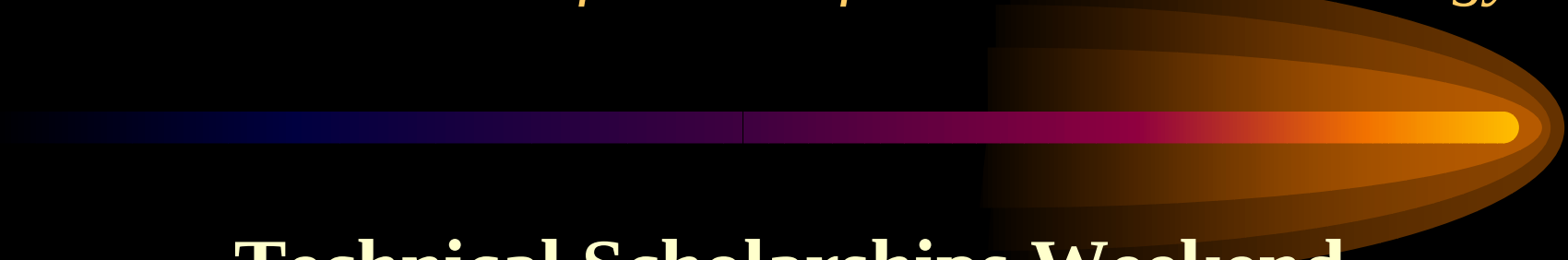
What's Math got to do with it?:

Mathematics at the frontier of science and technology



Technical Scholarships Weekend

17 & 18 February 2001

Old Dominion University

adapted with permission from Professor Tony Chan

Director, Institute for Pure and Applied Mathematics
Department of Mathematics, UCLA

Math Myths

- Math = terrifying

Myth #1: Math = Fear

Los Angeles Ti

ON THE INTERNET: WWW.LATIMES.COM
CIRCULATION: 1,095,007 DAILY / 1,385,373 SUNDAY

MONDAY, MARCH 15, 1999
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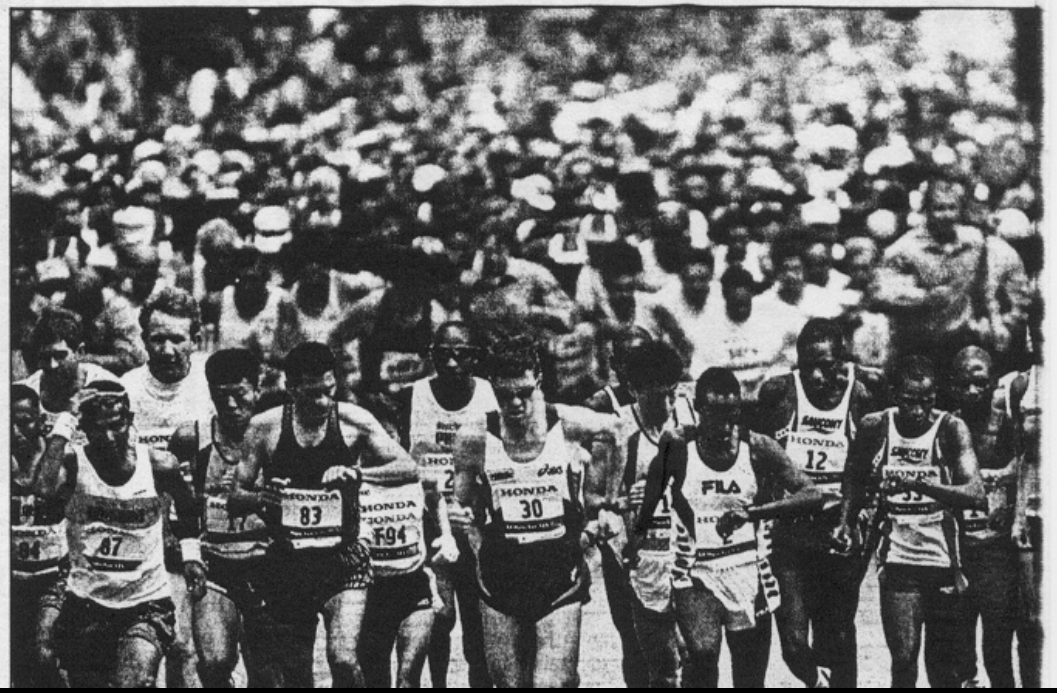
COLUMN ONE

Math Equals Fear at 2-Year Colleges

■ For many students, the subject is a nemesis that blocks them from a career or transfer to a university. Teachers struggle to provide help.

By JILL LEOVY
TIMES STAFF WRITER



Some other Math Myths

- Math = terrifying
- Math = static (Greeks, Newton,…)
- Math ≠ other sciences
- Math = solitary
- Math = impractical as a career

