

# SCIENCE IN THE NEW MILLENNIUM

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Ford Foundation      Sloan Foundation

NSF ADVANCE Leadership Award

Oklahoma Center for Advancement of Science & Technology

<http://cheminfo.chem.ou.edu/~djn/djn.html>

# **Recent competitiveness and innovation reports and legislation**

Faculty survey

Chemistry grad student attrition

# **Task Force on the Future of American Innovation**

- Science/engineering students declining
- Retirements increasing
- U.S. share of published papers is down
- Federal funding at a near standstill
- High-tech exports declining

# **National Academy of Sciences Rising Above The Gathering Storm**

- Chemical plant closures
- Students below standard in math and science
- Teacher training below average
- Fewer engineering graduates than China or India

# National Summit on Competitiveness

Discussed seriousness of global competitiveness challenge

Recommended actions regarding:

- Science and technology research
- Education
- Workforce development
- New technologies

# **American Competitiveness Initiative**

## **President George W. Bush**

State of the Union Address to Congress — 2006

“ ... encourage innovation throughout our economy and give our nation’s children a firm grounding in math and science.”

# US Congress competitiveness legislation

- National Innovation Act sponsored by Senators Ensign (R-NV) and Lieberman (D-CT)
- Senators Lamar Alexander (R-TN) and Jeff Bingaman (D-NM) introduced legislation based on the National Academies report, Protecting America's Competitive Edge (PACE).
- Senate Majority Leader Bill Frist (R-TN) and Minority Leader Harry Reid (D-NV) introduced the National Competitiveness Investment Act
- A Competitiveness Package containing similar type of legislation was unanimously passed in the U.S. House of Representatives Committee on Science; Science and Mathematics Education for Competitiveness Act, Early Career Research Act, and the Research for Competitiveness Act

"GENDER EQUITY: U.S. Agencies Quiz  
Universities on the Status of Women in Science"  
*Science* **2007**, 315 (no. 5820), March 30

- NSF, DOE, NASA officials visited 4 departments
- Monitored Title IX compliance during last 14 months
- DOE - Columbia (physics), NSF – Columbia (electrical engineering), NASA – Michigan (aerospace engineering) and Maryland (aerospace engineering)
- First time Title IX has been applied to physical sciences and engineering
- Prompted by 2004 GAO report “Gender Issues: Women’s Participation in the Sciences has Increased, but Agencies Need to Do More to Ensure Compliance with Title IX.”

# **Some Common Concerns of the Above Competitiveness and Innovation Reports and Legislation**

1. Increase US scientific workforce
2. Strengthen physical sciences
3. Make advances in energy, environment, high tech research and applications
4. Short time line (<10 years)

Recent competitiveness and innovation  
reports and legislation

**Faculty survey**

Chemistry grad student attrition

# Our Faculty Survey Methodology

1. Tenured/tenure track faculty headcount, disaggregated by race/ethnicity, by gender, and by rank
2. Faculty data from department chairs
3. “Top 50” departments in each discipline, NSF-ranked -> research expenditures
4. Obtain populations, instead of samples

**Table 1. Tenured/Tenure Track Chemistry Faculty at the "Top 50" Chemistry Departments by Race/Ethnicity and by Rank (FY 2001)\***

