role in future growth.

Identifying the technological opportunities and their probable economic effect is not difficult. The real problem facing U.S. companies is converting these opportunities into real economic success. The review's primary focus is upon identifying ten barriers to commercialization and making recommendations for overcoming them. The recommendations require action by all sectors of American life, sometimes unilaterally and occasionally together.

The barriers to commercialization are also ranked in order of importance. The two most important are inadequate tax incentives and the high cost of capital. The remaining barriers include two that require actions by individual companies. The Department found that there is a lack of integration and communication among functions within companies, and it also cites companies for being too complacent and dependent on the domestic market for growth opportunities.

The recommendations include fostering participative management by employees, training managers in the production process, eliminating provisions in foreign tax laws that discriminate against U.S. products, and updating business school curricula. They also reiterate recommendations of President Reagan's competitiveness initiative, such as those regarding improving export controls, reforming product liability and tort laws, and lifting antitrust restrictions.

Since the list of technologies was determined, there have been significant and highly publicized breakthroughs in the field of superconductors -- materials that have zero electrical resistance. Several developments must be achieved before their economic potential can be realized, particularly an improvement in the current-carrying capacity of these materials. Until it is known whether this is possible, superconductors should be considered a <u>potential emerging technology</u>.

The accompanying appendices describe in detail the technologies, barriers, and recommendations.

APPENDICES

APPENDIX A - DESCRIPTIVE TABLES

Table 1 - Emerging Technologies (4 pages)

Table 2 - Emerging Technologies Ranked by Economic Impact

Table 3 - Generic Barriers to Achieving Maximum Benefits from Emerging Technologies

APPENDIX B - DETAILED DESCRIPTIONS OF BARRIERS

APPENDIX C - RECOMMENDATIONS OF METHODS TO OVERCOME BARRIERS

Table 1

EMERGING TECHNOLOGIES

Technology	What does it do new or better?	Applied to what products or processes?	Used by What Major Industries?
1. Advanced Materials			
A. Ceramics	Better high temperature strength-to-weight properties	Heat engine components, turbine blades, heat shields	Automotive & aircraft engines
(high performance structural and electronic ceramics)	Better dielectric & optical properties	Electronic substrates, integrated optics	Electronic components
B. Polymer Composites	Higher strength-to-weight ratio	Structural components	Aerospace, automotive, ind. const.
(high strength fiber reinforced plastic resin)	Design flexibility because of spatial asymmetry	Structural components	Aerospace, automotive, ind. const.
C. Metals	Improved strength & high-temp performance	Structural components Super conducting components	Manufactured components
(rapid solidification, & metal matrix composites)	Improved magnetic properties	Electro-magnetic equipment	Electrical machinery
2. Electronics			
A. Advanced Microelectronics	Improved performance in speed, size	Semiconductor devices	Electronic & optical components & systems
(enhanced VLSI and VHSIC chips)	Improved magnetic properties	Information storage	Information processing
	Higher efficiency photovoltaic conversion	Solar cells	Energy generation

<u>Technology</u>	<u>What does it do new or better?</u>	<u>Applied to what products or processes?</u>	<u>Used by What Major Industries?</u>
B. Optoelectronics (optical fiber and light wave processing)	Improved performance in speed, size, capacity, and security	Electronic equipment, information processing	Communications & computers
	Higher density information storage	Computer systems of all sizes	Computers
C. Millimeter Wave Technology	When replacing radio systems it frees RF spectrum for other uses	Voice & data communication systems	Telecommunications carriers & corporate use for private circuits
3. <u>Automation</u>			
A. Manufacturing (computer integrated and flexible systems)	Flexible reconfiguration of production processes	All manufacturing processes	All manufacturing
	Integrated control of all production operations		
B. Business and Office Systems (computer applications within an organization)	Efficient information storage, retrieval, & exchange	Networking, word processing, & data base management	All organizations
C. Technical Services (computer applications in the provision of commercial services)	Efficient high-volume information storage, retrieval & exchange	Information retrieval and distribution, data base management, education and training	Financial services, electronic mail, telecommunications, professional service