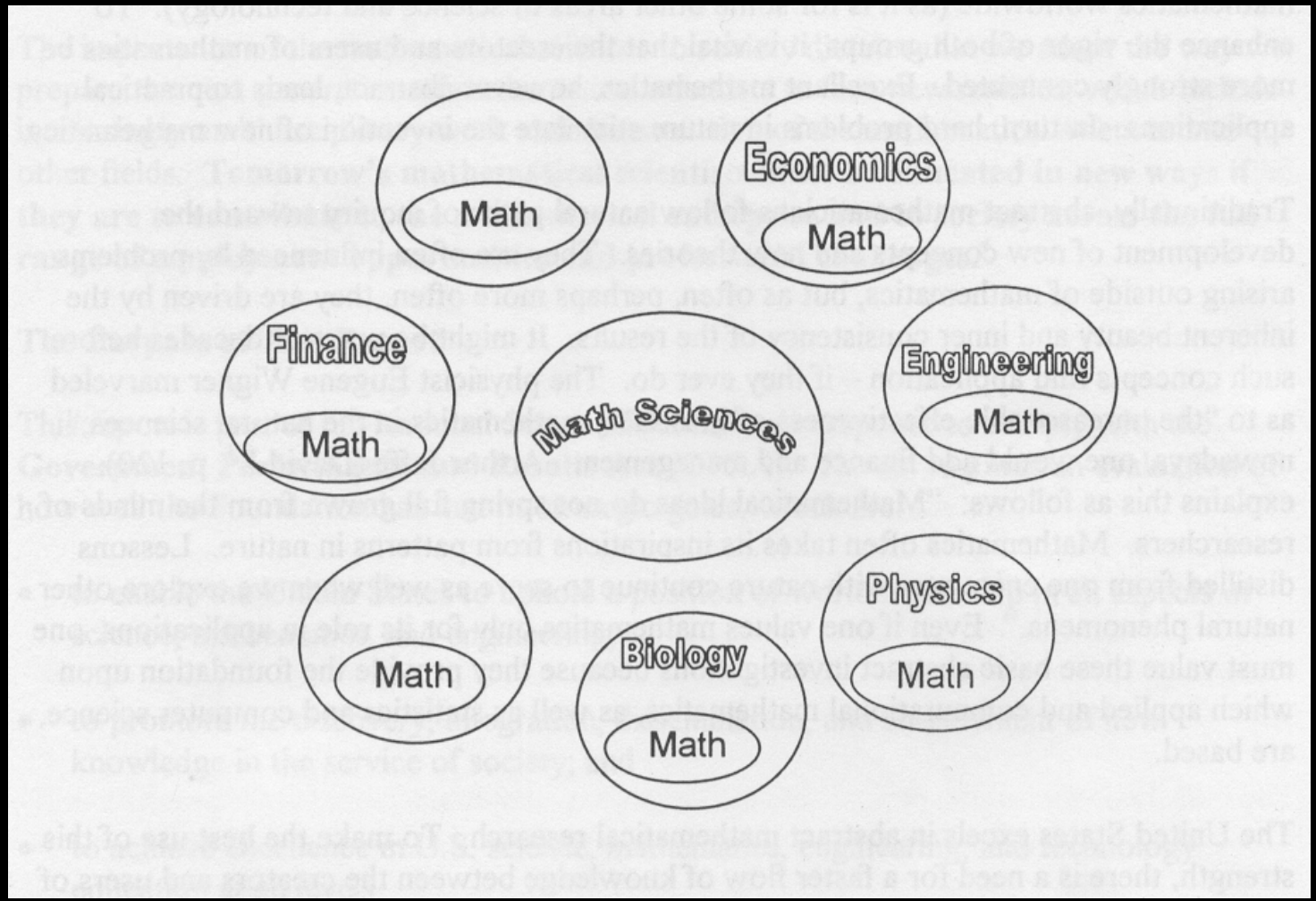
Math has an Image Problem

- Mathematicians — super-smart but “from another world”
- Actually, math lurks behind the curtain of popular subjects: simulation, forecasting, data mining, networks, polling, design, optimization, synthetic environments.
- Mathematicians have no monopoly on the practice of math — everyone (especially in science & technology) does it.