University	White				Black				Hispanic				Asian				Native Am.				Total
	Full	Assoc	Asst	Tot	Full	Assoc	Asst	Tot	Full	Assoc	Asst	Tot	Full	Assoc	Asst	Tot	Full	Assoc	Asst	Tot	
U of California, Berkeley	35.003	3.001	7.001	45.005	1	-	-	1	1	-	-	1	2	-	2	4	-	-	-	0	51.005
Johns Hopkins U	11	2	3.001	16.001	-	-	-	0	-	-	-	0	-	-	-	0	-	-	-	0	16.001
California Instit. Of Tech.	18.002	2	3	23.002	-	-	-	0	-	-	-	0	1	1	1.001	3.001	-	-	-	0	26.003
Pennsylvania State U	18.001	6.002	5.001	29.004	-	-	-	0	-	-	-	0	-	-	-	0	-	-	-	0	29.004
U of Illinois, Urbana	29.002	1.001	6.001	36.004	-	-	-	0	-	-	1	1	-	1	1	2	-	-	-	0	39.004
U of Colorado, Boulder	23.003	5.001	5.001	33.005	-	-	-	0	-	-	-	0	-	1.001	3.001	4.002	-	-	-	0	37.007
Purdue U	31.002	6.002	5.002	42.006	1	-	-	1	-	-	-	0	1	-	2	3	-	-	-	0	46.006
Stanford U***	17.001	2	2	21.001	-	-	-	0	-	-	-	0	-	1	2	3	-	-	-	0	24.001
Cornell U	23.001	4.001	3	30.002	1	-	-	1	1	-	-	1	1	-	-	1	-	-	-	0	33.002
U of Wisconsin, Madison	32.002	1.001	4.001	37.004	-	-	-	0	-	-	-	0	1	1	1	3	-	-	-	0	40.004
U of California, LA	34.004	7.002	6.002	47.008	-	1	-	1	-	1	-	1	-	1.001	1	2.001	-	-	-	0	51.009
U of Florida	30.001	10.001	2	42.002	-	1.001	-	1.001	1	-	1.001	2.001	-	-	1	1	-	-	-	0	46.004
U of Pennsylvania	20.002	4	3.001	27.003	-	-	-	0	-	-	-	0	2	-	1	3	1	-	-	1	31.003
U of Texas, Austin	30.001	5	8.002	43.003	-	-	-	0	-	-	-	0	-	-	-	0	-	-	-	0	43.003
Harvard U	19.001	-	2	21.001	-	-	-	0	-	-	-	0	2	-	2	4	-	-	-	0	25.001
U of Massachusetts, Amherst	16.002	8.001	4	28.003	-	-	-	0	-	1.001	1	2.001	-	-	-	0	-	-	-	0	30.004
Massachusetts Inst. Of Tech.	20.003	2	5.001	27.004	-	-	-	0	-	-	-	0	1	-	1	2	-	-	-	0	29.004
Georgia Instit. Of Tech	18	2	12.003	32.003	-	-	-	0	-	-	1	1	-	1	-	1	-	-	-	0	34.003
U of California, San Diego	30.004	4.001	4	38.005	1	1	-	2	-	-	-	0	2	1	3	6	-	-	-	0	46.005
U of Oklahoma	14	2	4.001	20.001	1	-	-	1	-	-	-	0	1	-	2.001	3.001	-	1.001	-	1.001	25.003
Northwestern U	21	-	2.001	23.001	-	-	-	0	-	-	-	0	-	-	1	1	-	-	-	0	24.001
Ohio State U	20.001	7.001	6.001	33.003	-	-	-	0	-	-	1.001	1.001	4	2	-	6	-	-	-	0	40.004
Rutgers, State U of NJ	26.005	6.002	3.001	35.008	-	1	-	1	-	1.001	-	1.001	1	-	1.001	2.001	-	-	-	0	39.010
Arizona State U	22	2	6	30	-	-	-	0	1.001	-	1	2.001	-	-	-	0	-	-	-	0	32.001
Texas A&M U	35.002	2.001	5.001	42.004	1	-	-	1	-	-	1	1	1	-	-	1	-	-	-	0	45.004
Princeton U	22	2.001	1	25.001	-	-	-	0	-	-	-	0	-	-	1	1	-	-	-	0	26.001
Columbia U	15.001	1	5.001	21.002	-	-	-	0	-	-	-	0	1	-	-	1	-	-	-	0	22.002
U of Notre Dame	14	5	6.002	25.002	1	-	-	1	-	-	-	0	1	-	-	1	-	-	-	0	27.002
U of California, Irvine	22.001	1.001	7	30.002	1	-	-	1	-	-	-	0	1	1	2.001	4.001	-	-	-	0	35.003
U of NC, Chapel Hill	29.003	-	10.002	39.005	-	-	-	0	-	-	-	0	-	-	-	0	-	-	-	0	39.005
U of Akron	10.001	2.002	3	15.003	-	-	-	0	-	-	-	0	1	-	1	2	-	-	-	0	17.003
U of Chicago	18.001	2	2.001	22.002	-	-	-	0	-	-	-	0	3	-	1.001	4.001	-	-	-	0	26.003
Indiana U, Bloomington	17	4	7.002	28.002	-	-	-	0	-	-	-	0	-	2	-	2	-	-	-	0	30.002
U of Southern California	17.001	1	2.001	20.002	1	-	-	1	-	1	-	1	1	1	1	3	1	-	-	1	26.002
Florida State U	21.003	9	4.001	34.004	-	-	-	0	-	-	-	0	-	-	3.002	3.002	-	-	-	0	37.006
U of Michigan	31.002	7.002	7.002	45.006	1	-	-	1	-	-	-	0	1	-	1	2	-	-	-	0	48.006
Colorado State U	16.002	6.002	5	27.004	-	-	-	0	-	-	-	0	-	1	1	2	-	-	-	0	29.004
U of Minnesota, Minneapolis	20.001	8.002	8	36.003	-	-	-	0	-	-	1	1	2	1	1	4	-	-	-	0	41.003
State U of NY, Buffalo	20	5.001	2	27.001	-	-	-	0	-	1	-	1	2	1	1	4	-	-	-	0	32.001
U of Utah	19.001	4	5.001	28.002	-	-	-	0	-	-	-	0	-	1	-	1	-	-	-	0	29.002
U of South Carolina	15	7.001	4	26.001	-	-	-	0	-	-	-	0	-	-	1.001	1.001	-	-	-	0	27.002
U of Kansas	12.002	7.001	5.003	24.006	-	-	-	0	-	-	-	0	-	-	-	0	-	-	-	0	24.006
U of Washington	26	4.002	4.002	34.004	2	1	-	3	-	-	1	1	-	1	2	3	-	-	-	0	41.004
Virginia Polytechnic Inst.	14.001	8.002	6	28.003	-	-	-	0	-	-	-	0	-	-	-	0	-	-	-	0	28.003
Yale	18.001	1	4.001	23.002	-	-	-	0	-	-	1	1	-	-	-	0	-	-	-	0	24.002
U of Rochester	14	1	5.001	20.001	-	-	-	0	-	-	-	0	-	-	-	0	-	-	-	0	20.001
U of Maryland	24.003	11.002	6	41.005	-	-	-	0	-	-	1	1	-	1	1	2	-	-	-	0	44.005
U of Arizona	23.004	4.001	3	30.005	-	-	-	0	-	1	1	2	1	-	1	2	-	-	-	0	34.005
State U of NY, Stony Brook	10	9.003	2.001	21.004	-	1	-	1	-	-	-	0	2	1	1	4	-	-	-	0	26.004
U of Georgia	22	3.001	4.001	29.002	1	-	-	1	-	-	-	0	-	-	-	0	-	-	-	0	30.002
<b>Chemistry Total</b>	1060.071**	205.042	232.044	1497.157	12**	6.001	0	18.001	4.001	6.002	12.002	22.005	36	21.002	44.009	101.011	2	1.001	0	3.001	1641.175
<b>Percent within race</b>	71%	14%	15%	100%	67%	33%	0%	100%	18%	27%	55%	100%	36%	21%	44%	100%	67%	33%	0%	100%	
<b>Percent of grand total</b>	64.6%	12.5%	14.1%	91.2%	0.7%	0.4%	0%	1.1%	0.2%	0.4%	0.7%	1.3%	2.2%	1.3%	2.7%	6.2%	0.1%	0.1%	0.0%	0.2%	100%
<b>Females in column</b>	6.7%	20.5%	19.0%	10.5%	0%	16.7%	0%	5.6%	25.0%	33.3%	16.7%	22.7%	0.0%	9.5%	20.5%	10.9%	0%	100%	0%	33%	10.7%

