My Students Are Smarter Than Me!

A. Malcolm Campbell
Laurie J. Heyer

DAVIDSON

HHMI Quantitative Biology/Bio Math
July 21, 2008

“ Support your claims with data.”

Today’s students face new pressures from the rapidly changing science and from a globally competitive market. If students only study in their majors, then their options will be limited. Biology has matured to the point where math and computer science are needed to make sense of the vast datasets. If a student seeks a research career, he or she had better pursue an education that enhances his or her quantitative skills. Since our students’ needs are changing, what must we do as their teachers to keep up with the changing demands? How can we retool ourselves and our courses? Do we need new courses? Should we team teach more? Can we tweak what we have and honestly meet the needs of our students? This presentation will offer some answers and invite an honest discussion from the audience.

Today's students face new pressures from the rapidly changing science and from a globally competitive market.

New Interdisciplinary Fields and Methods

Proteomics

Bioinformatics

Genomics

Systems Biology

Synthetic Biology

Computational Biology

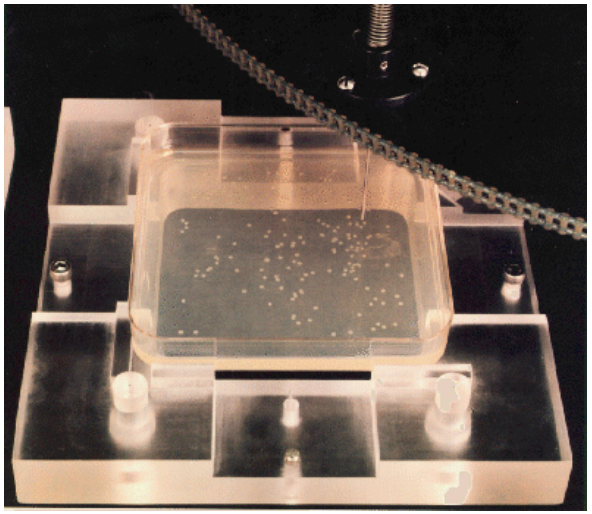
Metabolomics

Climate Modeling

Bioengineering

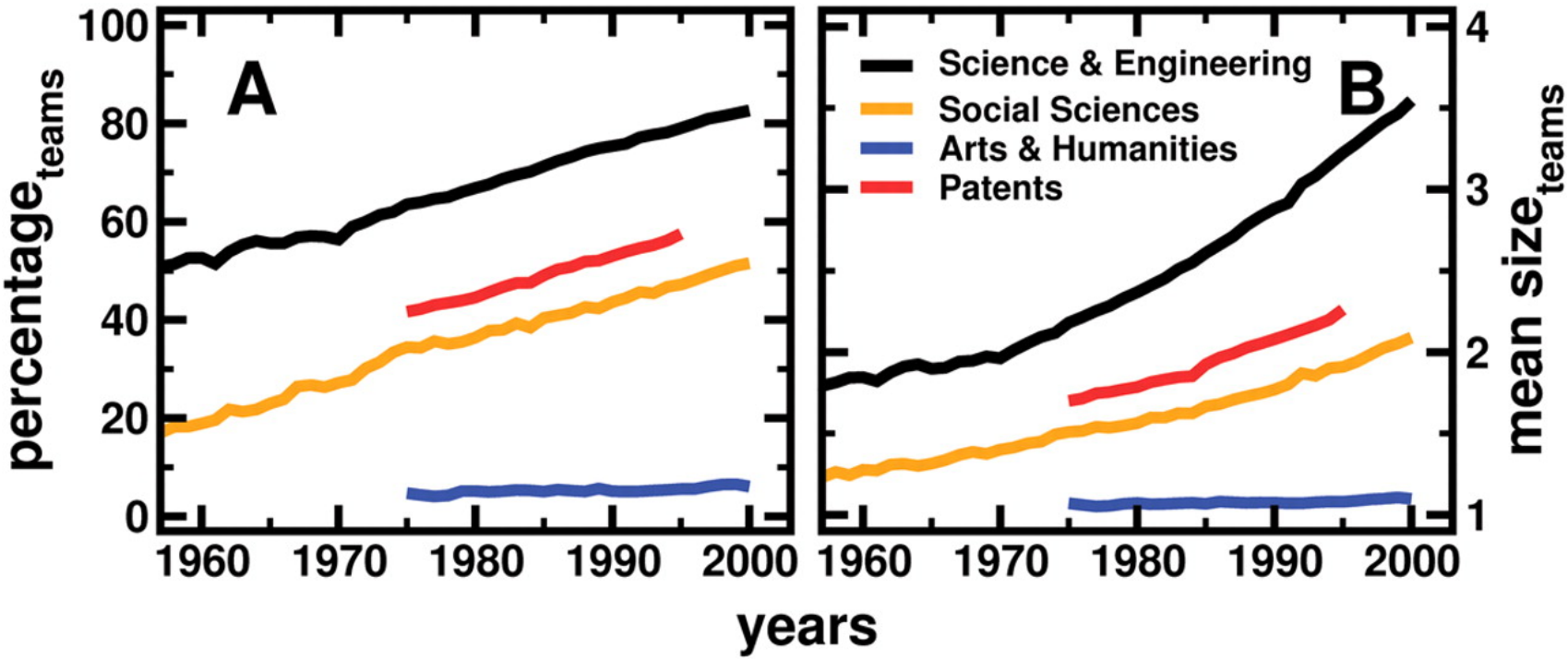
Conservation Biology

High Throughput & Automated Data Collection



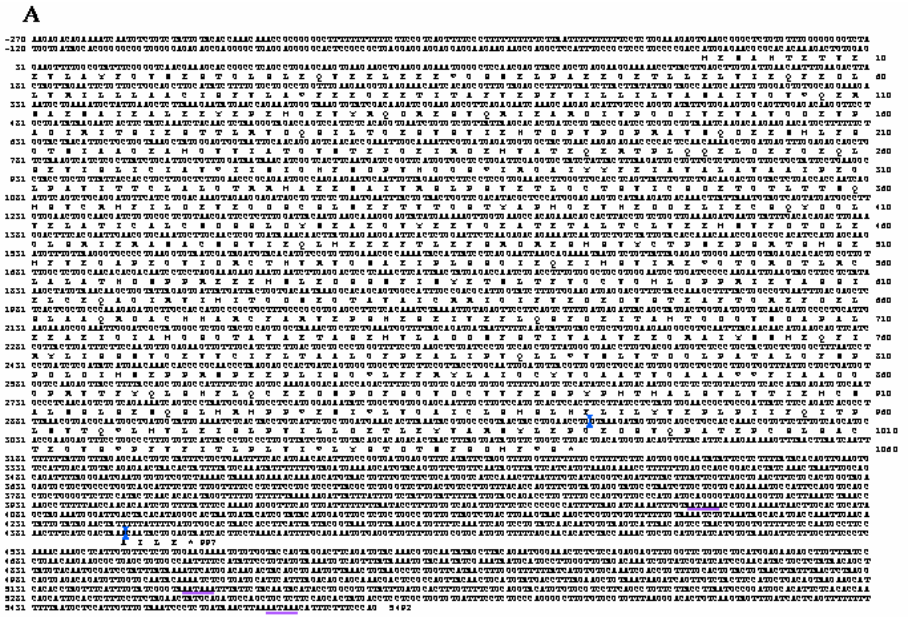
Collaborations Are More Common

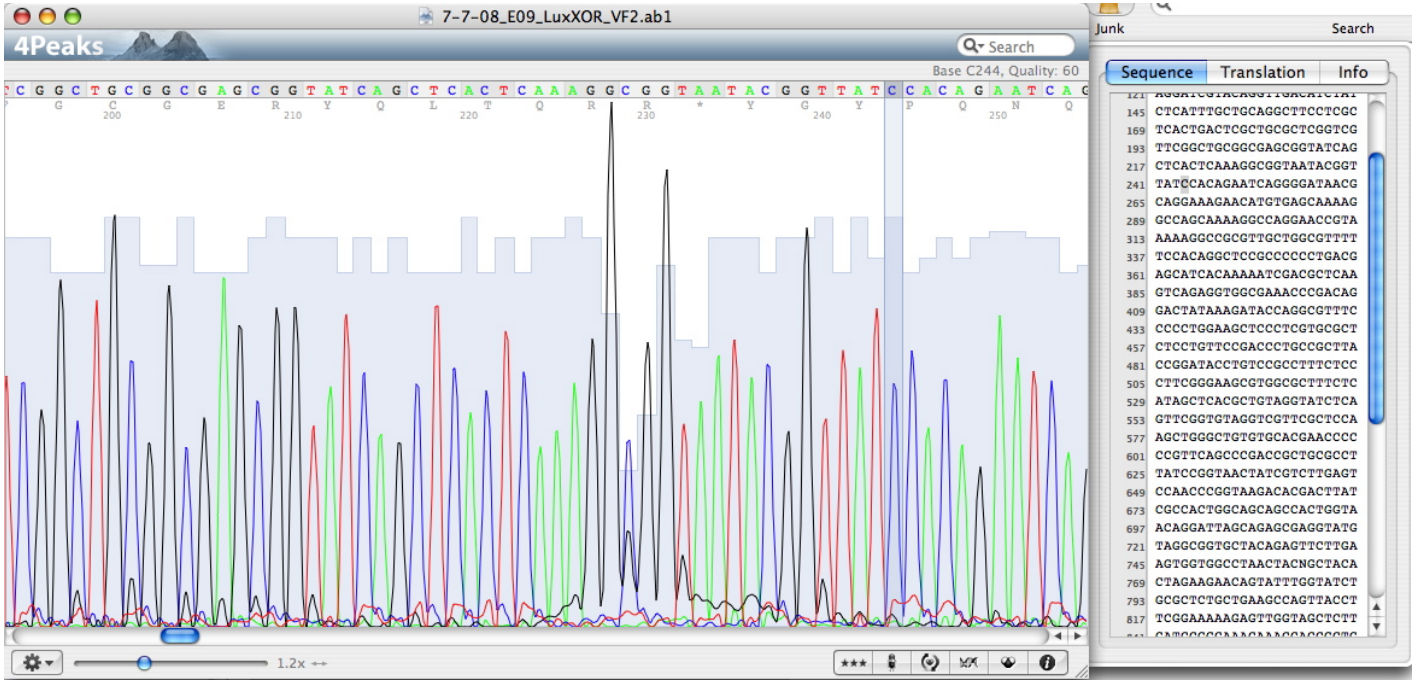
Team-authored publications



Stefan Wuchty, Benjamin F. Jones, and Brian Uzzi, 2007

My PhD involved cloning & sequencing a cDNA and characterizing the protein.





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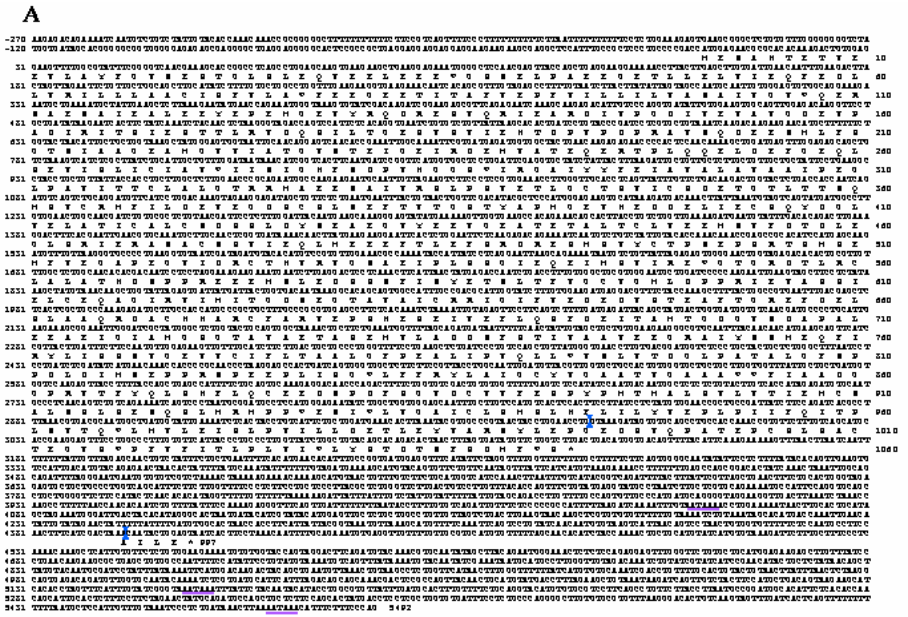
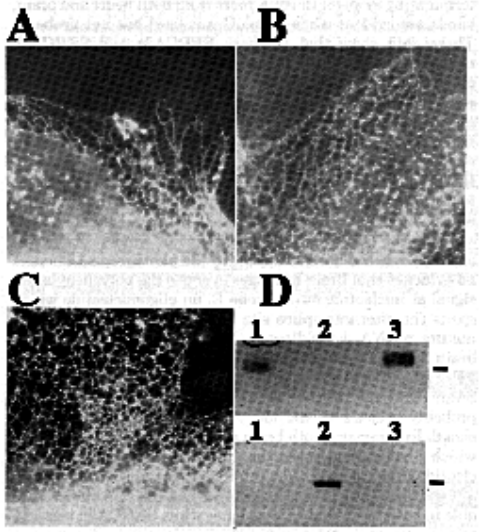


