

# Women and the Future of Physics

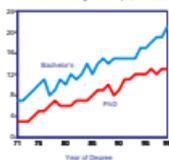
Howard Georgi

Harvard University









Source: AIP Statistical Research Center. Data from Maloney & Nicholson, *Physics and the Degree*.

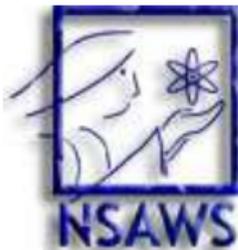
data - and the state  
of physics education



portrait of a  
personal journey



recommendations  
for the future

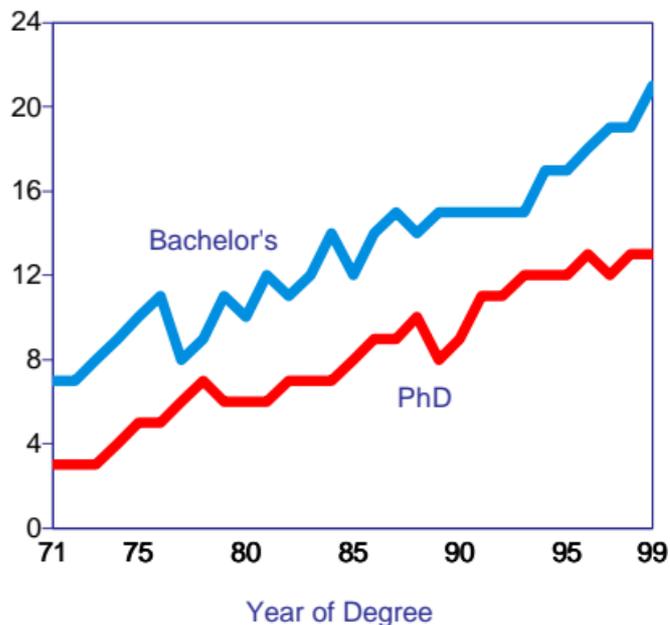


recent conference put on by **WISHR**

**W**omen **I**n **S**cience at **H**arvard-**R**adcliffe

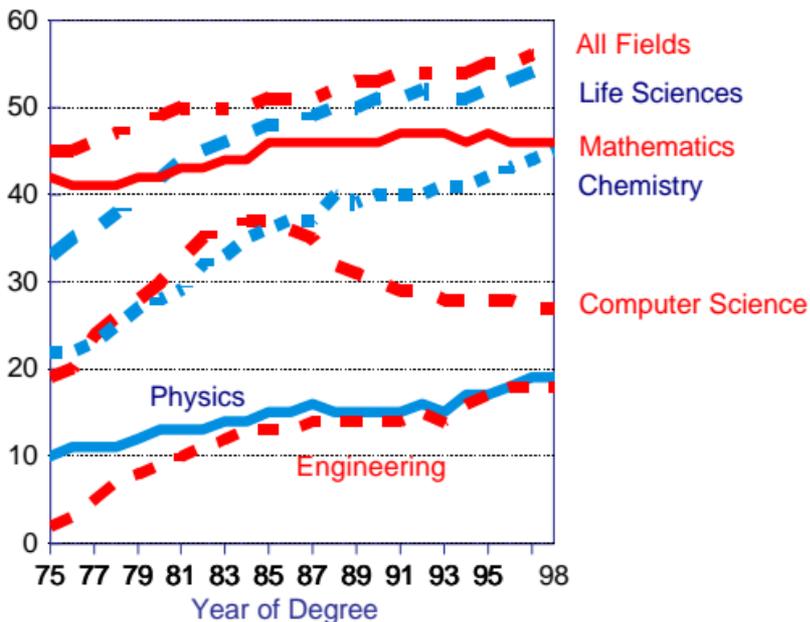
reminded me of some familiar but puzzling data on the percentage of women receiving degrees in various fields

# % of women getting physics degrees



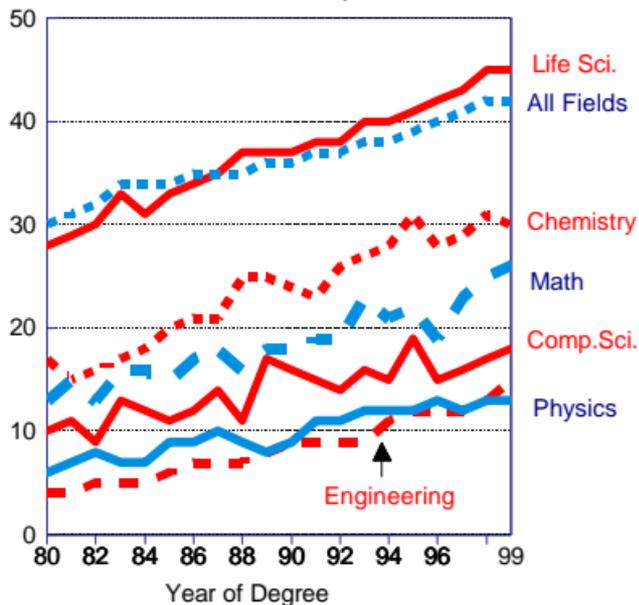
Source: AIP Statistical Research Center. Data from Mulvey & Nicholson, *Enrollments and Degrees Report*.

# % of women getting BAs by field



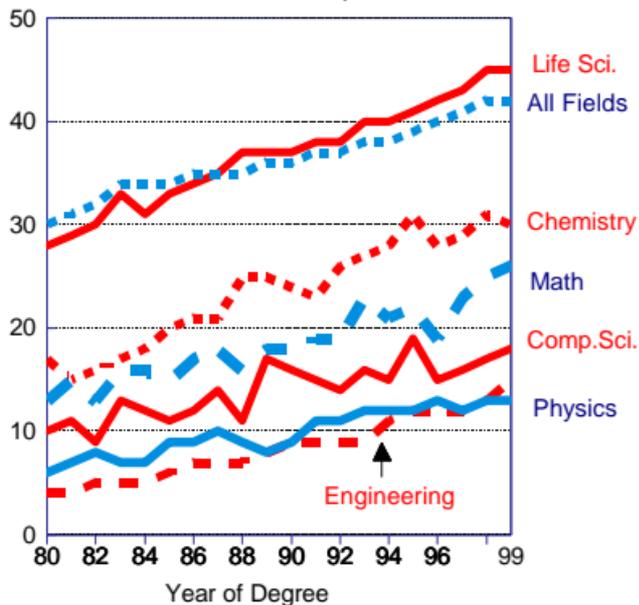
Source: AIP Statistical Research Center, Data from Mulvey & Nicholson, Enrollments and Degrees Report, and the National Center for Education Statistics.

# % of women getting PhDs by field



Source: AIP Statistical Research Center. Data from Mulvey & Nicholson, *Enrollments and Degree Report*, and National Opinion Research Center.

# Worse than Math and Chemistry???



Source: AIP Statistical Research Center. Data from Mulvey & Nicholson, *Enrollments and Degree Report*, and National Opinion Research Center.

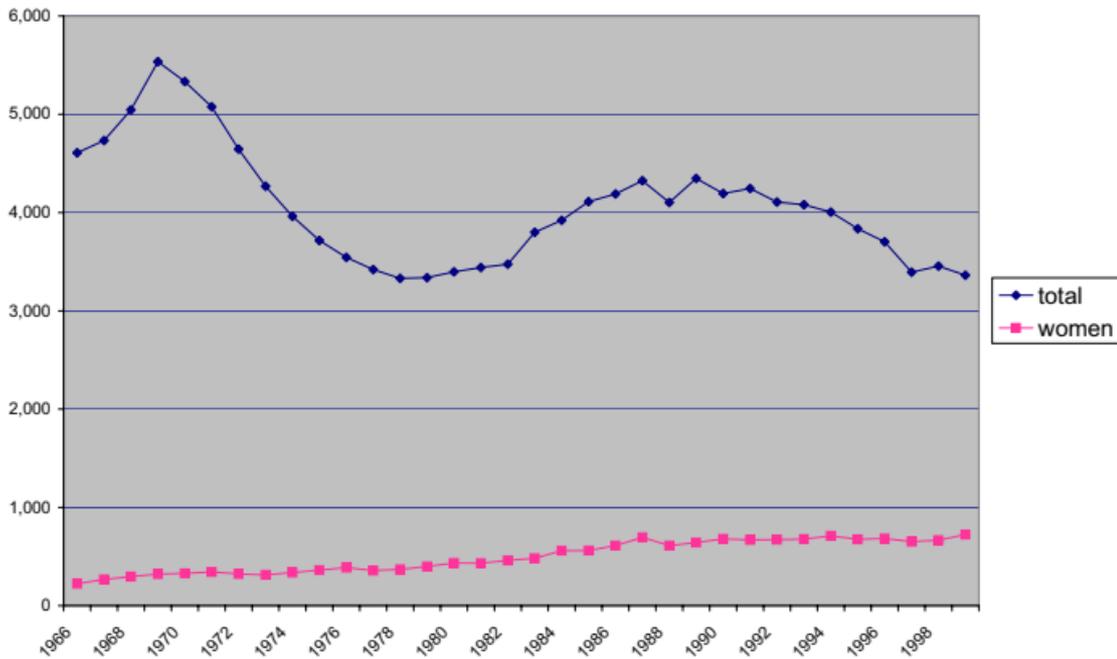
[www.nsf.gov/sbe/srs/nsf02327/start.htm](http://www.nsf.gov/sbe/srs/nsf02327/start.htm)