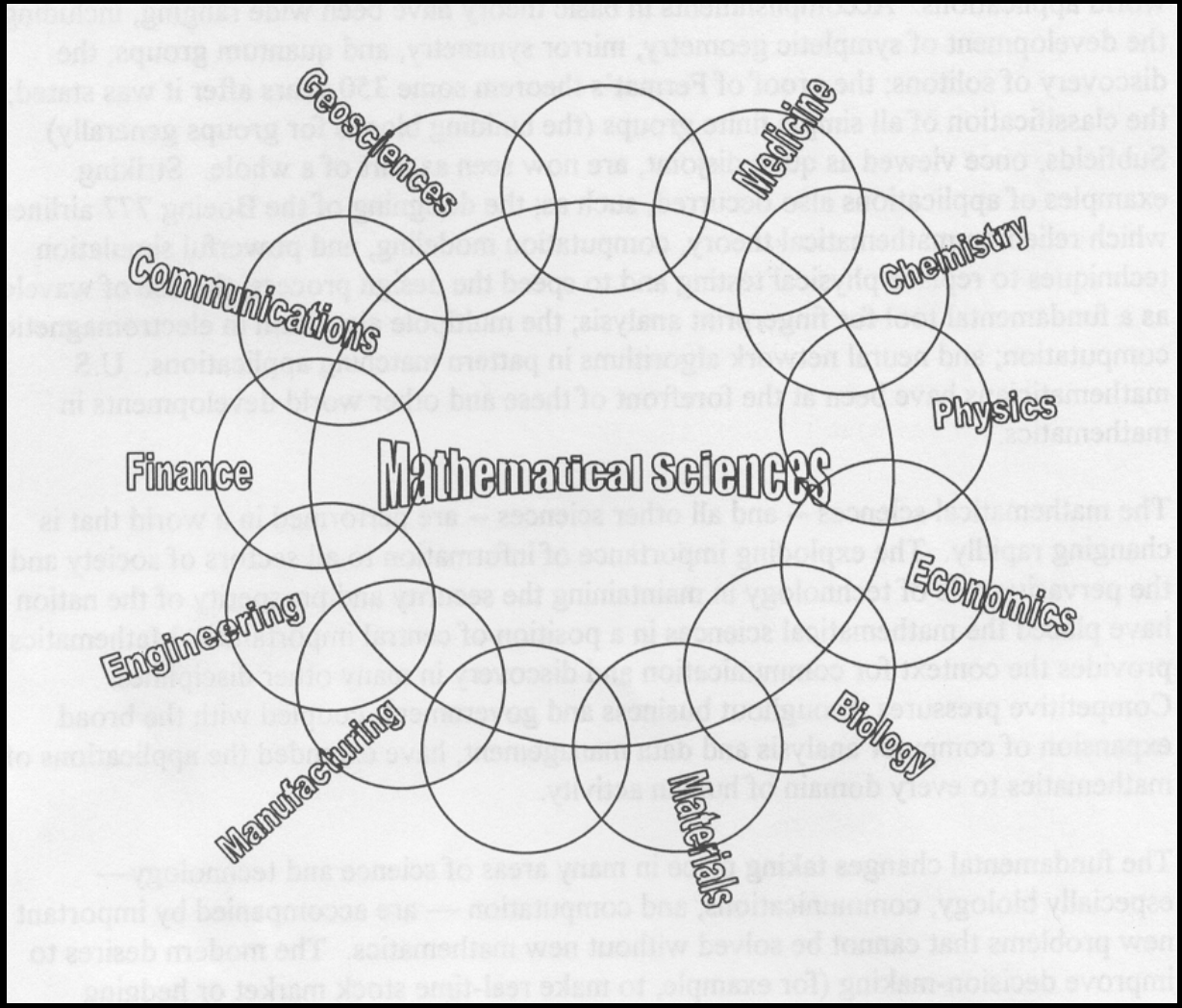
Intellectual Foci of the Sciences

Field	The Study of …
Mathematical Sciences	Patterns, structures, abstract models of reality
Physics	Space-time, energy, matter
Chemistry	Molecular structure of matter
Biology	Genomics, organisms, ecologies
Materials Science	Materials, structures
Earth sciences	The earth: crust, core, oceans, atmosphere
Astronomy	Origin and evolution of planets, stars, and the universe

Common misconception



Math at the Frontiers of Science



Major Subfields of Math Sciences

Subfield	The Study of …
Foundations	Logical underpinnings of mathematics
Algebra and Combinatorics	Structures, discreteness
Number Theory and Algebraic Geometry	Properties of numbers and polynomials
Topology and Geometry	Spatial structures, patterns, shapes
Analysis	Extensions and generalizations of the calculus
Probability	Randomness and indeterminate phenomena
Applied Mathematics	Modeling, analyzing, optimizing systems
Computational Mathematics	Experimental mathematics, computer based
Statistics	Analysis, application, and collection of data

Math in Society

Problem/Application	Contribution from Mathematics
MRI and CAT Imaging	Integral geometry
Internet: search engines, compression	Graph theory, linear algebra, wavelets
Options valuation	Black-Scholes model and Monte Carlo simulation
Global reconnaissance	Signal processing, image processing, data mining
Confidentiality and integrity	Number theory, cryptology/combinatorics
Modeling of atmosphere and oceans	Wavelets, statistics, numerical analysis
Analysis of the human genome	Data mining, pattern recognition, algorithms
Rational drug design	Data mining, combinatorics, statistics
String Theory (Theory of Everything?)	Geometry
Aerodynamic design	Differential equations, optimization
Earthquake analysis and prediction	Statistics, dynamical systems/turbulence

An Ancient Subject

Pythagorus of Samos

569-475 B.C. (?)

musician, geometer,

first “pure” mathematician

A Modern Subject

Karen Uhlenbeck, 1942 -

(University of Texas,

National Academy of Sciences)

expert in partial

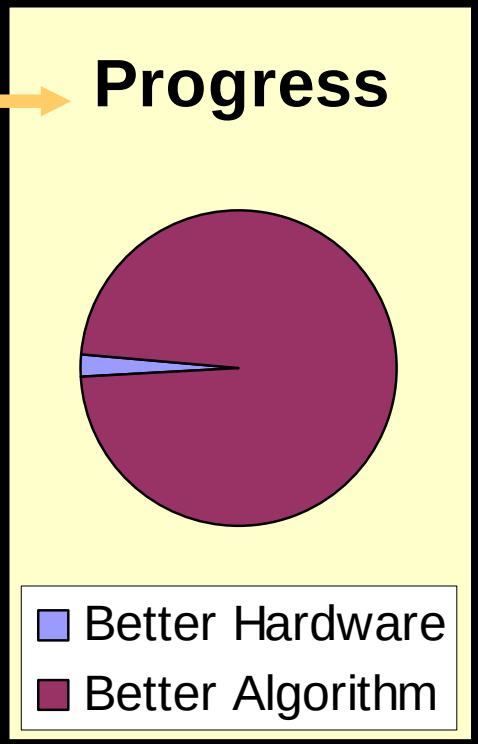
differential equations

Why is Math Ubiquitous?

- Math allows description, analysis, and prediction (simulation) of quantitative systems
- Math exposes structures & patterns of nature
- Math leverages wisdom, through abstraction
- Most physical laws are expressed in mathematics: Newton's laws, Maxwell's equations, Schrodinger's equation, Einstein's relativity, etc.
- Norbert Wiener: *"The unreasonable effectiveness of math…"*

Advances in Computing not just Hardware

- For the solution of important differential equations *"… the progress made through better methods from 1945 to 1978 exceeds the progress made through faster computers "* by 40 times*
- Factoring a large integer using modern mathematical techniques would be 120,000 times faster than using techniques from the 1970's. So if it took 1 day to do the problem now, it would have taken over 300 years then.



* From "Numerical Methods, Software, and Analysis", 1983, by John R. Rice, Purdue University.
**From "The future of integer factorization", 1995, by Andrew Odlyzko, AT&T Bell Laboratories.

An Example of a Math Proof

Theorem: There is no largest prime number.

Proof: Assume there is a largest prime number.