Technology	What does it do new or better?	Applied to what products or processes?	Used by What Major Industries?
4. Biotechnology			
A. Genetic Engineering	Improved diagnostic and therapeutic drugs	Health Services	Medicine, Pharmaceuticals
(design & production of highly selective agents)	Improved plants, pesticides, & animal supplements	Foods and pesticides	Agriculture Food processing
	Neutralize pollutants	Environmental control processes	Chemical manufacturing & treatment
B. Biochemical Processing	Improved control of chemical processes, outputs, and yields	Chemical separations and reactions, biosensors	Chemical manufacturing
5. Computing			
A. Computing Equipment	Faster, lower-cost computing	Information processing and computer control	Potentially all
(supercomputers, parallel processing, computer arch.)			
B. Artificial Intelligence Techniques	Improved computer replication of human judgment	Information processing and computer control	All applications using computers
(includes expert systems, natural language, and robotic control)			

Technology	What does it do new or better?	Applied to what products or processes?	Used by What Major Industries?
6. Medical Technology			
A. Drugs (other drugs are included in category 4 - Biotechnology)	Improved immunology and treatment	Health Services	Medicine, Pharmaceuticals
B. Instruments & Devices	Improved diagnostic and therapeutic systems	Magnetic Resonance Imaging & CAT scanning, radiation treatment	Medicine
7. Thin Layer Technology (semiconductor applications also are included in Electronics)			
A. Surfaces & Interfaces	Improved control and yield of chemical reactions	Chemical catalysis	Chemical manufacturing, food processing
	New electronic & optical properties	Semiconductor devices, surface modification and coatings	Electronic components, computers
B. Membranes	New chemical properties, better chemical separation techniques	Chemical separations	Chemical manufacturing, food processing

Table 2

EMERGING TECHNOLOGIES RANKED BY ECONOMIC IMPACT

Group A (Highest)	Advanced Materials; Composites
	Biotechnology; Genetic Engineering
	Electronics; Optoelectronics
	Electronics; Advanced Microelectronics
	Computing; Computing equipment
	Automation; Manufacturing
Group B	Automation; Business and Office Systems
	Biotechnology; Biochemical Processing
	Medical Technology; Drugs
	Advanced Materials; Ceramics
	Automation; Technical Services
	Computing; Artificial Intelligence Tech.
	Medical Technology; Devices
Group C	Thin Layer Technology; Membranes
	Advanced Materials; Metals
	Thin Layer Tech.; Surfaces & Interfaces
	Electronics; Millimeter Wave Technology

Table 3

GENERIC BARRIERS TO ACHIEVING MAXIMUM ECONOMIC BENEFITS FROM EMERGING TECHNOLOGIES

1. High costs of capital funds in the U.S. relative to foreign competitors.

2. Tax incentives for U.S. companies relative to foreign competitors to deploy emerging technologies (including the stability of tax regulations).

3. Poor integration of manufacturing, design, and R&D functions.

4. Inadequate laws, regulations, and enforcement protecting intellectual property rights in the U.S. or overseas.

5. Complacency and dependence on the domestic market.

6. Restrictive trade policies in foreign markets.

7. Federal or State regulations on corporate activities intended to protect the public health and safety (e.g., building codes, environmental laws, drug approval regulations, and occupational health regulations).

8. Export controls on advanced technologies and high-technology products.

9. Restraints and uncertainty caused by product liability and tort laws.

10. Anti-trust restrictions against cooperative ventures for marketing or production methods. There may still be perceived barriers against cooperative R&D, but legal restrictions against procompetitive R&D were eased by legislation in 1984.

APPENDIX B

DETAILED DESCRIPTIONS OF GENERIC BARRIERS TO ACHIEVING MAXIMUM ECONOMIC BENEFITS FROM EMERGING TECHNOLOGIES

1. High costs of capital funds in the U.S. relative to foreign competitors.

Higher interest rates, lower debt-equity ratios, cultural practices, and tax laws combine to make the effective cost of capital funds for U.S. firms up to twice as high as their Japanese competitors. For example, U.S. savings rates, as a percentage of GNP, have historically been, and continue to be, among the lowest of developed countries (and about half that of Japan). Recent declines in the value of the dollar relative to foreign currencies have reduced some capital cost differentials, but the above factors combine to keep that differential high.