SOURCES: Tabulated by National Science Foundation/Division of Science Resources Statistics;

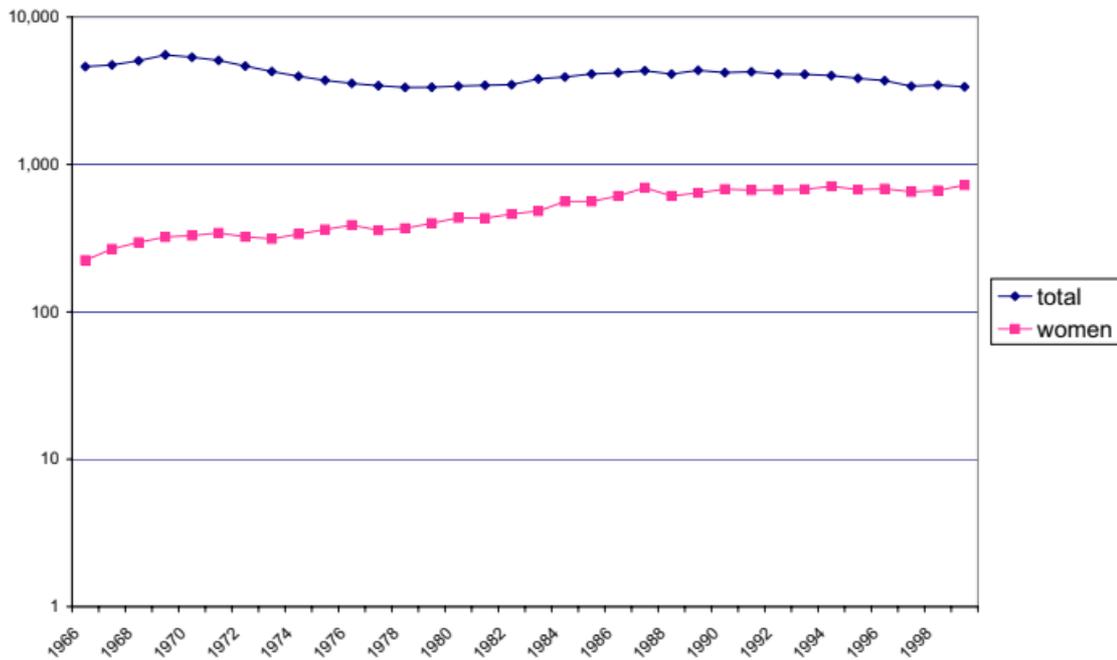
data from Department of Education /National Center for Education Statistics: Integrated Postsecondary Education Data System Completions Survey;