List all the primes as p1, p2, …., pn.

Let p = p1*p2*…*pn + 1.

Then p is prime because no prime divides into it.

Also, p > pn. Hence, contradiction!

E.g.: Suppose 7 is largest prime. Then 2*3*5*7 + 1 = 211 is also prime.

An Example of "Pure" Math: Fermat's Last Theorm

The equation:

$$X^n + Y^n = Z^n$$

has no integer solutions for $n > 2$.

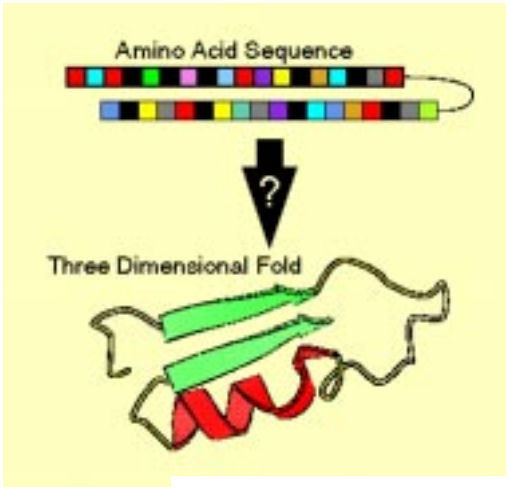
(Note: $n = 2$ has many solutions — Pythagoras)

What's playing in classrooms and laboratories near you?

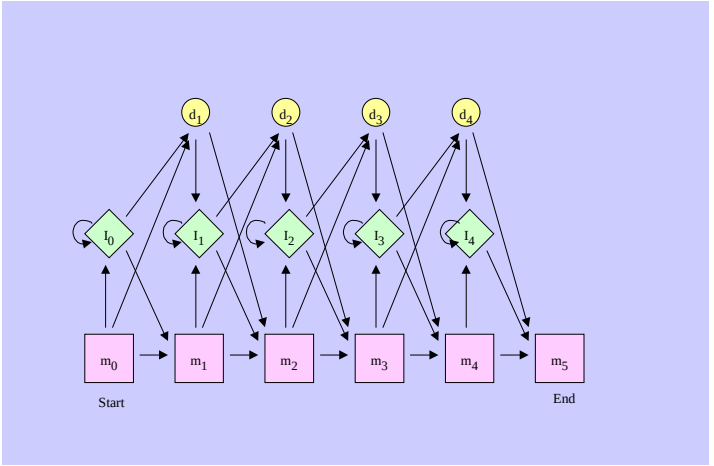
- Functional Genomics
- Finance
- Communication Networks
- Modeling and Simulation of physical systems
- Image processing

Functional Genomics

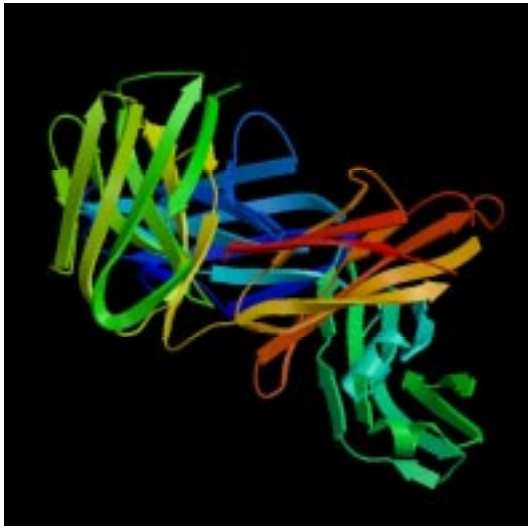
The Protein Folding Problem



A hidden Markov model for sequence analysis



m= match state (output), I = insert state (output), d= delete state (no output)

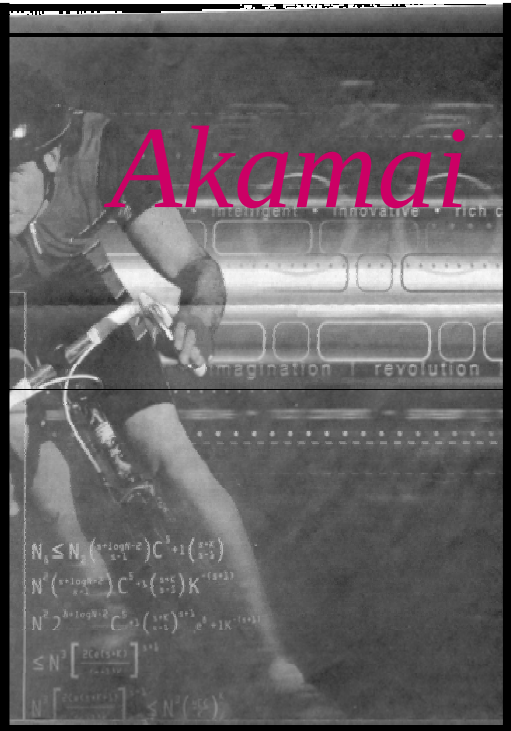


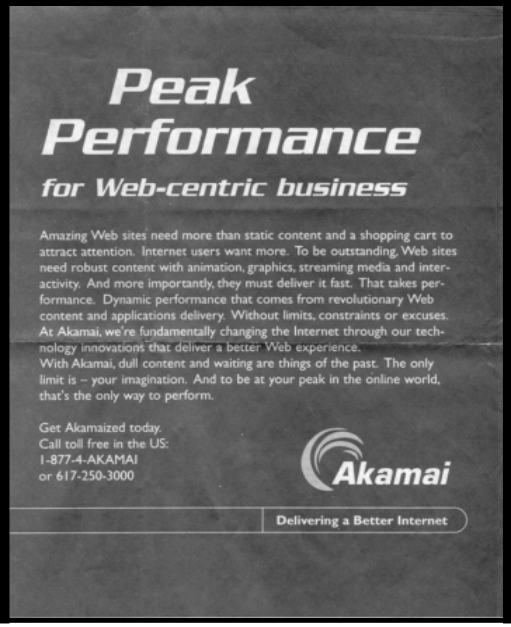
β sandwich
β protein
immunoglobulin
PDB: 7FAB

Slides from “Molecular biology databases”, by Terry Speed, based on Chapter 2 of “Post-genome Informatics” by Minoru Kanehisa, Oxford University Press, 2000.