\*By chemical research expenditures FY1998, NSF; numbers after decimals designate females. \*\*One prof. changed departments mid-year & is counted twice. \*\*\*Declined; data are from other sources.

Reference: "The Nelson Diversity Surveys" Nelson, D. J.: Norman, OK, 2002; <http://cheminfo.chem.ou.edu/faculty/djn/diversity/top50.html>

# Indicators Revealed by Our Data

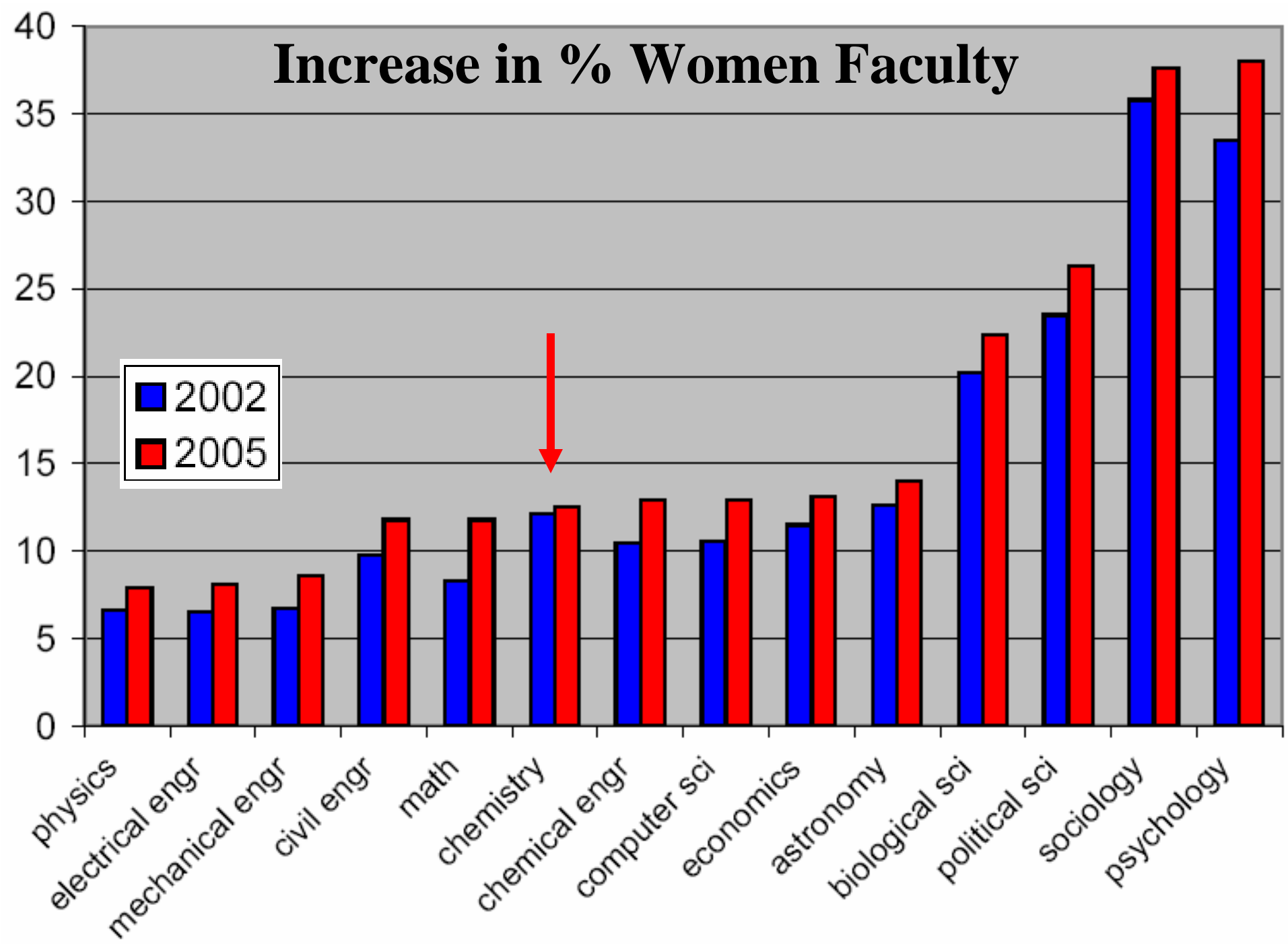
- Critical mass of women? (15 – 30%)
- Utilization of hiring pool? (compare % women in PhDs vs in asst profs)
- Sufficient same-gender mentors? (compare % women in BS vs in faculty)
- Assess pipeline (NSF PhD & BS data)
- Compare and group disciplines due to patterns in faculty data and student data