and NSF/SRS: Survey of Earned Doctorates

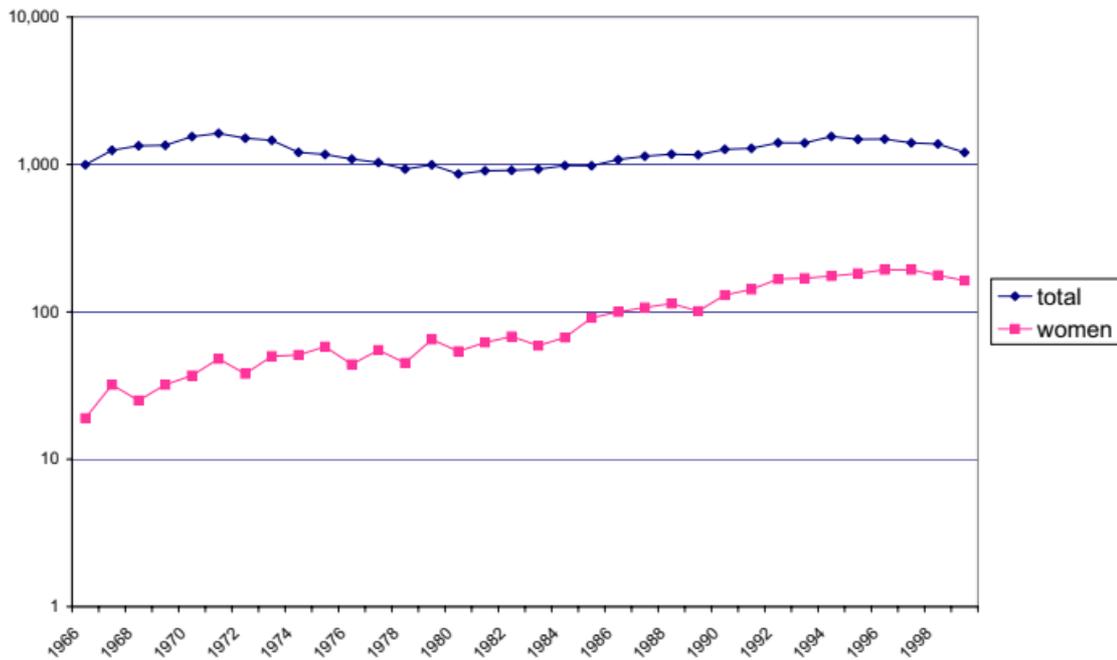
## BAs in Physics



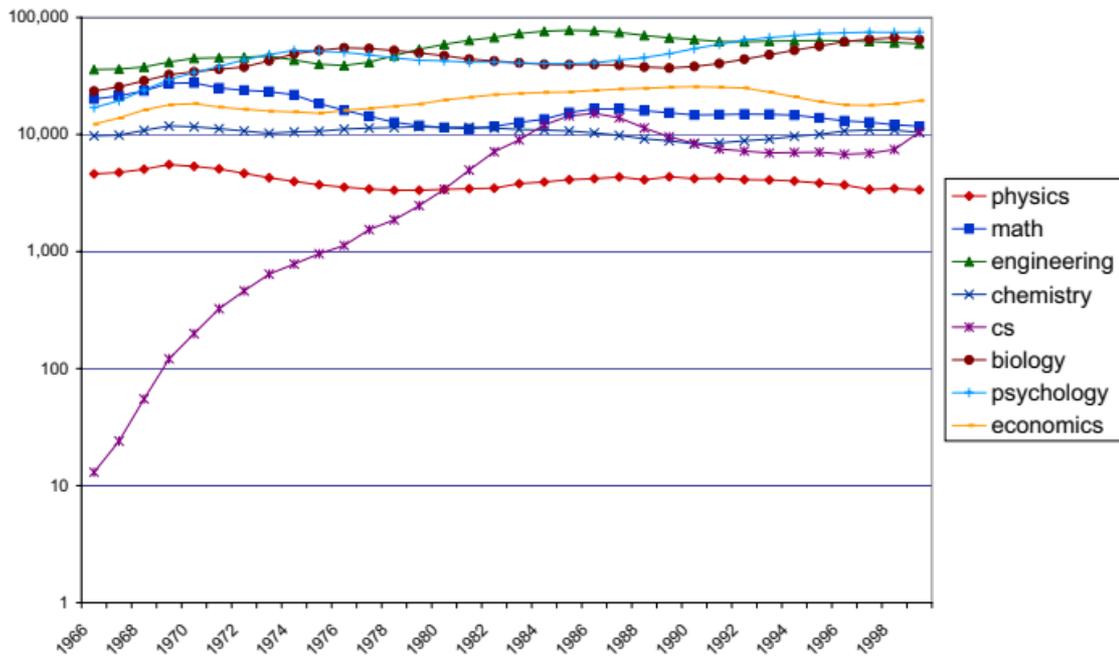
## BAs in Physics



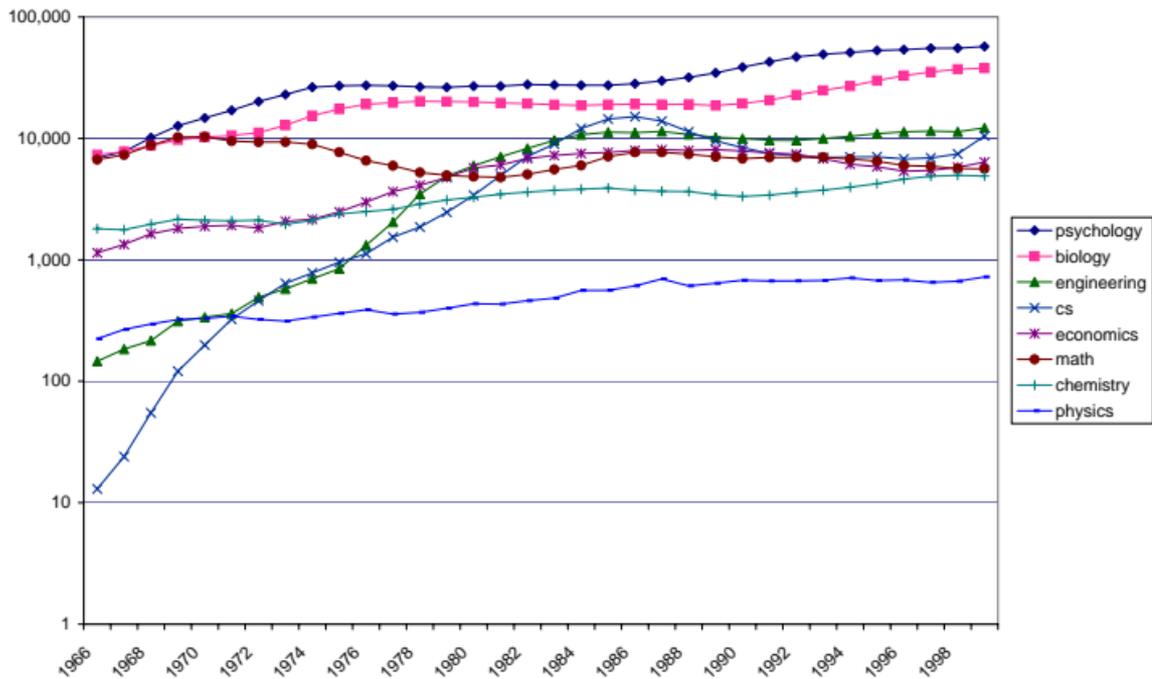
## PhDs in Physics



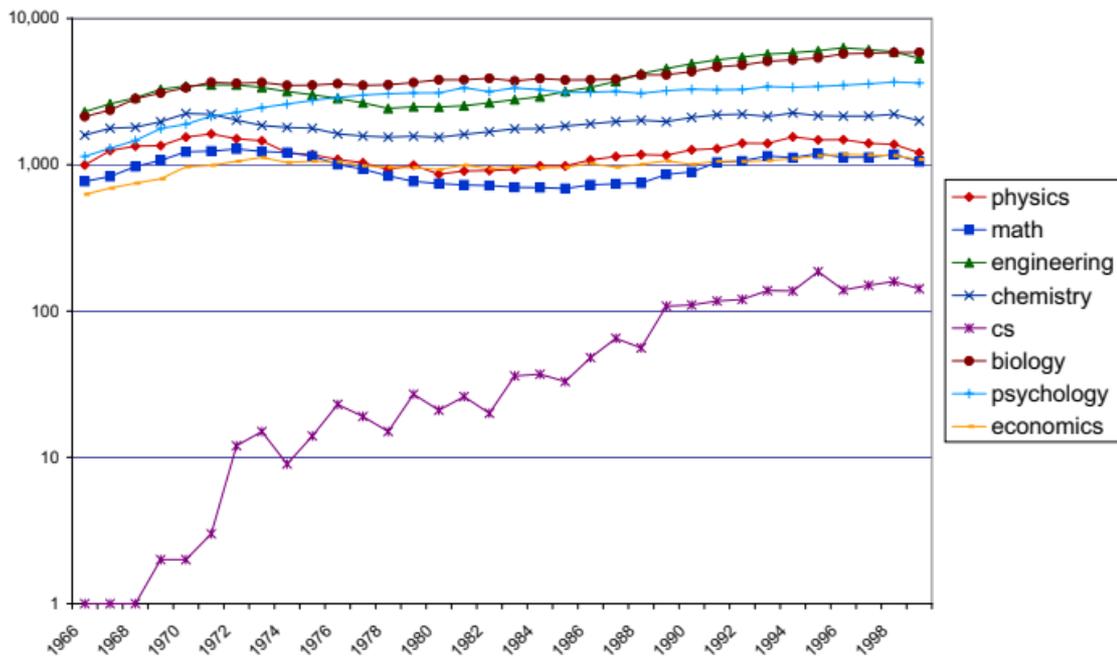
## BAs by field



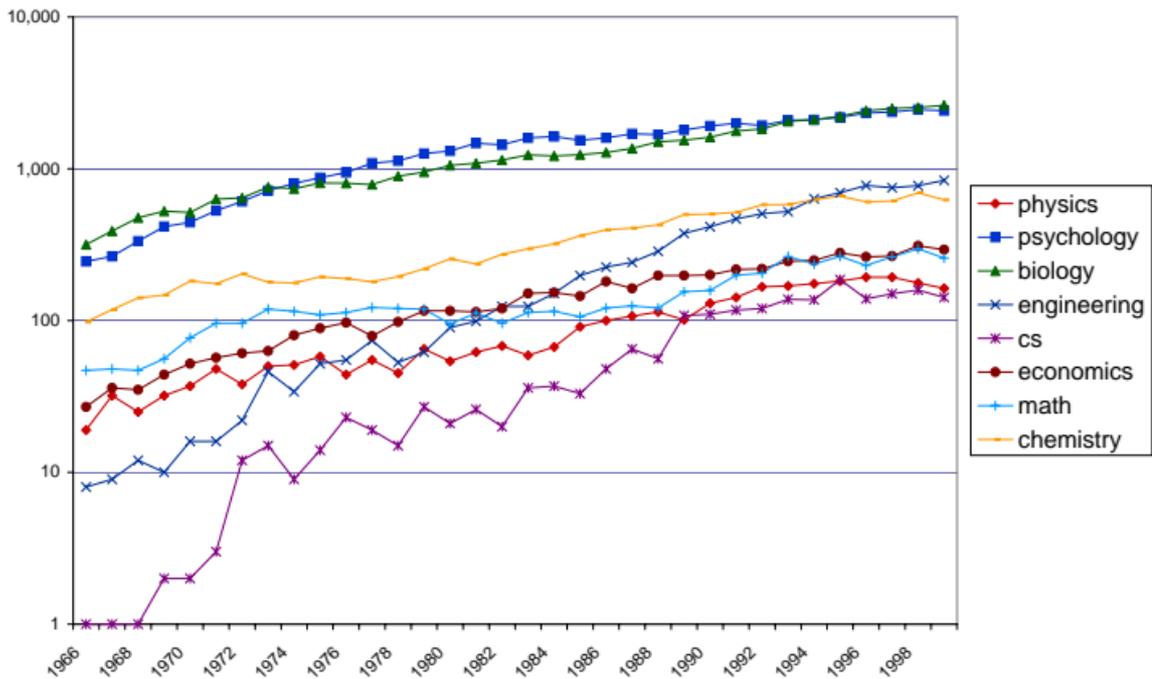
## Women BAs by field



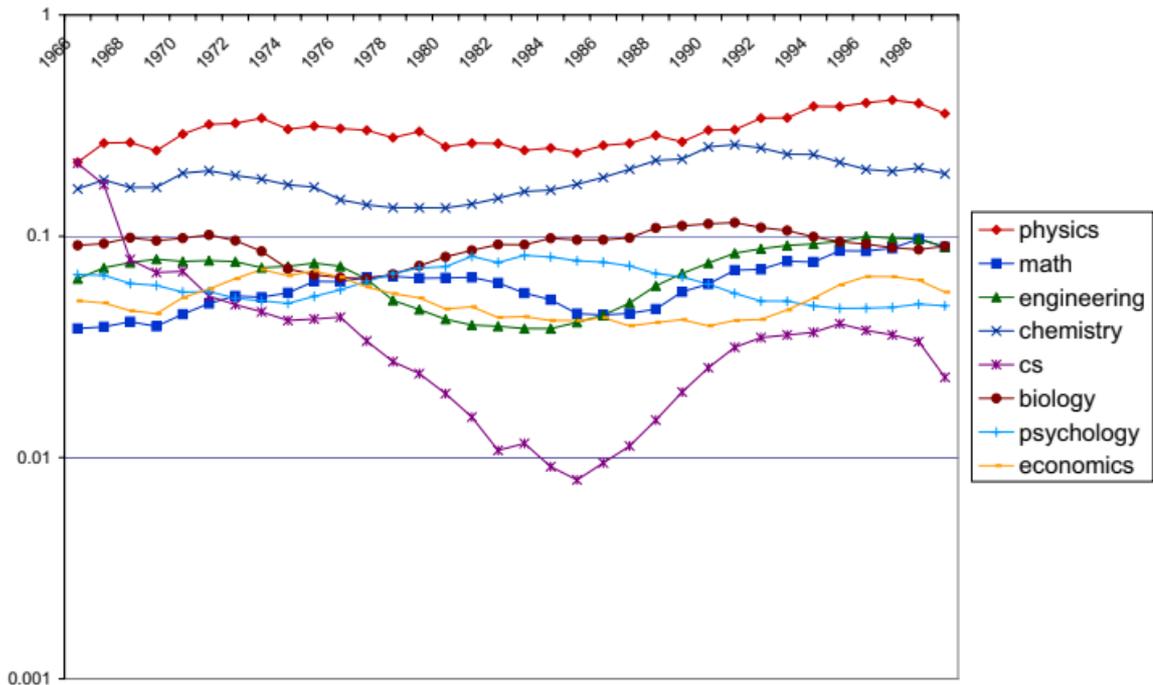
## PhDs by field



## Women PhDs by field



## PhDs / BAs



there is a lot of structure - probably many things are going on - but three things stand out about physics

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**1: it is MALE - there are very few women**

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- 1:** it is MALE - there are very few women
- 2:** it is SPARSE - there are very few people period - particularly at the undergraduate level
- 3:** and it is FOCUSED on advanced degrees

**1:** it is MALE - it is there are very few women

**2:** it is SPARSE - there are very few people period - particularly at the undergraduate level

**3:** and it is FOCUSED on advanced degrees  
conclusion — the small number of women in physics doesn't tell the whole story - it is important to understand how maleness relates to sparseness and focus

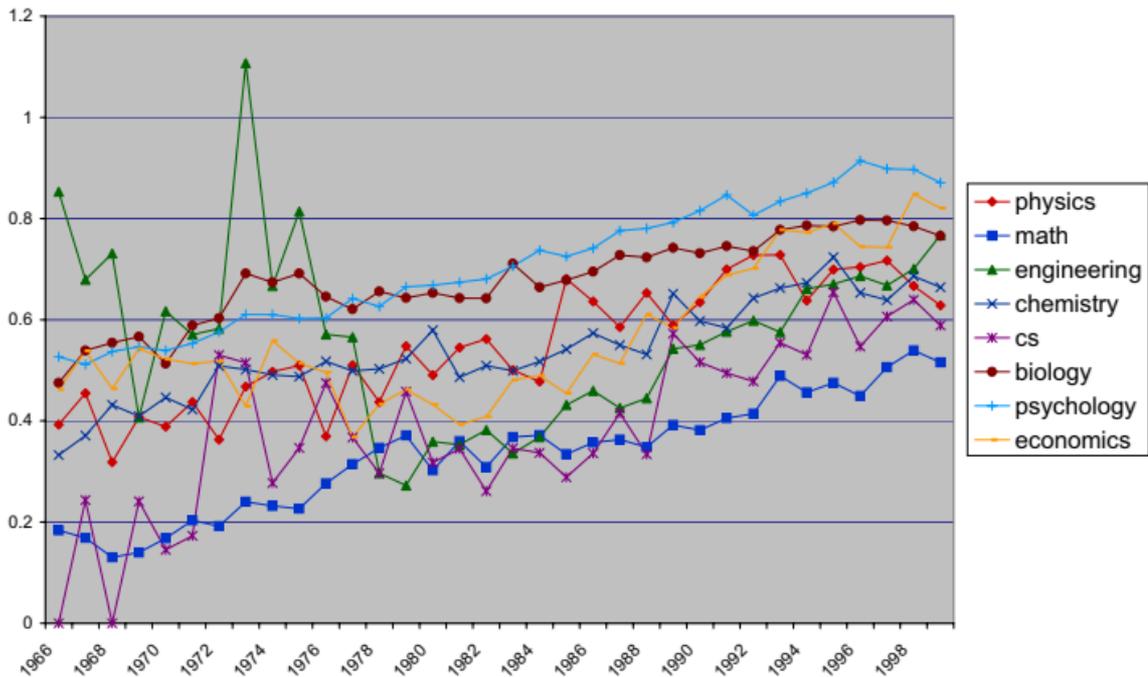
attempt to tease out something that isolates  
a simple gender effect - standard trick in  
experimental physics and phenomenology -  
ratio of ratios

$$P \equiv \frac{\text{Women PhDs/Women BAs}}{\text{Men PhDs/Men BAs}}$$

attempt to tease out something that isolates a simple gender effect - standard trick in experimental physics and phenomenology - ratio of ratios - “Pipeline ratio”

$$P \equiv \frac{\text{Women PhDs/Women BAs}}{\text{Men PhDs/Men BAs}}$$

## Pipeline ratio



Why am I here giving this talk?

Why am I here giving this talk?

A brief history of my personal journey from  
unconsciousness to activism

Why am I here giving this talk?

A brief history of my personal journey from unconsciousness to activism — in the hopes that it may encourage others to examine more closely their own beliefs about the issue of women in science.

# Harvard physics

70s

80s

90s

00s

## Harvard physics

70s

male enclave

80s

beginnings  
of integration

90s

significant  
group of women  
with real diversity

00s

Harvard physics

women in  
graduate  