Financial Mathematics

- Nova documentary about the Black-Merton-Scholes Formula. The film tells the fascinating story of the invention of the Black-Scholes Formula, a mathematical “Holy Grail” that forever altered the world of finance and earned its creators the 1997 Nobel Prize in Economics.

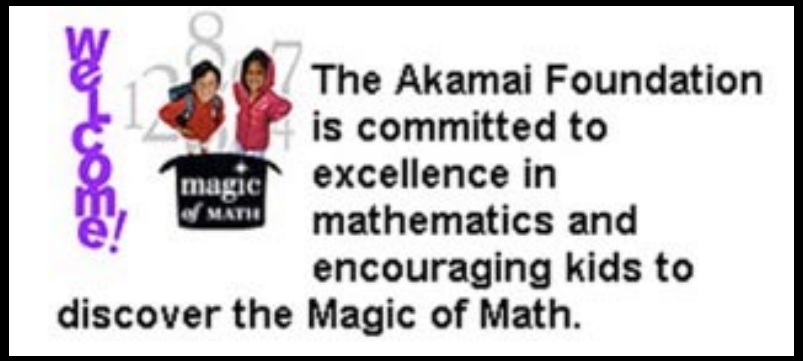




Communication Networks

MIT Professor of Applied Mathematics Tom Leighton, who had an office down the hall from web guru Mr. Berners-Lee, was intrigued by a challenge from the latter. ... Leighton recognized that a solution to web congestion could be found in applied mathematics and algorithms.

Leighton and graduate student Lewin were joined by other scientists with expertise in computer science and data networking to develop the mathematical algorithms necessary to handle the dynamic routing of content — now a $5 billion NASDAQ company.



CUSTOMERS:

Abercrombie & Fitch

Adobe

Apple

C-SPAN

CBS

Chicago Sun-Times

CNN Interactive

GO Network

iVillage.com

KBkids.com

LA Times

Lands' End

Lycos

Monster.com

Oxygen Media

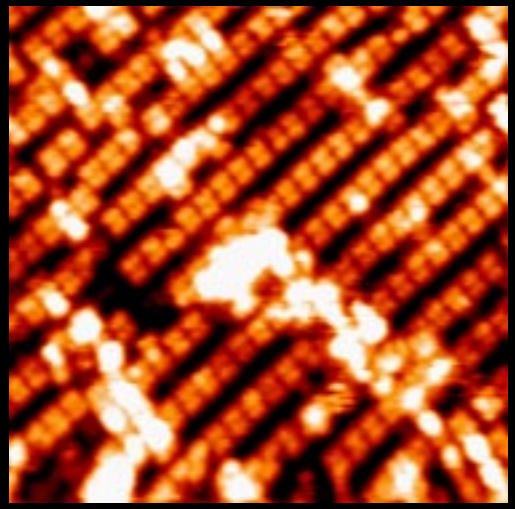
Reuters

Times Company Digital

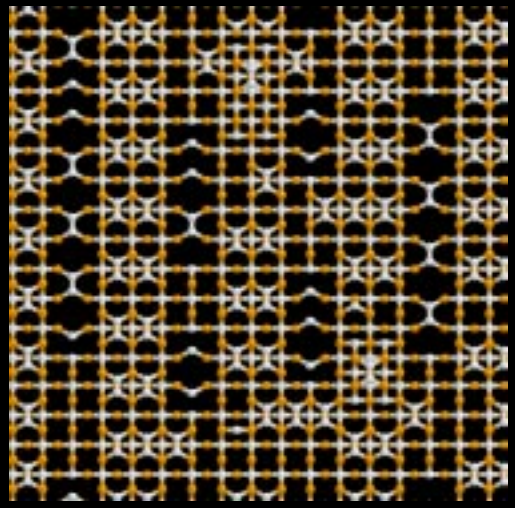
Washington Post

Yahoo

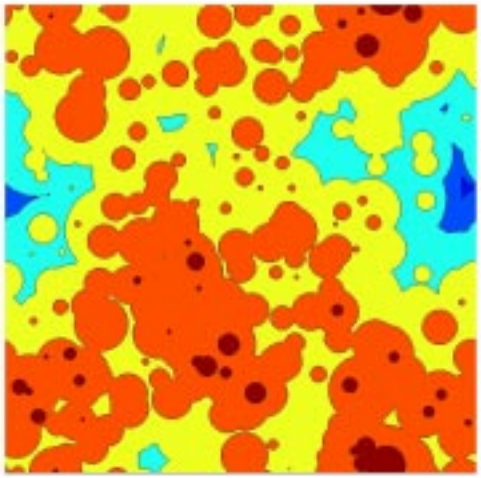
Math Modeling & Simulation of Crystal Growth



STM micrograph



atomistic model

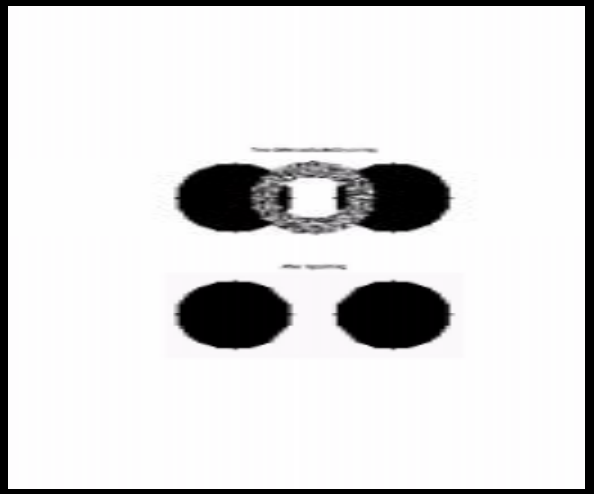


continuum model

- Goal: Improved design and fabrication of semiconductor materials
- Strategy: Mathematical modeling, numerical simulation, feedback control
- Applications: satellite communications, CD players, cell phones, lasers.