2. Tax incentives for U.S. companies relative to foreign competitors to deploy emerging technologies (including the stability of tax regulations).

Foreign countries continue to employ a variety of incentives to encourage the growth of new technologies. These range from subsidies for the conduct of R&D to import protection of the products derived from the new technologies, at least in their early marketing stages. U.S. firms receive few such subsidies. Some predict that recent changes in the tax law will have a stultifying effect upon venture capital, thus denying U.S. firms access to a previously major source of funding for new high-technology firms.

Frequent changes have made it difficult for U.S. businessmen. Drafting of regulations often lag behind legislation significantly. These changes and delays have created an air of uncertainty in business planning: uncertainty is always an anathema to the businessman.

3. Poor integration of manufacturing, design, and R&D functions.

For rapid movement of new technologies through the functions of R&D, design, product development, and production, it is necessary to have effective communication among these functions. Lack of willingness and opportunity of key technical staff to move with the emerging technology from R&D into manufacturing, for example, has been common in U.S.

organizations, although much improvement has occurred in recent years. A contributing factor in the U.S. has been the lower status, reflected in lower salaries and recognition, given to manufacturing relative to other branches of engineering.

Lack of cooperation and integration among institutions in the U.S. is just as important a barrier as among functions within a firm. For example, more rapid application of new technologies could be the result of closer coupling of firms to technical activities in Universities and Federal laboratories, and from intercompany cooperation to jointly address generic or structural technical problems of a longer-term nature. In this category would fall the classic Government research (carried out by NBS, NOAA, and NTIA) to provide technical data and standards that industry needs to design reliable new products/processes, but single firms do not have the incentive, expertise, or funds to develop themselves.

The Japanese are said to be particularly strong in integrating functions; this may partly account for the rapid speed with which their firms introduce new products into the market. Rotation of staff among these functions in Japan also helps this integration process.

4. Inadequate laws, regulations, and enforcement protecting intellectual property rights in the U.S. or overseas.

U.S. businesses rely upon strong intellectual property protection to realize the benefits of emerging technologies. In fact, the rate of development of emerging technologies may well depend upon patents as incentives and security for R&D or marketing investment, and upon trademarks to build and protect reputations for quality. Barriers exist where laws, regulations or enforcement procedures are inadequate. When innovation is neither rewarded nor encouraged, markets are either forfeited, left untapped, or are underdeveloped. Examples of domestic barriers include (1) the inadequacy of the statutory 17-year patent term for certain agricultural and pharmaceutical products which are subject to extensive premarket testing, and (2) the absence of effective protection for process patent holders against imports of products made abroad under the patented process.

On the international front, it is well recognized that many countries do not offer adequate intellectual property protection and, in some cases, actually sanction abuse of intellectual property rights. This would include, for example, a nation's outright appropriation of foreign-owned technologies or of creative and artistic works. This robs the inventor or creator and, of course, the associated business concern of any possibilities of realization of world market potential.

5. Complacency and Dependance on the Domestic Market

This barrier encompasses the attitudinal problems generated by the size and ready availability of the U.S. market for new products and services -- the lack of an immediately apparent need to compete with Japan and other countries head-to-head in the international marketplace. American companies, separately and in joint ventures, must aggressively seek export opportunities abroad and anticipate challenges in the U.S. from new foreign competitors. This barrier also encompasses the attitudinal differences toward "risk taking" between U.S. and Japanese firms and the cultural differences in approaches to production and marketing. The Japanese preference is to produce and market technological improvements in small increments, thereby gaining a foothold and experience in the marketplace. The U.S. approach is to complete as much research and development as possible before producing and marketing a new product which "leapfrogs" existing technology.

6. Restrictive Trade Policies in Foreign Markets

Restrictive trade policies take many forms -- laws, regulations and practices -- with an overriding consequence of protecting a home market from foreign products. Although most of these policies are sponsored by governments, business practices and social mores may also act as significant trade barriers.

<u>Direct Government Practices</u> are one type of policy affecting trade. Included here are:

- Tariffs and other import duties designed to protect a domestic market rather than to raise revenues.
- Import licensing designed to create uncertainty, delays, and discrimination for foreign products.
- Government procurement (i.e., buy national products)
- Product development and export subsidies programs.