program

70s

male enclave

s  
t  
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80s

beginnings  
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90s

significant  
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00s

Harvard physics

women in  
graduate  
program

me

70s

male enclave

s  
t  
e  
a  
d  
y

an oblivious nerd

80s

beginnings  
of integration

i  
n  
c  
r  
e  
a  
s  
e

a strong  
supporter of  
women in science

90s

signifigant  
group of women  
with real diversity

an  
activist

00s



Bob Fitch/Black Star

# Women and the Future of Physics

Howard Georgi

Harvard University

the 70s

# Standard Model of FUNDAMENTAL PARTICLES AND INTERACTIONS

The Standard Model summarizes the current knowledge in Particle Physics. It is the quantum theory that includes the theory of strong interactions (Quantum Chromodynamics or QCD) and the unified theory of weak and electromagnetic interactions (electroweak). Gravity is omitted on this chart because it is one of the fundamental interactions even though not part of the "Standard Model".

## FERMIONS

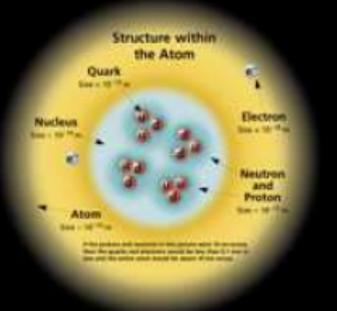
matter constituents  
spin = 1/2, 3/2, 5/2, ...

Leptons			Quarks		
Flavor	Mass (GeV/c <sup>2</sup> )	Electric charge	Flavor	Approx. Mass (GeV/c <sup>2</sup> )	Electric charge
$e^-$ electron	$<1 \cdot 10^{-6}$	0	u up	0.003	2/3
$\mu^-$ muon	0.00011	-1	d down	0.006	-1/3
$\tau^-$ tauon	1.7771	-1	c charm	1.3	2/3
$\nu_e$ electron neutrino	<0.0002	0	s strange	0.1	-1/3
$\nu_\mu$ muon neutrino	0.106	-1	t top	175	2/3
$\nu_\tau$ tauon neutrino	<0.02	0	b bottom	4.3	-1/3

Note: the vector angular momentum of particles, spin, is given in units of  $\hbar$ , which is the quantum unit of angular momentum, where  $\hbar = h/2\pi = 6.58 \cdot 10^{-16}$  Jsec =  $1.054 \cdot 10^{-27}$  Jsec.

Electric charges are given in units of the proton's charge. W bosons the electric charge of the proton is  $1.60 \cdot 10^{-19}$  coulombs.

The energy unit of particle physics is the electronvolt (eV). The energy gained by one electron if it moves a potential difference of one volt. **Masses** are given in GeV/c<sup>2</sup>. Remember:  $E = mc^2$ , where  $c$  (speed of light) =  $3 \cdot 10^8$  m/sec. The mass of the proton is 0.938 GeV/c<sup>2</sup> =  $1.67 \cdot 10^{-27}$  kg.



## BOSONS

force carriers  
spin = 0, 1, 2, ...