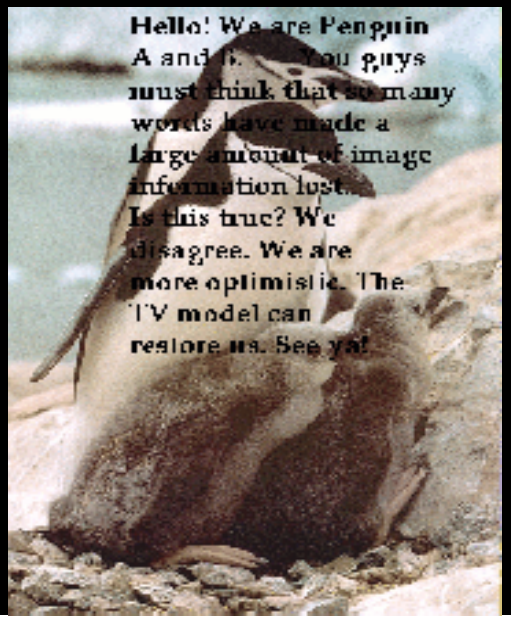
Image Processing: Inpaintings

Disocclusion



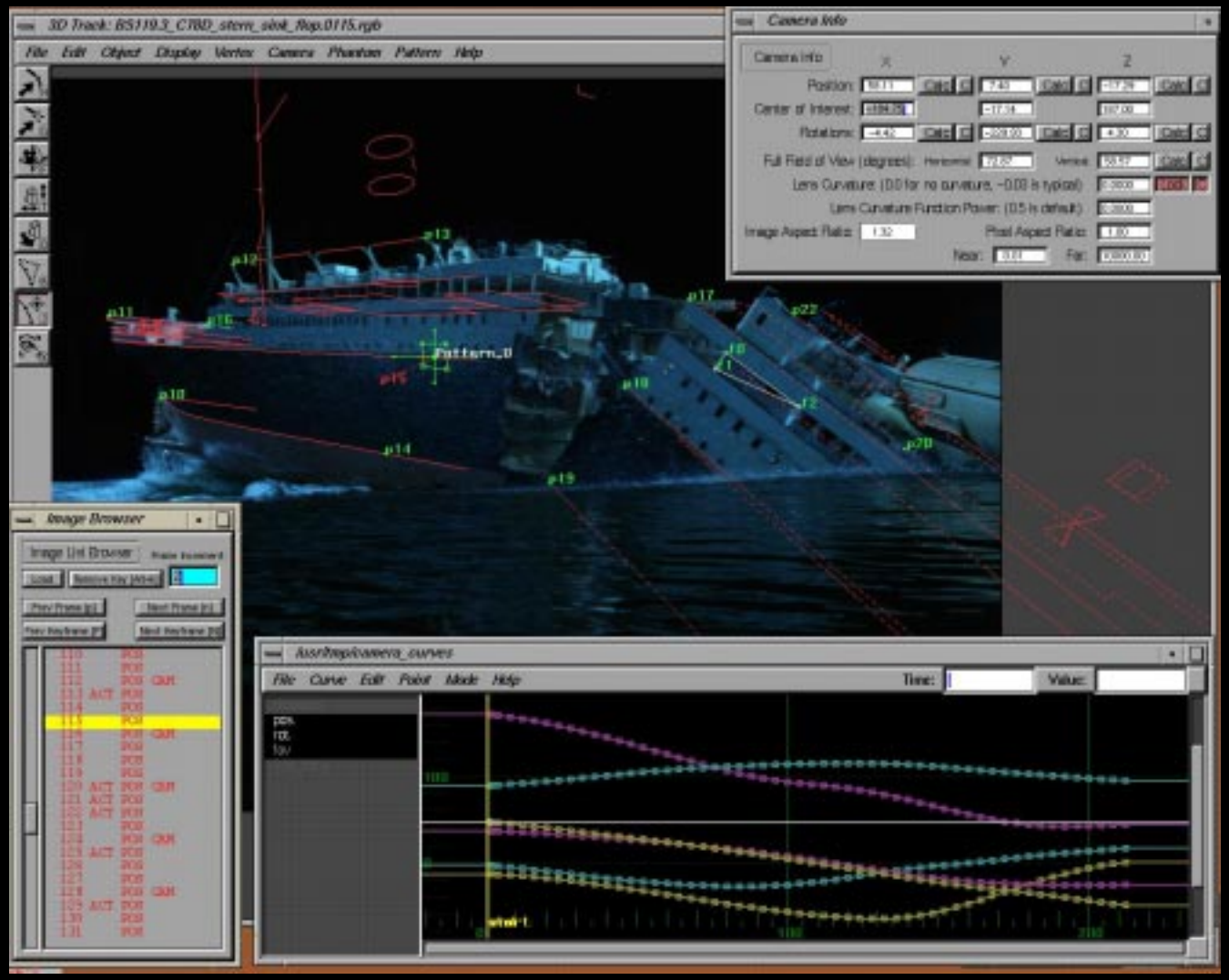
Scratch Removal

Graffiti Removal

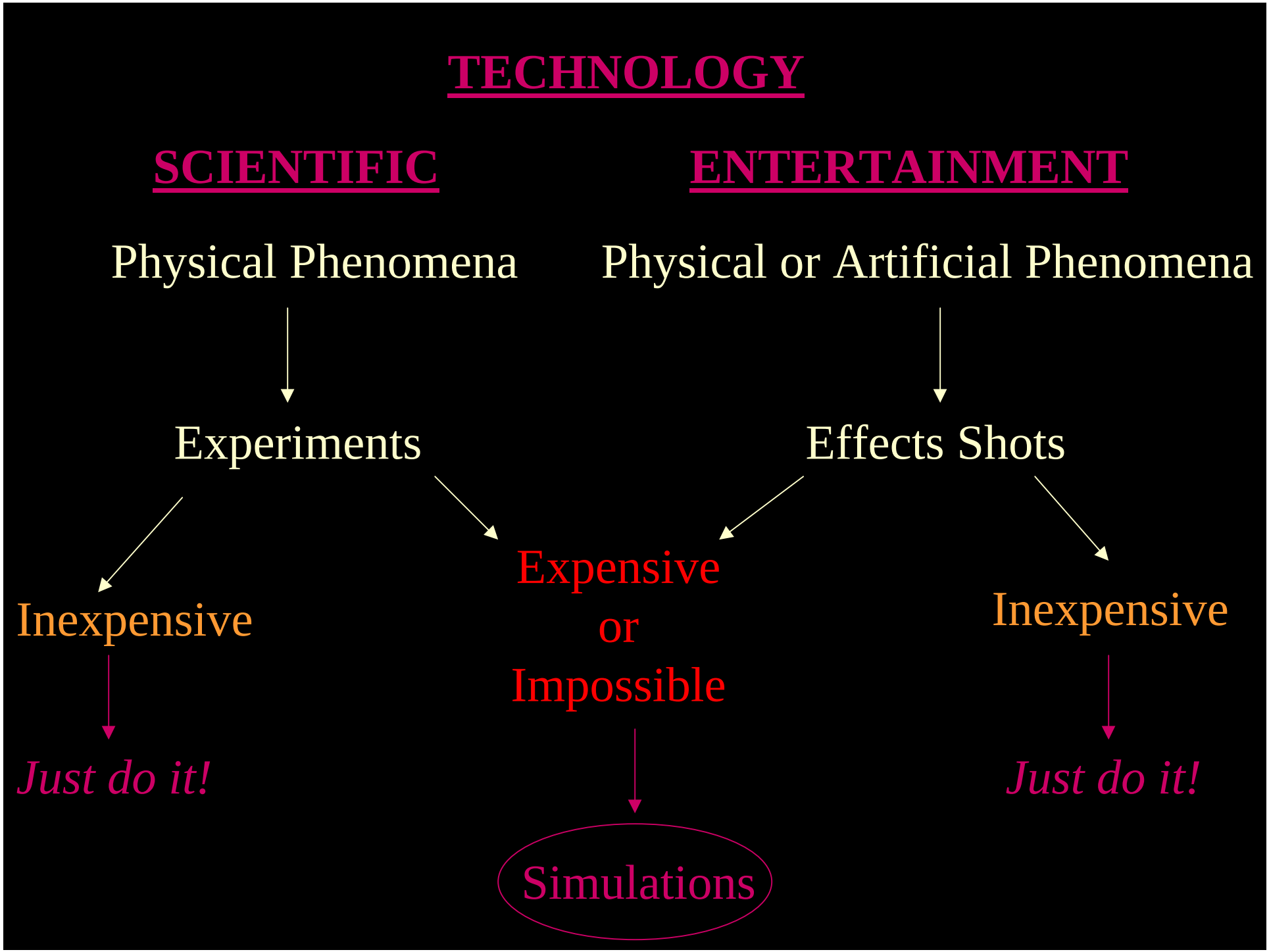


Synthetic Images

What's Math got to do with it



Picture courtesy of Doug Roble, Digital Domains.


TECHNOLOGY
SCIENTIFIC
ENTERTAINMENT
Physical Phenomena
Physical or Artificial Phenomena
Experiments
Effects Shots
Inexpensive
Expensive
or
Impossible
Inexpensive
Just do it!
Just do it!
Simulations

Newt Gingrich Letter (9/28/2000)

...

As the former NIH director, Harold Varmus indicated, the biological research is dependent on continuing breakthroughs in basic science-math research. Over the last 7 years (from fiscal 1994 through 2001) we have increased the NIH research budget from $11.544 billion to $19.729 billion. That is an increase of 71% since 1994. By contrast we have increased the NSF research budget in the same period only from $2.472 billion to $3.134 billion or an increase of 27%. This will ultimately lead to an atrophying of our investment in math, physics, chemistry and other basic knowledge and then to a decline in our national security, in our economic growth, and in our ability to do medical research. Our current economy is a reflection of past investments in scientific research (the computer chip and the internet are only two examples of government funded progress).

...

Harold Varmus Letter (10/4/2000)

...

Scientists can wage an effective war on disease only if we--as a nation and as a scientific community--harness the energies of many disciplines, not just biology and medicine. The allies must include mathematicians, physicists, engineers and computer and behavioral scientists. I made this case repeatedly during my tenure as director of NIH, and the NIH has made significant efforts to boost its support of these areas. But in the long run, it is essential to provide adequate budgets for the agencies that traditionally fund such work and train its practitioners. Moreover, this will encourage the interagency collaboration that fuels interdisciplinary science. Only in this way will medical research be optimally poised to continue its dazzling progress.