% FEMALES\*

DISCIPLINE	STUDENTS			PROFESSORS FY2002			
	BS 2000	PhD 83-92	PhD 93-02	asst	assoc	prof	all
chemistry FY'03	47.3%	22.8%	31.3%	21.5%	20.5%	7.6%	12.1%
math	48.2%	20.5%	27.2%	19.6%	13.2%	4.6%	8.3%
computer sci	27.7%	17.9%	20.5%	10.8%	14.4%	8.3%	10.6%
astronomy FY'04	32.7%	12.7%	20.6%	22.0%	16.5%	9.5%	12.6%
physics	21.4%	9.0%	13.3%	11.2%	9.8%	4.6%	6.6%
chemical engr	35.7%	14.4%	22.3%	21.4%	19.2%	4.4%	10.5%
civil engr	24.5%	10.2%	18.7%	22.3%	11.5%	3.5%	9.8%
electrical engr	13.1%	6.4%	11.5%	10.9%	9.8%	3.8%	6.5%
mechanical engr	13.9%	6.0%	10.4%	15.7%	8.9%	3.2%	6.7%
economics	32.3%	22.4%	29.3%	19.0%	16.3%	7.2%	11.5%
political sci	50.1%	31.0%	36.6%	36.5%	28.6%	13.9%	23.5%
sociology	70.2%	51.1%	58.9%	52.3%	42.7%	13.9%	35.8%
psychology	76.5%	55.0%	66.1%	45.4%	40.1%	13.9%	33.5%
biological sci	58.4%	36.5%	44.7%	30.2%	24.9%	14.8%	20.2%

\* Females were 50.9% of the 2000 general population.

# Increase in % Women Faculty



## Female Underrepresented Minority (URM) Faculty at "Top 50" Science & Engineering Departments

	<u>Black females</u>	<u>Hispanic females</u>	<u>Native American females</u>
chemistry	2	5*	1
math	2	7***	0
computer science	0	0	0
astronomy	2*	2*	0
physics	0	8***	0
chemical eng	2	3	0
electrical eng	7	3	0
mechanical eng	3	2*	0
civil eng	2	3**	0
	===	===	==
total	20	33	1
 *URM female full prof	 1	 11	 0

# Concerns revealed

- 1. Chemistry data show the highest source for pipeline, leakiest pipeline, and no critical mass among faculty.**
- 2. Chemistry shows least improvement between 2002 – 2005.**
- 3. At this rate of change, it is going to take a long time to reach parity; what does the future hold for chemistry in the US?  
(Chemistry departments in UK are closing. )**
- 4. Engineering “pipeline” source is too small**