Gauged Electroweak			Strong Interactions		
Name	Mass (GeV/c <sup>2</sup> )	Electric charge	Name	Mass (GeV/c <sup>2</sup> )	Electric charge
$\gamma$ photon	0	0	g gluon	0	0
$W^+$	80.4	-1			
$W^-$	80.4	+1			
$Z^0$	91.187	0			

Color charged particles interact by exchanging gluons. Gluons are confined to color-neutral particles called hadrons. The confinement (confinement) results from the exchange of gluons among the color charged particles. The color charged particles (quarks and gluons) create what's called the color flux-tube between them. This energy eventually is converted into small sized quark-antiquark pairs (hadron pairs). The quarks and antiquarks that combine into hadrons, share and the particles emit an average. This type of hadron pair has been observed in various processes of jet formation.

**Residual Strong Interaction**  
The strong binding of color-neutral particles and requirement to form nuclei is due to residual strong interactions between their color-charged constituents. It is easier to the residual strong interaction that binds nucleons together to form nuclei. It can also be viewed as the exchange of mesons between the nucleons.

## PROPERTIES OF THE INTERACTIONS

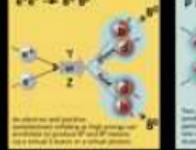
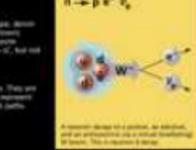
Baryons (qqq) and Antibaryons (qqq)					
Quark	Antiquark	Quark	Antiquark	Mass	Spin
p	antip	uud	$\bar{u}\bar{u}\bar{d}$	0.938	1/2
n	antin	udd	$\bar{u}\bar{d}\bar{d}$	0.938	1/2
$\Delta^+$	antidelta	uud	$\bar{u}\bar{u}\bar{d}$	1.232	3/2
$\Delta^0$	antidelta	uud	$\bar{u}\bar{d}\bar{d}$	1.232	3/2
$\Delta^-$	antidelta	udd	$\bar{u}\bar{d}\bar{d}$	1.232	3/2

Property	Interaction	Gravitational		Electroweak		Strong	
		Mass-Energy	Flavor	Electric Charge	Color Charge	Parity	Spin
Participates	Participates	All	Quarks, Leptons	Electrically charged	Quarks, Gluons	Hadrons	Hadrons
Strength	Strength	Universal	Universal	Universal	Universal	Universal	Universal
Range	Range	Infinite	Infinite	Infinite	Infinite	Infinite	Infinite

Mesons (qq)					
Quark	Antiquark	Quark	Antiquark	Mass	Spin
$\pi^+$	$\pi^-$	u	$\bar{d}$	0.140	0
$K^+$	$K^-$	u	$\bar{s}$	0.494	0
$\rho^+$	$\rho^-$	u	$\bar{d}$	0.770	1
$\omega$	$\omega$	u	$\bar{u}$	0.782	0
$\phi$	$\phi$	s	$\bar{s}$	1.020	0

**Matter and Antimatter**  
For every baryon (qqq) there is a corresponding antibaryon (qqq). Matter and antimatter have identical mass and spin but opposite charges. Some antiquarks require bars (e.g.,  $\bar{u}$ ,  $\bar{d}$ ,  $\bar{s}$ ,  $\bar{c}$ ,  $\bar{b}$ ,  $\bar{t}$ ,  $\bar{\nu}_e$ ,  $\bar{\nu}_\mu$ ,  $\bar{\nu}_\tau$ ) are their own antiparticles.

**Figures**  
These diagrams are an artist's conception of physical processes. They are not real and have not been actually seen. Diagrams are intended to show the flow of quarks in the gluon field, and not the exact path.



**The Particle Antennae**  
Look the event recorded with the Large Hadron Collider at CERN. The event shows the production of a Z boson and a photon, which then decay into a quark-antiquark pair.

**Summary**  
The Standard Model of particle physics is a quantum field theory. It describes the interactions between quarks and leptons via the exchange of gauge bosons (photons, gluons, W and Z bosons).

**DISCUSS**  
The Standard Model is a quantum field theory. It describes the interactions between quarks and leptons via the exchange of gauge bosons (photons, gluons, W and Z bosons).

<http://pdg.lbl.gov/pep.html>



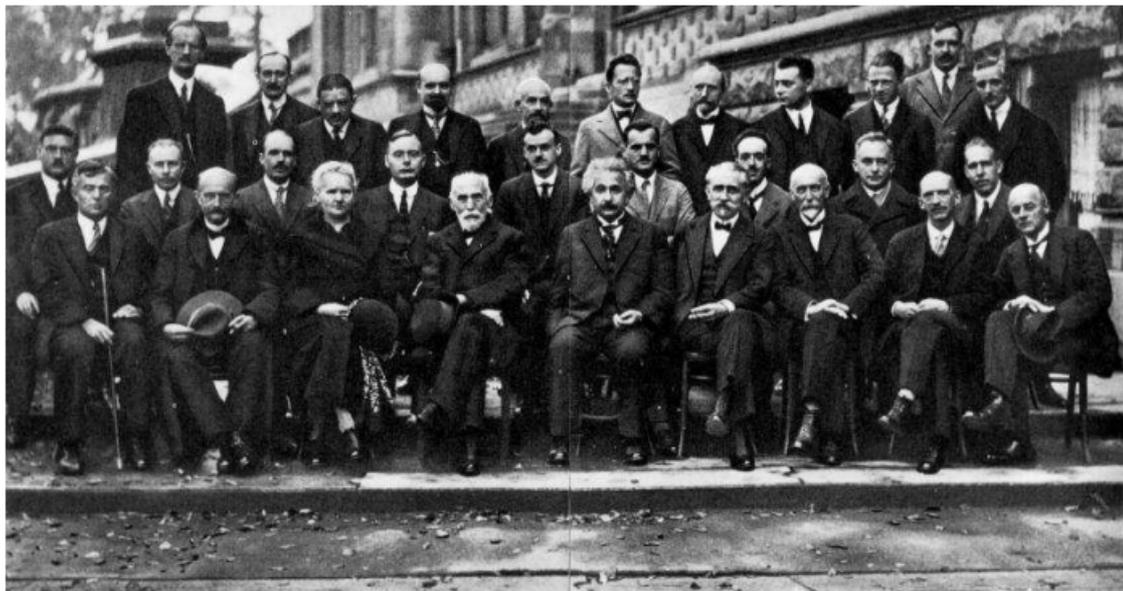
Office of the Dean  
Harvard College  
2002 – 2003

TELE  
SOME  
ONE!