<u>Indirect Government Practices</u> are a second type of policy. Included here are:

- Standards codes, testing, labeling, and certification requirements which interfere with market availability and acceptance of foreign products.
- Local or domestic content (e.g. rules or origin)

requirements on foreign products which adversely affect technology and process innovations.

- Market reserve policies that designate certain markets for domestic products only.
- Disregard of intellectual property rights by foreign governments which undermine the ability to exploit markets with new products.

Non-trade and Non-government Measures and Practices are a third type. Included here are:

- Public health and safety laws that indirectly restrict the importation of foreign products.
- Local and national distribution systems that discriminate against foreign products through interlocking relationships among manufacturers, wholesalers, and financial institutions.

7. Federal or State regulations on corporate activities intended to protect the public health and safety (e.g., building codes, environmental laws, occupational health regulations, and drug approvals).

Emerging technologies generally require, somewhere in their development and production, some form of environmental and/or health clearance or regulation. This will occur on the Federal or State levels depending on which of the Federal regulation(s) apply.

Those technologies involving large-scale use of new materials, particularly in the broader electronics categories, will have to continue to meet the existing water, air and disposal requirements. In the case of new and exotic materials, such as the new semiconductor compounds (e.g. Gallium Arsenide), OSHA regulations are constantly being revised to protect against potential hazards, while EPA has control of various emissions through clean air and clean water legislation.

Solid waste reclamation also will enter into the cost of using new technologies. Disposal of new composite materials as scrap in products that have reached the end of their useful life, will impose a new set of costs and possible barriers. The present case of what to do with worn-out lead storage batteries is a good example of what might happen to a higher technology material with end-of-cycle toxicity.

For those technologies involved in medical and health care, regulations covering production, product certification, standards, OSHA considerations and disposal add to the burden of time/testing, as well as to the cost of meeting stringent health and environmental standards. The current issues surrounding the regulation and testing of genetically-altered naturally occurring organisms is a prime example of an emerging technology in the early stages of development.

The costs and time delays involved are further exacerbated if competing countries have less stringent certification and environmental requirements. Technologies in those countries are often put into production faster, thus putting U.S. suppliers at a competitive disadvantage. There are several recent examples in the pharmaceutical industry of the effect of these differences.

8. Export controls on advanced technologies and high-technology products.

While the need for control of the export of technology for purposes of U.S. national security has been clearly established, the costs attributable to "over-control" are also now becoming more apparent. That is, the Executive Branch's inability to decontrol goods and technology -- that are no longer strategic or are available from foreign competitors--is now seen as inhibiting our ability to remain technologically superior to our international competitors as well as contributing to the erosion of our defense industrial base . The Department of Commerce is trying to establish interagency procedures that will facilitate the decontrol to take place as Congress intended.

9. Restraints and uncertainty caused by product liability and tort laws.

With increasing frequency, claims are made that innovation and ability to compete are retarded in the U.S. by product liability and tort laws. The resulting uncertainty and instability have brought about a need for reform. Reasons include:

- -- A patchwork of 50 different state laws on product liability. Cases based on similar facts, but tried in different states, can produce strikingly different and contradictory results.
- -- The enormous transaction costs for all parties involved in litigation.
- -- The high costs of insurance for product-liability related protection.

Over the past 20 years our product liability law has moved away from fault as its basic guiding principle. The Commerce Department has taken the position that as a matter of fairness to manufacturers and as an incentive to them to construct new and safe products, businesses should generally be held liable only for behavior based on fault.

10. Anti-trust restrictions against cooperative ventures for marketing or production. There may still be perceived barriers against cooperative R&D, but legal restrictions against procompetitive R&D were eased by legislation in 1984.

Many U.S. anti-trust restrictions have been in place, substantially unchanged, for over 75 years. In these times of strong foreign competition and worldwide markets, U.S. firms are at a disadvantage when compared to foreign firms not subject to such strong, legal strictures. Production economies not envisaged when the original laws were enacted are now possible. These economics permit firms jointly to build and operate facilities at lower cost, thus improving world-competitive positions. Facilities housing flexible automated manufacturing systems are one example, but other shared facilities are also possible. Joint production by large firms, joint marketing of the products, and mergers of such large firms are subject to close scrutiny by U.S. Federal agencies, even though they may increase efficiency. This is viewed as an anachronism, particularly in the light of foreign practice.