Recent competitiveness and innovation  
reports and legislation

Faculty survey

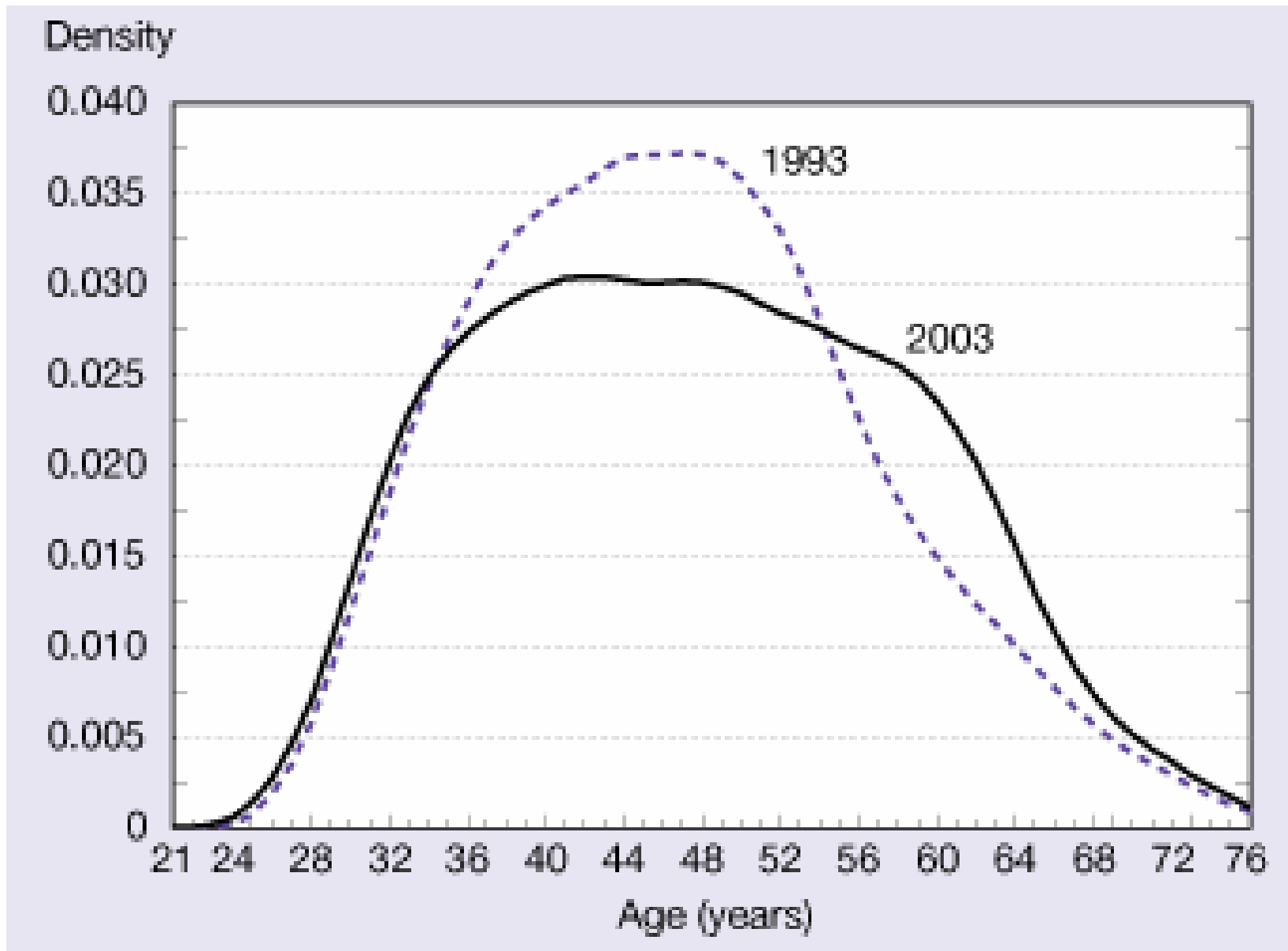
**Chemistry grad student attrition**

It is now generally accepted that US physical sciences must thrive in order for our country to maintain economic and scientific leadership, yet US scientific workforce development gives cause for concern.

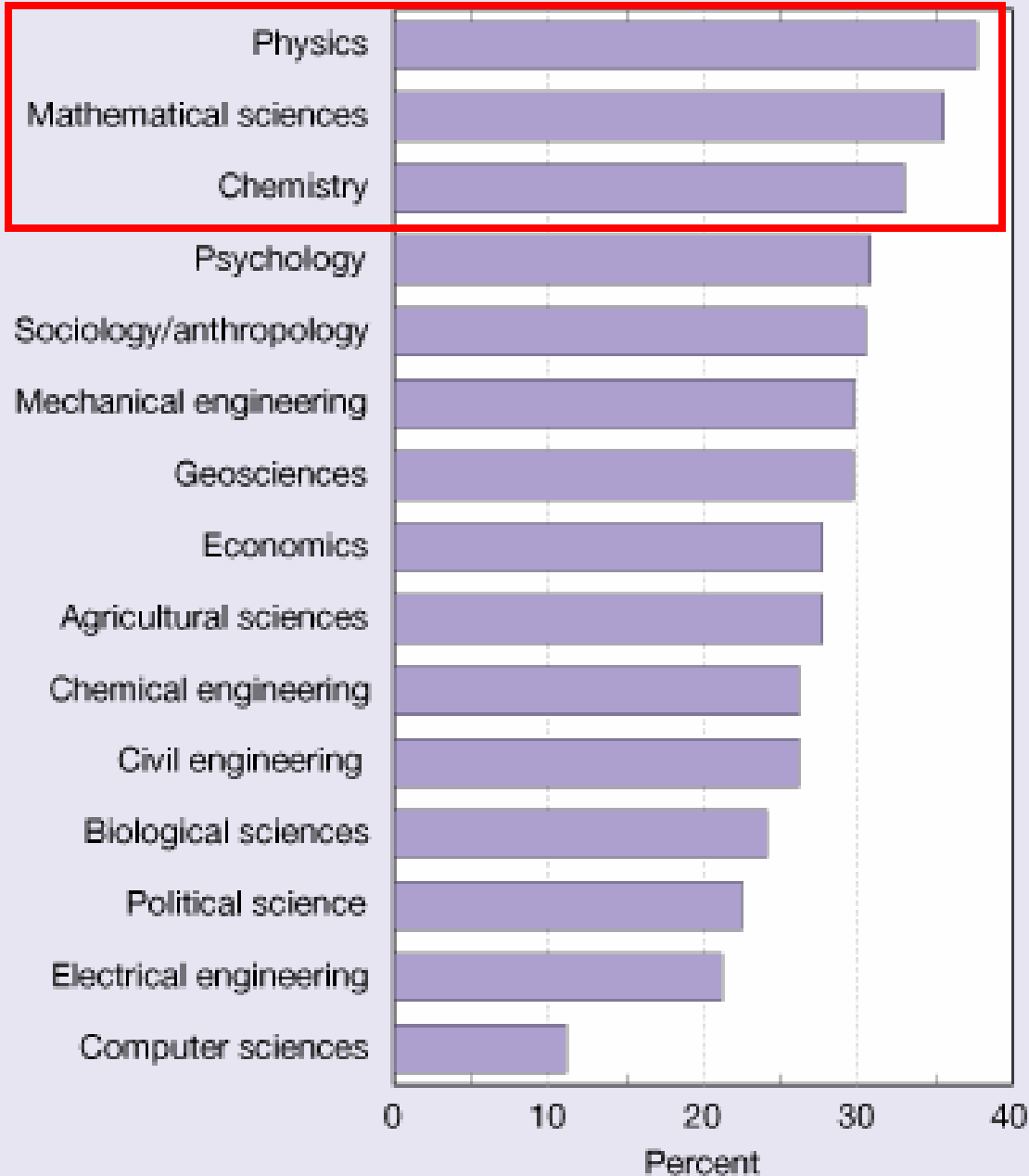
At the 27<sup>th</sup> Latin America Congress on Chemistry (FLAQ) 17Oct2006, Nobel Laureate Sir Harold (Harry) Kroto said “Real progress in nanotechnology will only be possible on the basis of a fundamental understanding of chemistry.”