Responding to Sexual Harassment,  
Sexual Assault and Rape



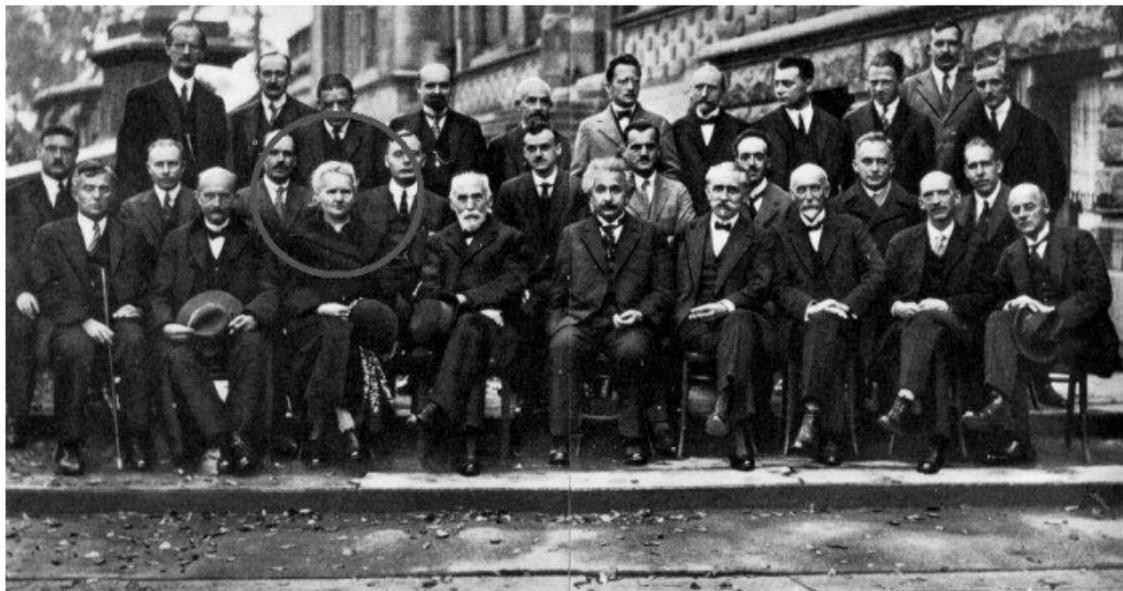
the 80s



Photographie Benjamin Couprie

28, Avenue Louise, Bruxelles

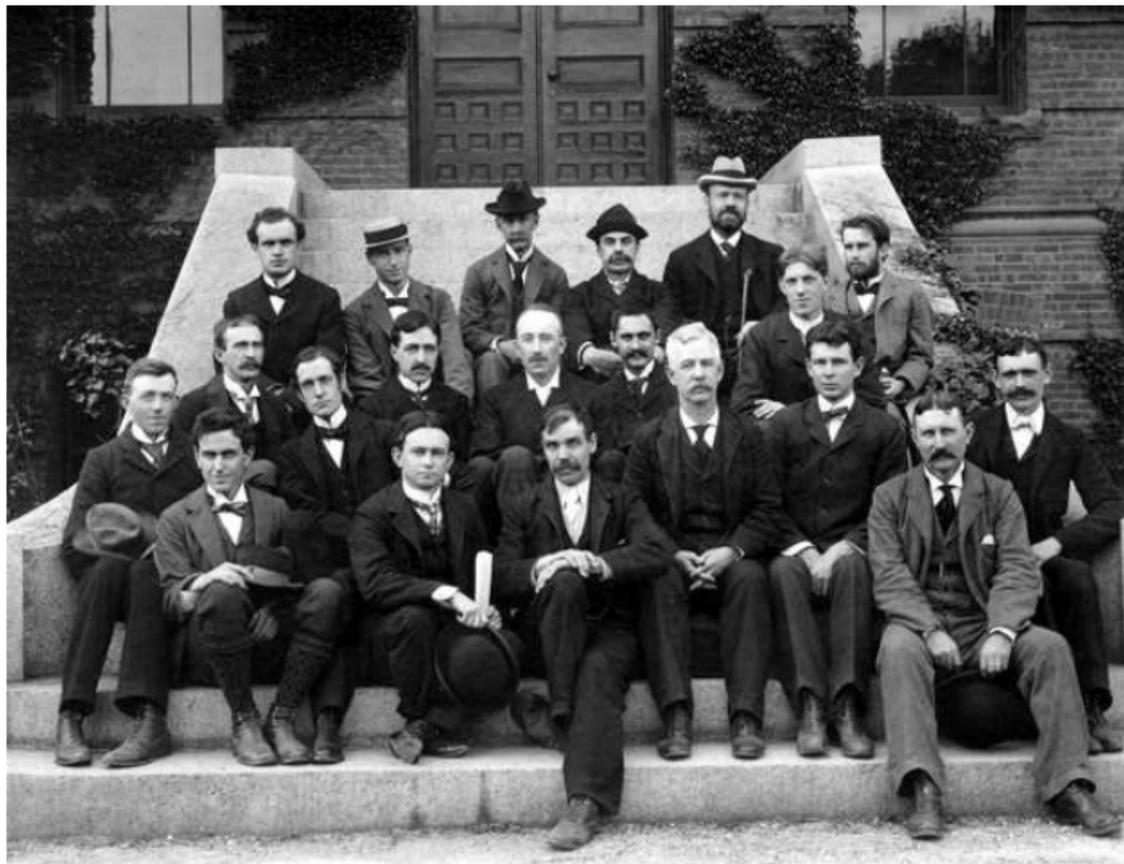
								R. H. FOWLER	
A. PICCARD	E. HENRIOT		ED. HERZEN	TH. DE DONDER	E. SCHRÖDINGER		W. PAULI	W. HEISENBERG	L. BRILLOUIN
		P. EHRENFEST				E. VERSCHAFFELT			
P. DEBYE	M. KNUDSEN	W. L. BRAGG	H. A. KRAMERS	P. A. M. DIRAC	A. H. COMPTON	L. V. DE BROSLIE	M. BORN		N. BOHR
I. LANGMEIR	M. PLANCK	MADAME CURIE	H. A. LORENTZ	A. EINSTEIN	P. LANGEVIN	CH. E. GUYE	C. T. R. WILSON		
								O. W. RICHARDSON	



Photographie Benjamin Couprie

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									O. W. RICHARDSON



Harvard



LEFT



Seeking the world's best and brightest  
young scholars.

> [Home](#) > [Admissions](#)



## Admissions Information for Prospective Graduate Students

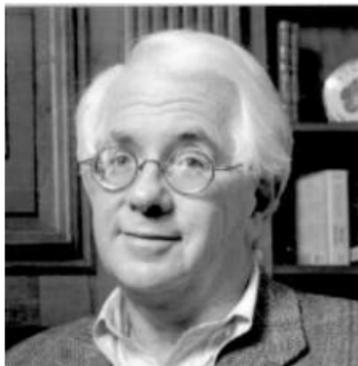
The Graduate School invites applications from students whose breadth of academic experience and fitness for the specific field of study suggest the potential for scholarly achievement.

In general, only applicants holding the BA or equivalent, with distinguished undergraduate records, are admitted. (See [Academic Requirements](#).) Faculty recommendations and the applicant's statement of purpose are carefully weighed. Research papers, publications, and other original works may also be considered by the admissions committees during their evaluations.

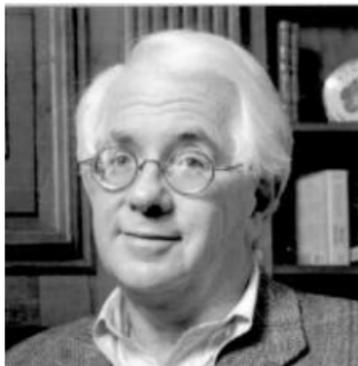
Persons holding a PhD or its equivalent, or who have completed most of the work required to earn the PhD elsewhere, may apply to a PhD program in the



Students flocked to Harvard to work with  
Nobel Prize Winners Shelly Glashow and  
Steven Weinberg



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Nobel Prize Winners Shelly Glashow and  
Steven Weinberg



Working with me was easier!









the 90s





Chair of the Physics Department



Chair of the Physics Department  
Lots of responsibility



Chair of the Physics Department  
Lots of responsibility - no power



Chair of the Physics Department

Lots of responsibility - no power

Deluged with statistics

course  
grading index = average grade  
in a course

— average grade of the students  
in all their other courses

course  
grading index = average grade  
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almost always negative for physics courses!

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broken down by gender - women were much  
more negative

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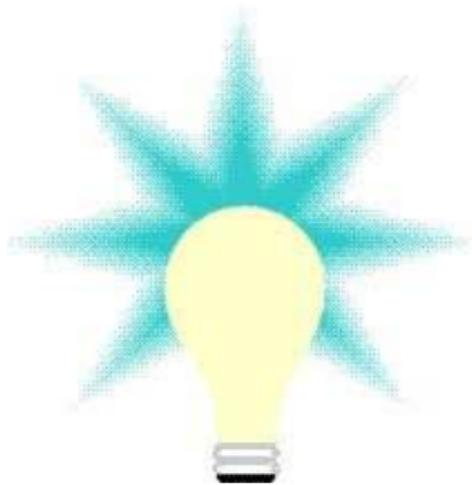
I had other data broken down -

data from senior surveys broken down by  
gender

data from senior surveys broken down by  
gender showed that our women physics  
concentrators had a miserable experience

data from senior surveys broken down by gender showed that our women physics concentrators had a miserable experience

Many of our women physics concentrators were trapped in an emotionally abusive relationship with the Harvard Physics Department!!!



This turned me into an activist for Women  
in Physics!

THE CLASSIC *NEW YORK TIMES* BESTSELLER

# You Just Don't Understand

"Utterly fascinating. . . .  
A classic in the field."

—SAN FRANCISCO CHRONICLE

WOMEN AND MEN IN  
CONVERSATION

DEBORAH  
TANNEN

WITH A NEW AFTERWORD BY THE AUTHOR

# Failing at Fairness

How Our  
Schools  
Cheat Girls



*"Failing at Fairness is an eye-opener for any parent or teacher truly interested in equality. This book provides anyone who cares about girls with the stuff that courage is made of." —Elizabeth Debold, The San Francisco Chronicle, author of Mother Daughter Revolution*

**MYRA and DAVID SADKER**

from Brown College Dean's Office

- Observe Classroom Dynamics
- Personalize Large Classes
- Shift from a Competitive to a Cooperative Educational Model
- Consider a Variety of Examination Options
- Encourage Active Participation in Labs
- Fight Narrow Stereotypes of Science
- Provide Diverse Role Models
- Make Yourself Available
- Foster Self-Confidence

from Brown College Dean's Office

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Similar steps needed at the Department level —

from Brown College Dean's Office

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- Encourage Active Participation in Labs
- Fight Narrow Stereotypes of Science
- Provide Diverse Role Models
- Make Yourself Available
- Foster Self-Confidence

Similar steps needed at the Department level — treat students as individuals

Lots of little things!