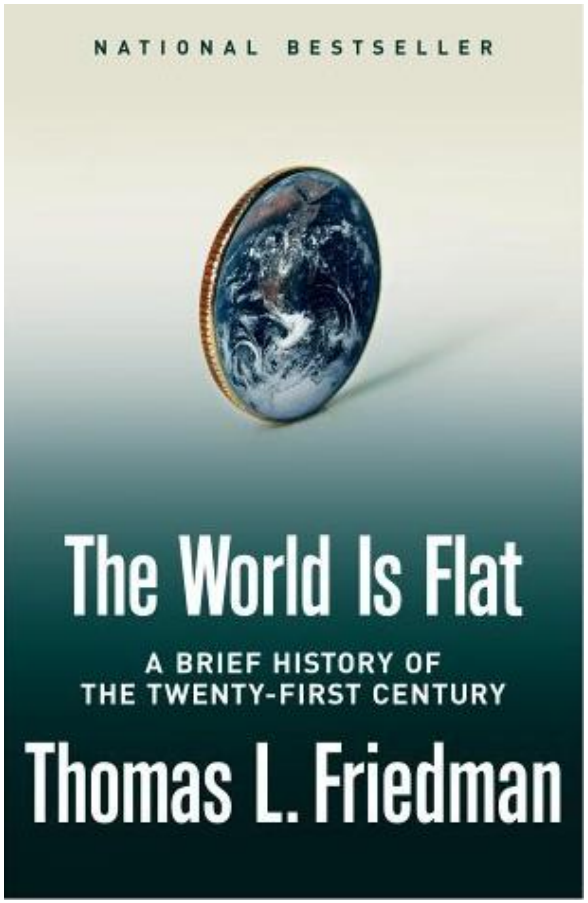
When did you get your PhD?
What has changed for you?



The World Is Flat:
A Brief History of the Twenty-First Century

10 "flatteners" leveling the global playing field:

#1 Collapse of Berlin Wall
#2 Netscape
#3 Workflow software
#4 Open sourcing
#5 Outsourcing
#6 Offshoring
#7 Supply chaining
#8 Insourcing
#9 In-forming (*e.g.*, Google)
#10 Personal digital devices