# Demographics of US Scientists

Ageing scientific workforce; retirements will increase shortly



# Demographics of US Scientists

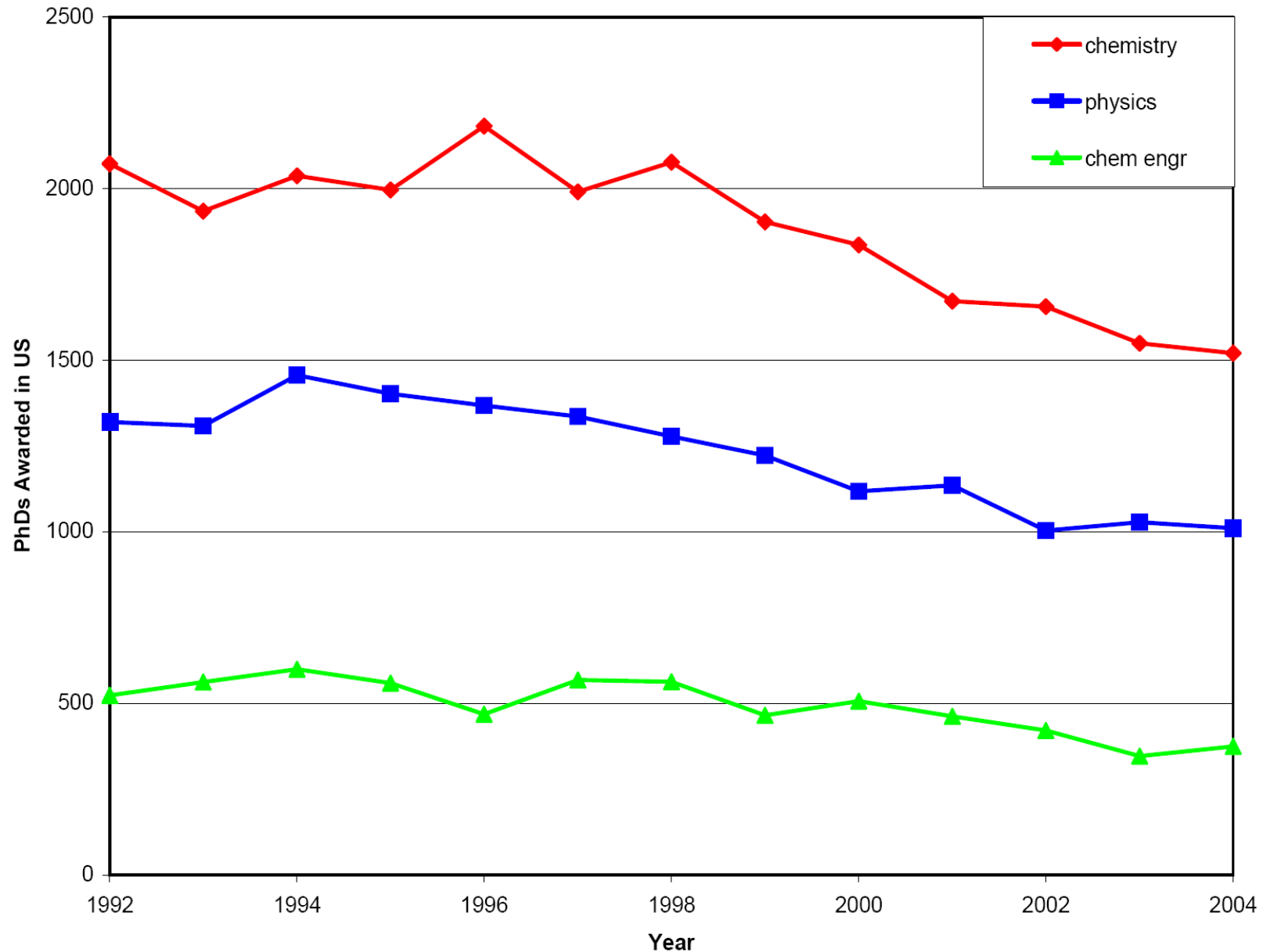


Percent of workforce over age 50 by discipline.