Talking to the women concentrators and graduate students

Women in Physics Dinners

Site Visit by CSWP

Improved advising

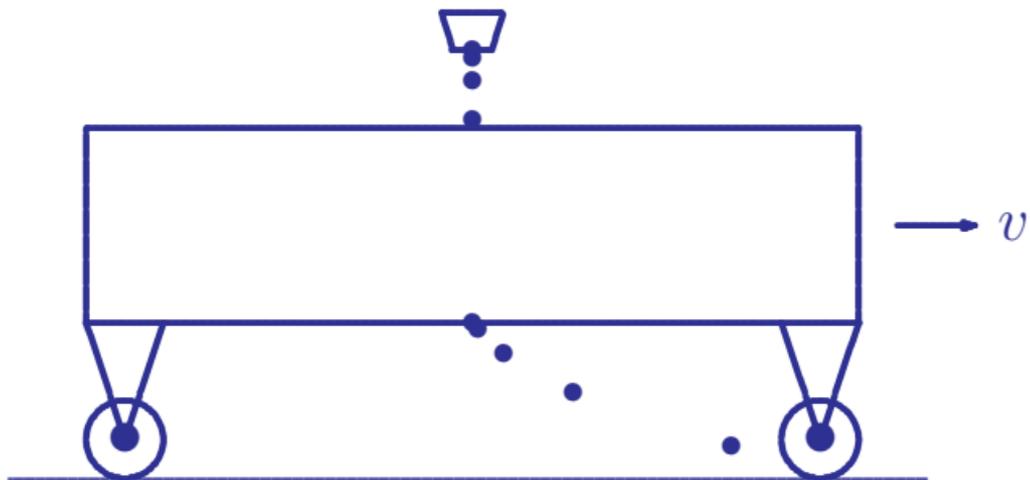
Biannual picnics

Physics Department Holiday Caroling

most important - tenured women faculty







hotshot course		year	women	men
physics 55	{	1987	2	46
		1988	10	56
physics 16	{	1998	8	42
		1999	17	46
		2000	6	49
		2001	15	42
		2002	18	50
		2003	16	63

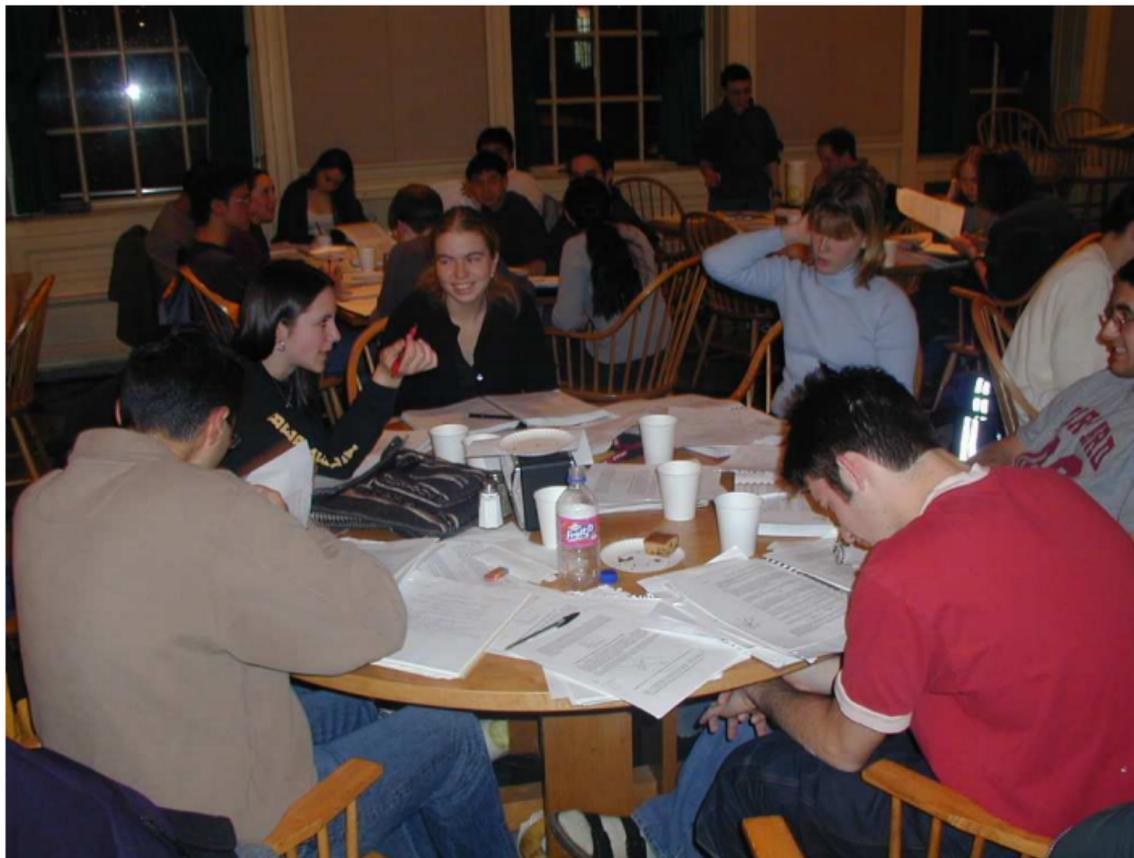
emphasize that it is hard but humane  
have explicit rules of coherence and  
readability for problem sets  
give students several ways to do well  
talk very explicitly about whether to take  
the course  
PRS, take-home/in-class exam system ...  
attract study groups to my office and the  
House dining hall with food  
hang out to see how they work