Cooperative funding of procompetitive R&D was eased by changes enacted in 1984 which, among other things, reduced damages to be assessed to losses actually incurred. These changes are still not as widely known as they might be, with the result that some cooperative U.S. ventures are not being undertaken in fear of anti-trust prosecution.

APPENDIX C

RECOMMENDATIONS OF METHODS TO OVERCOME BARRIERS

BARRIER: HIGH COST OF CAPITAL IN THE U.S. RELATIVE TO FOREIGN COMPETITORS

Efforts to reduce Federal budget deficits should continue because of negative effects of the high deficits on capital markets and on interest rates.

State and local level efforts to meet local capital needs should be encouraged. The creation of venture capital pools would help increase the availability of capital for the new, high-risk developments that sometimes have very large innovation and competitive payoffs. Investment rebates and other incentives might also be used.

Actions should be taken to increase aggregate savings in the U.S. Additional tax incentives (beyond the recent tax reform), direct appeal to savers, and other actions could increase savers willingness to save rather than consume. Increased savings levels are necessary to help increase capital supply and lower interest rates. The U.S. savings level is much lower than in competitor nations.

BARRIER: TAX INCENTIVES FOR DEVELOPMENT OF NEW TECHNOLOGIES

In order to encourage rapid commercialization of technological advances, any future changes in the tax law should focus on the incentives available for long-term investment in all factors of the production, marketing, and distribution processes. Changes in cost recovery provisions should not force U.S. companies into a competitive disadvantage. American businesses must have confidence that major tax changes will not be made repeatedly.

The tax laws of foreign countries should be analyzed to determine if they discriminate against U.S. products being sold there. Discriminatory effects should be alleviated through negotiation or, if necessary, compensated through legislation.

BARRIER: POOR INTEGRATION OF MANUFACTURING, DESIGN, AND R&D MARKETING FUNCTIONS

All managers should have a grounding in the basic production process of the company. Beyond this, managers should receive cross-functional training so they have at least a minimal appreciation of finance, personnel, technology development, marketing, as well as production.

Top management must foster attitudes throughout management staff that foster flexibility, change, innovation and adaptability.

Business schools must update curricula to train business students in the total process -- from R&D to marketing and servicing. Business students must see any particular specialization within the fullest context of what is required for corporations to achieve maximum productivity.

BARRIER: INTELLECTUAL PROPERTY PROTECTION

Industrial firms in the U.S should take great care in transferring their technology and other intellectual property to foreign firms. For protecting the competitiveness of the nation as a whole, firms should establish safeguards against non-economic transfers.

Export control procedures should be changed to include intellectual property protection agreements and concerns, so that sales by U.S. firms are protected and enhanced.

Insist other nations protect U.S-owned intellectual property. Treaties, reciprocal agreements, tariffs, and other mechanisms used by the U.S. government in dealing with other nations should incorporate strong intellectual property provisions. U.S. laws could be strengthened to insure reciprocity and to prevent unapproved imports of products made abroad by processes patented in the U.S. Enforcement in other countries is often the weakest link in the protection process.

Ownership of rights stemming from collaborative research should be clarified. The goal is to eliminate uncertainty and thus maximize the incentives to rapidly commercialize technological developments by U.S. firms. Similarly, actions should be taken to assure that ownership rights and other benefits from Federally-funded research flow to U.S. organizations.

Ways should be sought to obtain payments from foreign graduate students for the intellectual property they benefit from while doing research in the U.S.

BARRIER: COMPLACENCY AND DEPENDENCE ON THE DOMESTIC MARKET

We must foster entrepreneurial risk-taking. Several steps can be taken. Promote greater ownership by executives of corporate stock so that executives become owners, not simply managers. Include employees in "participative management" so that more decisions are made by those closest to production operations. Incentive systems must be improved so that more employees feel they have a greater stake in the success of the company.