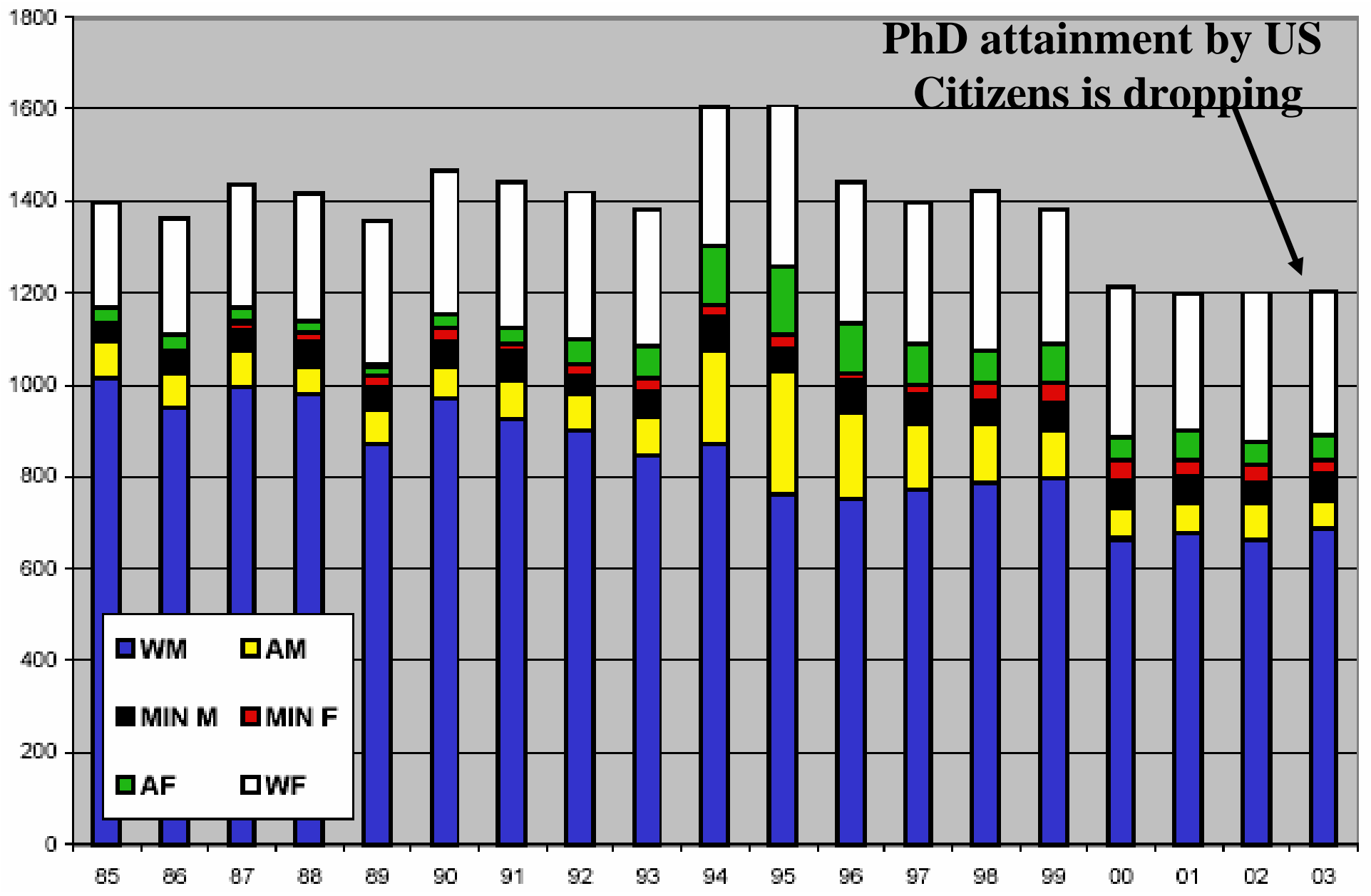
US scientific workforce is oldest in the physical sciences.

# Trends in US PhD Attainment

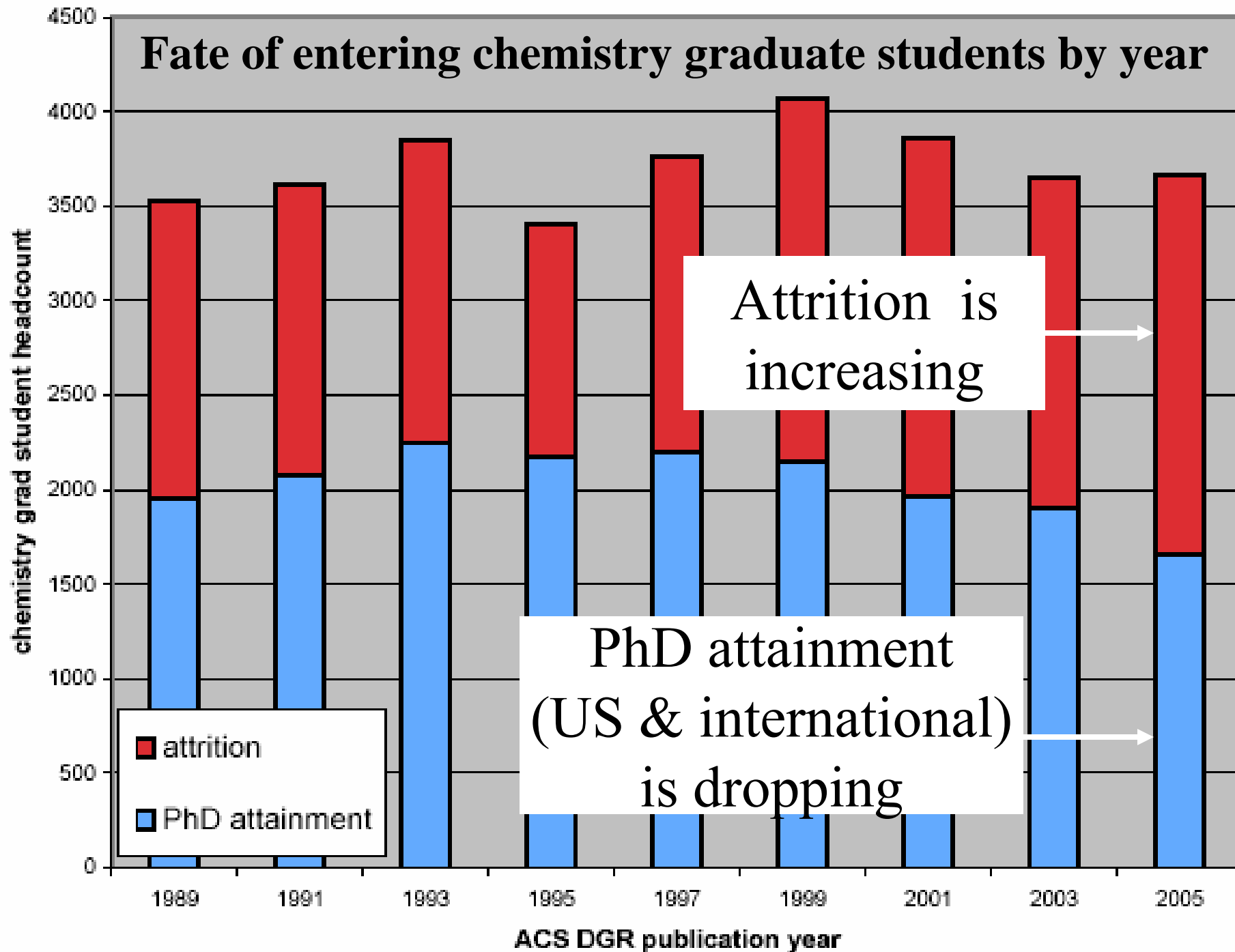
Projection of too few scientists attaining PhDs