The writer is president of Memorial Sloan-Kettering Cancer Center and a former director of the National Institutes of Health.
He received the Nobel Prize in Medicine in 1989.

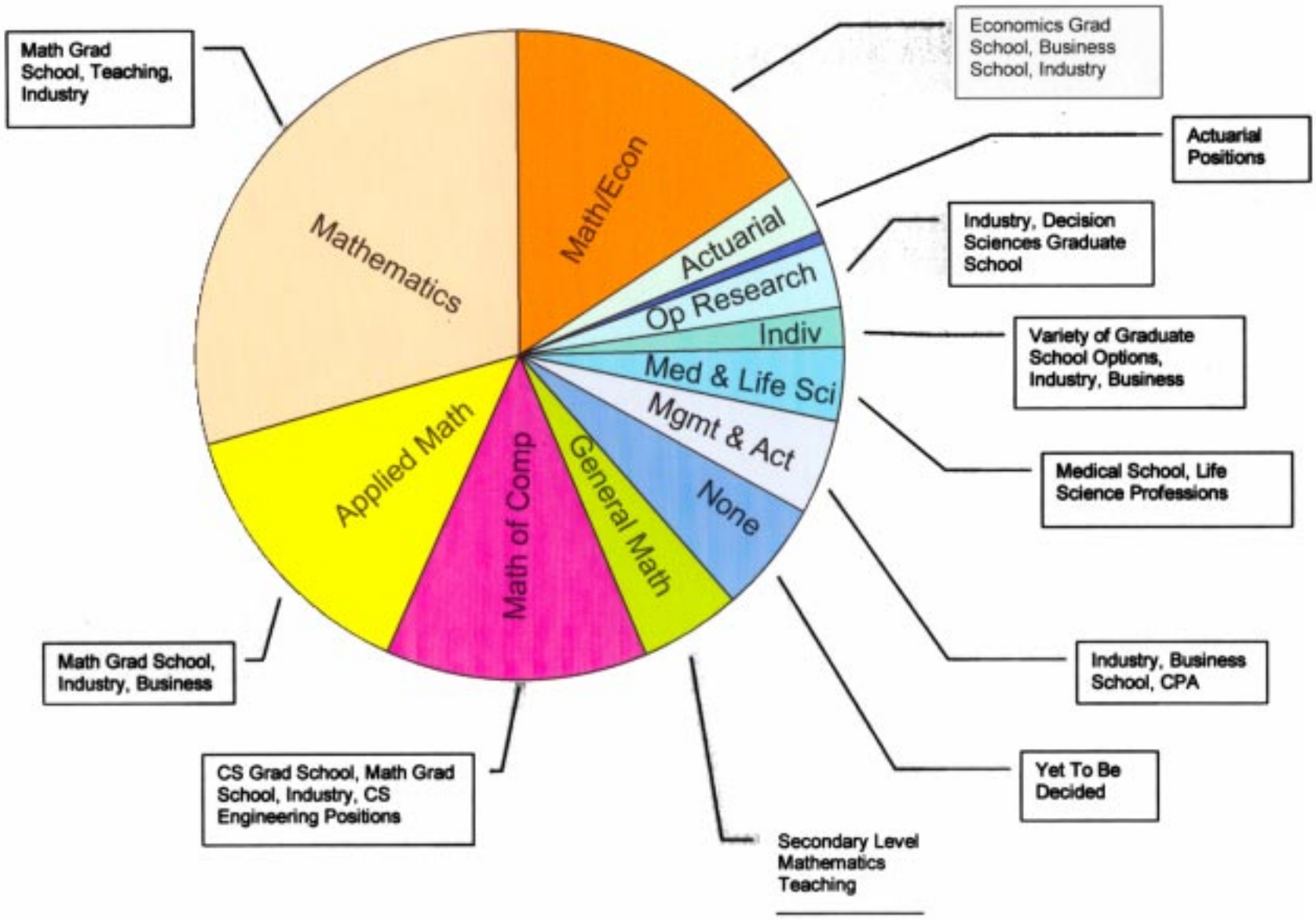
Mathematics & Statistics at ODU

- One of about 25-30 primarily Applied and Computational Departments in the US
- 28 faculty for about 40 majors and 30 graduate students (and thousands of student clients from other departments!)
- 3 UG majors: Mathematics, Statistics, Mathematics Education
- Core department in new Computational Sciences & Engineering Initiative

Sample Research Projects in Math & Stat at ODU

- Human radiation risk abatement in spacecraft
- Parallel computer algorithms for optically thick radiation transport
- Dynamics of protein folding (optimal drug design)
- Prediction of noise from ducted fan-jet engines
- Digital image compression
- Survival analysis of heart transplants
- Prostate cancer bio-markers

Graduate School and Career Opportunities for Math Majors



Do New Math — Win a Million Bucks!

- The Clay Mathematics Institute has just created the Millenium Prize; see http://www.claymath.org/prize_problems
- Seven problems that have defied solution for ages are singled out for $1million in prize money each (Poincaré conjecture, Riemann hypothesis, etc.)
- The proof of Fermat's last theorem (from the 1650's) in 1993 has reinvigorated such quests

Math Myths Revisited

- Math = fear
- Math = static (Greeks, Newton,…)
- Math ≠ other sciences
- Math = solitary
- Math = impractical as a career

Math Myths Debunked

- Math = joyous
- Math = dynamic (internet, genomics, …)
- Math = at the frontiers of other sciences
- Math = collaborative
- Math = foundational for evolving careers
- Math = “cool”

Mathematics is

Empowering!

See you in class in the Fall!

http://www.math.odu.edu