Shift emphasis in our business schools so that executive responsibilities are taught more within the context of "owners" responsibilities rather than "management" responsibilities.

We must promote a greater sense of the "common good" so that government, management and labor interact on a basis of achieving positive goals rather than on the historic adversarial basis.

We must foster the awareness that there is no longer anything such as a purely "domestic" market. What we think of as the U.S. domestic market is, in fact, part of the global market. Thus as soon as a product leaves the shipping dock, it has hit the world market, even if it is only being shipped across town. This perspective must permeate all management levels.

BARRIER: RESTRICTIVE TRADE POLICIES IN FOREIGN MARKETS

Adaptability to foreign preferences should be improved by U.S. firms. The result should be U.S.-made products that better meet the special preferences of consumers in other nations and better performance in the marketing/distribution systems overseas. Increased exports and reduced trade deficits are the obvious goal.

Foreign languages should be introduced earlier into the U.S. educational process, so that our citizens will have a greater ability to understand foreign needs/preferences, and have an increased ability to successfully do business overseas.

BARRIER: FEDERAL AND STATE REGULATIONS FOR PROTECTION OF HEALTH AND SAFETY

Wherever possible, domestic regulations (from such sources as EPA, OSHA, FDA, and SEC) should be reduced and simplified in order to minimize their negative effects on industry's use of new technology. In some cases, foreign competitors have an advantage of less stringent or loosely enforced regulations.

A better balance should be achieved between the desirable safety goals of domestic regulations and the economic costs to U.S. manufacturers and businesses. In addition to the added costs, firms often have the application of new technology or marketing of new products delayed significantly. In the current global economy, we should recognize that economic viability is as important a national goal as public safety. The key is to balance these goals in a meaningful way.

BARRIER: EXPORT CONTROLS ON ADVANCED TECHNOLOGIES AND HIGH-TECHNOLOGY PRODUCTS

The January 1987 President's Competitiveness Initiative directs the Cabinet to review the export controls program and provide recommendations to achieve the following:

- Decontrolling those technologies that offer no serious threat to U.S. security;
- Strengthening enforcement controls on those technologies that could harm U.S. security;
- Eliminating unilateral controls in those areas where there is widespread foreign availability;
- Reducing the time required to acquire a license by at least one-third and implementing a fair, equitable, and timely dispute resolution process;
- Seeking agreement with our allies for concrete actions to be taken which will make export control procedures more uniform and enforcement more rigorous;
- Seeking overall to level the competitive playing field while strengthening multinational controls over products and technologies that can contribute to Soviet military capabilities; and
- Recognizing the continued improvement in U.S./People's Republic of China (PRC) relations and the commitment of the PRC to protect sensitive technology, and working with our allies to further liberalize high technology trade with China.

BARRIER: RESTRAINTS AND UNCERTAINTY CAUSED BY PRODUCT LIABILITY LAWS

The January 1987 President's Competitiveness Initiative proposes several methods to overcome this barrier. Proposed legislation would:

- Retain a fault-based standard of liability;

- Eliminate joint and several liability except in cases where defendants have acted in concert;
- Limit noneconomic damages to a fair and reasonable amount;
- Provide for periodic, instead of lump sum, payments of damages for future medical care or lost income;
- Reduce awards in cases where a plaintiff also is compensated by other sources, such as government benefits;
- Reduce transaction costs by limiting attorneys' contingent fees to reasonable amounts on a sliding scale; and
- Encourage litigants to resolve more cases out of court.

BARRIER: ANTI-TRUST RESTRICTION AGAINST COOPERATIVE VENTURES

The January 1987 President's Competitiveness Initiative proposes several methods to overcome this barrier. The statutory proposals include:

- Amending Section 7 of the Clayton Act to distinguish more clearly between pro-competitive mergers and mergers that would create a significant probability of increased prices to consumers;
- Limiting private and Government antitrust actions to actual (rather than treble) damages, except for damages caused by overcharges or underpayments;
- Removing unwarranted and cumbersome restrictions on interlocking directorates;
- Clarifying the application of U.S. antitrust laws in private cases involving international trade; and
- Requiring that any antitrust claims remaining against other defendants after a partial settlement in a case be appropriately reduced.