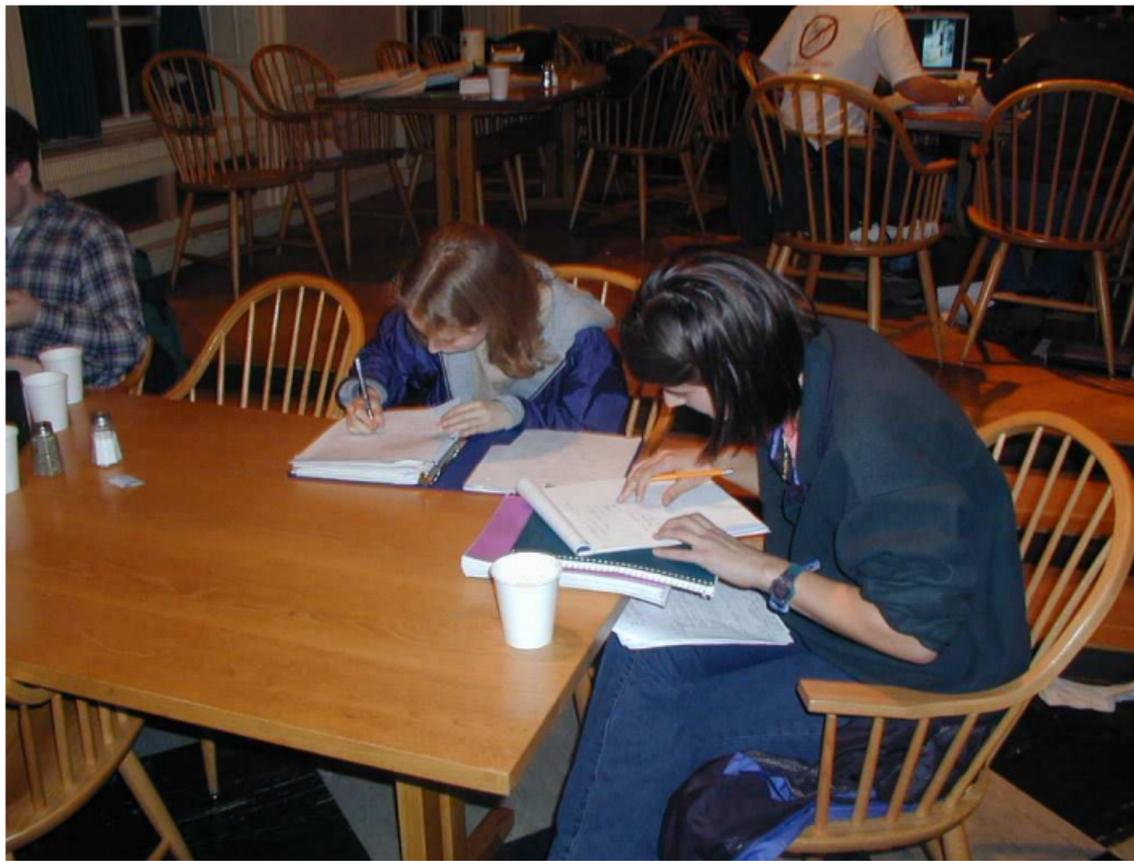


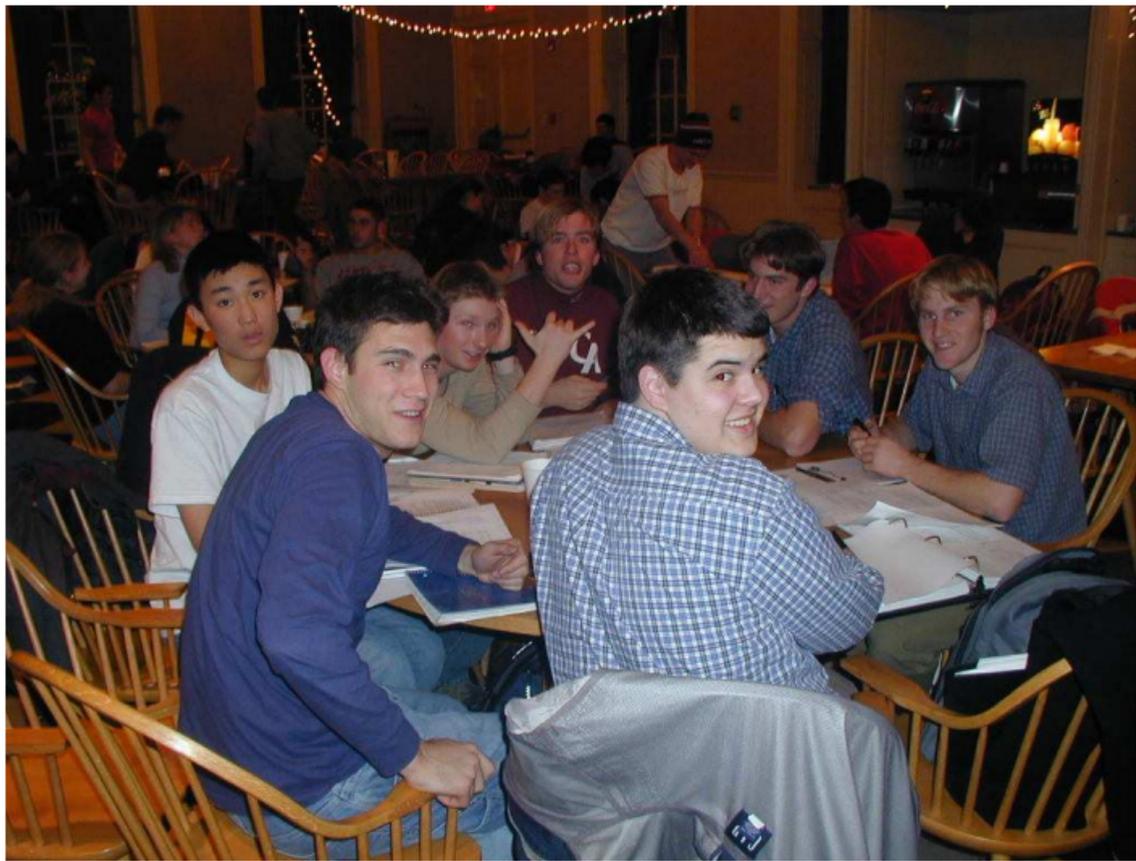












Life, love, and physics meet head on  
in the brand new musical  
that everyone is talking about!



# Les Phys



Written and composed by Peter Dong

May 9, 10, 11 at 8pm and May 11 at 2pm  
in the Agassiz theater



Produced by Jeffrey Filippini and Steven Padnick

Directed by Kaitlin Heller

Choreographed by Sara Heller

Music direction by Peter Dong

Vocal direction by Aaron Dinkin and Ezra Keshet

Tickets \$8 General Admission \$5 Student  
at the Harvard Box Office Group discounts available

IF I WERE A SCIENTIST  
WORKING IN A BIG LAB,  
I'D SHOUT "EUREKA!"  
EVERY SO OFTEN JUST  
TO BOOST MORALE.



# CONCLUSIONS

Why were our women concentrators so unhappy?

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Conversely, efforts to encourage women in physics will help broaden the field for both genders.

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Why were our women concentrators so unhappy? SPARSENESS and FOCUS of physics magnifies the problems of the women in the field.

Conversely, efforts to encourage women in physics will help broaden the field for both genders.

And a broader program is more fun!

past time to outgrow the hypermacho  
lone-ranger approach to physics that  
leads to sparseness and focus



*Physics*  
*The few. The proud.*

lingers in our mythology, in our faculty  
meetings, in our selection committees  
and in our classes

Recommendations:

NO-BRAINERS

# CLIMATE

Treat women colleagues as colleagues.  
And if one of your other colleagues  
doesn't do this, call him (or her) on it.

Strongly and openly support rules and guidelines designed to protect women students from harrassment or intimidation. Make it clear that you care.

Not only protect but actually encourage and cultivate the complainers and the whistleblowers. Many times, the problems are not obvious, and if you drive them underground things will get worse rather than better.

Maintain an ombudscommittee of people who are willing to have their shoulders cried on. NOT THE CHAIR or THE DEAN! And reporting to the chair or dean only if necessary and with the permission of the crier.

# RECRUITMENT AND HIRING

Don't ever compromise quality or adopt quotas. Don't look for a woman because you have to have a woman. But don't measure quality in a naive, superficial and one-dimensional way.

Searches - junior faculty as well as senior faculty, should be broad based, not very narrowly defined, and should involve the whole department - not a group.

Searches should not be done precipitously - it is important to give people adequate time to get past first impressions, because these may be strongly affected by subconscious biases.

# TEACHING

Pay as much attention to HOW we teach as to WHAT we teach. Treat students as people and as individuals.

Encourage study groups and cooperative behavior in the classroom. Students learn better from other students than they do from you and they learn best by doing the teaching themselves.

Be aware of gender differences in classrooms. Treat women fairly without singling them out. Use relevant examples (*ie.* relativistic chocolate chip cookies rather than space war).

# BARELY-BRAINERS

## RECRUITMENT AND HIRING

Encourage faculty based initiatives to promote diversity. These should be slightly subversive.

Choose Department Chairs who have a clue.

# WHY SO SLOW?

THE ADVANCEMENT OF WOMEN

VIRGINIA VALIAN

"COMPELLING."

—NATALIE ANGIER, NEW YORK TIMES

Prospective chairs should take Mahzarin Banaji's implicit association test for subconscious prejudice.

They need to be shocked out of the comfortable belief that they know what they are doing in evaluating people.

Pay special attention to search practices that perpetuate the old-boy network — such as “targets of opportunity” — focusing a search much more narrowly than one should - is a good recipe for failing to find women and minorities

# TEACHING AND CLIMATE

Ask to get statistics broken down by gender, race, and whatever else you can think of. Sure, the results won't be statistically significant. But who cares? You should be trying to understand what is going on - not prove it.

For the next generation of scientists it is important to emphasize that science is a team activity in which many different skills are needed, and that one of the most important skills in making a scientific collaboration work is the ability to communicate with, to teach and to learn from others.

Require the nerds to use complete sentences (rules of coherence).

When you encourage study groups, you need to make sure that less self-confident students can find study groups they are comfortable with and can contribute to.

Competition is fine - but “hitting a homerun” is not the right metaphor -  
the team also needs a pitcher  
“Touchdown” would be better

Help and encourage the nerds (students and faculty) who perpetuate hypermacho behavior to grow up by complimenting good behavior and calling attention to and whenever possible punishing bad behavior, from showing off in section to making snide remarks in faculty meetings.

# BRAINERS

hard issues to which I don't have good solutions

Life-style issues — this one is really hard, but there are ways of making a difference — example of women in physics in France — women are expected to work so there is good child care and there are more women physicists - even though the culture is not particularly conducive to treating women as colleagues

No good deed goes unpunished! We need sensible reward structures in a research university for teaching, mentoring, and other good citizenship.

More women at the top can help

Female Dean  $\rightarrow$  time change in faculty meetings

# SUMMARY

sure - it is not all our fault

we are fighting difficult societal and  
cultural stereotypes

but we can make a difference!

Physicist are good, intelligent, committed people. We should set an example for the society at large, not be dragged kicking and screaming into compliance with rules.

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Dealing with the issue of women in physics is a special opportunity to make the field more welcoming in general.

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or stamp collecting.

—Ernest Rutherford.

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