# Chemistry PhD Recipients, by Race, by Gender, by Year



# Fate of entering chemistry graduate students by year



# Chemistry has largest grad student population, of physical sciences and engineering

BS and PhD Attainment by Discipline, Race, and Gender										
DISCIPLINE	BS recipients 2004					PhD recipients 2004				
	total #	women	URM	Asian	W male	total #	women	URM	Asian	W male
chemistry	8,955	51.0%	17.0%	11.2%	37.7%	1180	32.4%	8.3%	9.8%	56.5%
math	13,073	46.1%	12.3%	10.0%	42.3%	510	30.2%	7.0%	11.0%	55.9%
computer sci	52,544	24.7%	20.7%	15.6%	51.6%	447	22.8%	7.0%	17.0%	58.8%
astronomy	282	41.5%	10.2%	6.8%	49.4%	115	28.7%	5.6%	7.5%	62.6%
physics	3,967	21.6%	10.0%	6.0%	66.9%	559	15.4%	5.2%	8.4%	73.3%
chemical engr	4,817	35.6%	13.8%	11.3%	50.5%	312	25.6%	8.1%	19.5%	56.4%
civil engr	9,084	24.1%	14.0%	5.7%	62.6%	224	29.0%	13.7%	15.9%	50.0%
electrical engr	19,069	14.0%	16.8%	22.6%	54.8%	498	13.7%	10.0%	23.0%	58.7%
mechanical engr	13,754	13.7%	11.5%	7.0%	71.7%	299	14.7%	9.0%	21.0%	63.2%
economics	22,763	32.5%	13.1%	18.7%	49.5%	399	31.8%	8.9%	10.9%	54.7%
political sci	46,046	51.1%	19.9%	6.7%	38.5%	732	38.0%	13.0%	5.0%	51.0%
sociology	26,704	71.5%	28.0%	6.3%	18.9%	466	62.4%	14.6%	6.2%	29.0%
psychology	81,039	77.8%	21.2%	5.6%	16.4%	2788	67.9%	14.4%	5.7%	27.2%
biological sci	62,253	62.5%	16.6%	12.9%	27.5%	4185	47.7%	9.0%	12.0%	42.7%
earth sci	3,125	42.7%	6.3%	2.2%	53.5%	426	39.0%	7.1%	5.3%	90.3%

# REVIEW

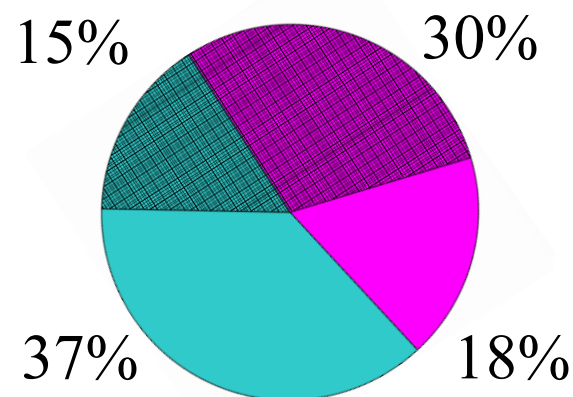
Physical sciences workforce challenges:

- These scientists are nearest to retirement.
- They have the greatest PhD attainment, but PhD attainment is dropping.
- They have great attrition, higher than in engineering or physics.

Need demographics of faculty & students in place, those leaving (and eventually, why).

## Physical sciences workforce answers:

- Determined faculty demographics.
- Compared to BS & PhD student demographics.
- Can't determine exact demographics of PhD students leaving. But **estimate** by letting %women in students entering = 1999 BS % women (47%)
- Chemistry average data:  
45% attrition →  
PhDs 68%**MALE** 32%**FEMALE** →
- Cannot determine causal effects.



# **Providing inspiration to the next generation**

Much attention is being focused on great global crises, in areas such as energy, environment, water, food supply, etc.

We must insure that doors these areas are open to women and minorities in order to insure that they will be inspired to become scientists.

In order for them to devote their careers to science, they must be convinced that they will have a place in these important and challenging areas.

# Collect challenges

1. Increase US citizens in science and engineering
2. Strengthen physical sciences
3. Make advances in energy, environment, high tech research and applications
4. Short time line (<10 years)

**BUT**

5. Chemistry has the greatest pipeline source, smallest increase in underrepresented groups, and greatest attrition
6. Engineering has better prospects, but its pipeline source is too small to make increases rapidly

# **Need new novel programs**

1. Capture attrition of chemistry graduate students
2. Move students to engineering college to work in nationally identified critical research areas
3. Simultaneously solves graduate school problems of high attrition in chemistry and low student pipeline source in engineering
4. Enrich engineering disciplines with physical sciences knowledge and training
5. Short time line (PhDs in 3 to 5 years)
6. Draws from a pool naturally rich in underrep groups
7. Provides a win-win situation for all

# Acknowledgements

Oklahoma Center for Advancement of Science & Technology

OCCAST»

**ADVANCE  
LEADERSHIP  
AWARD**



FORD FOUNDATION