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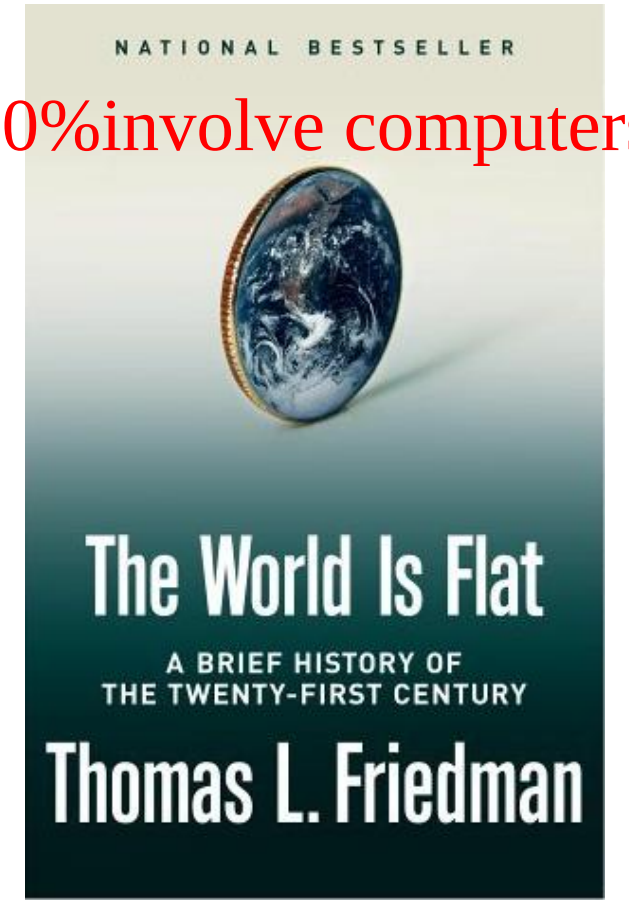
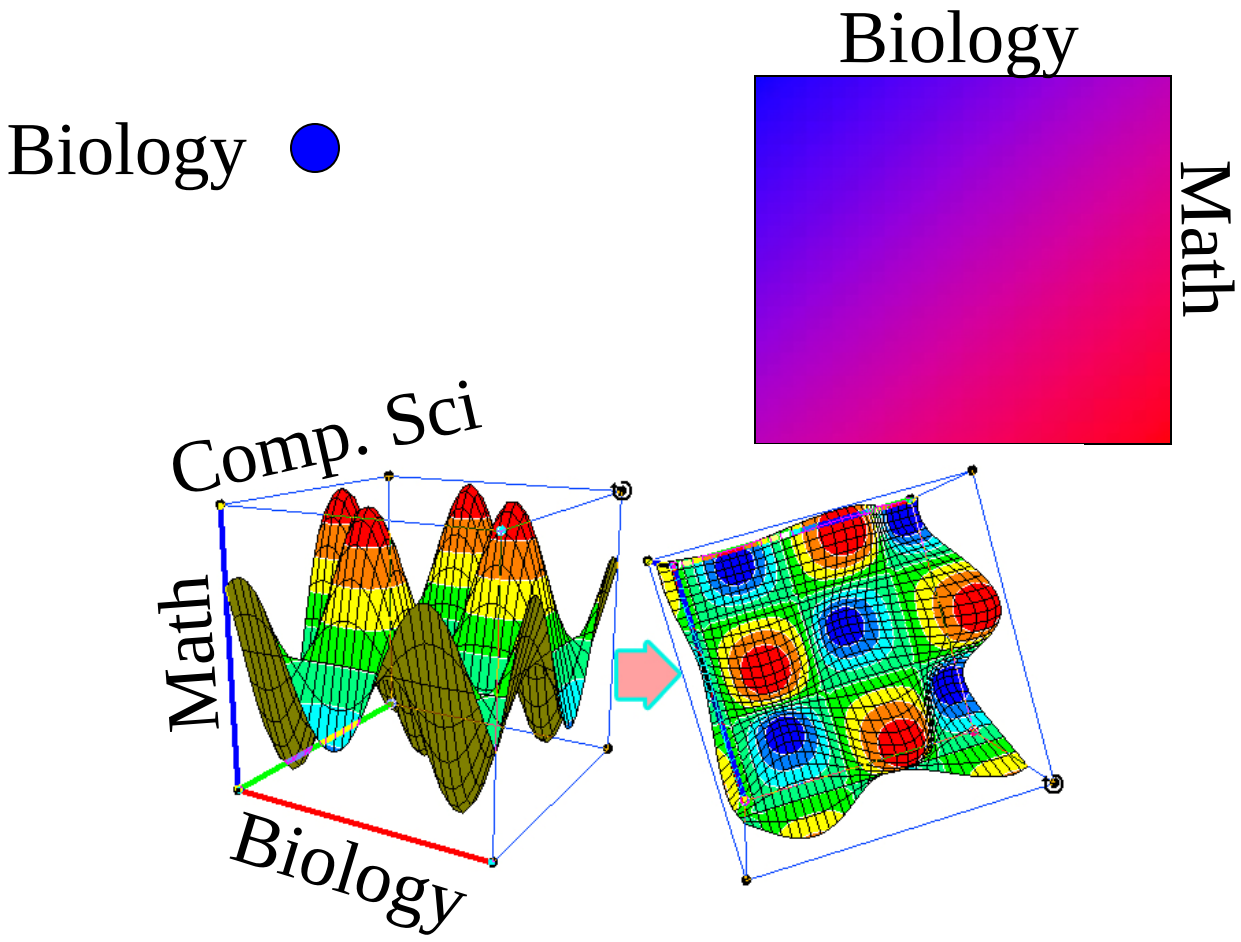
#10 Personal digital devices

60%involve computers



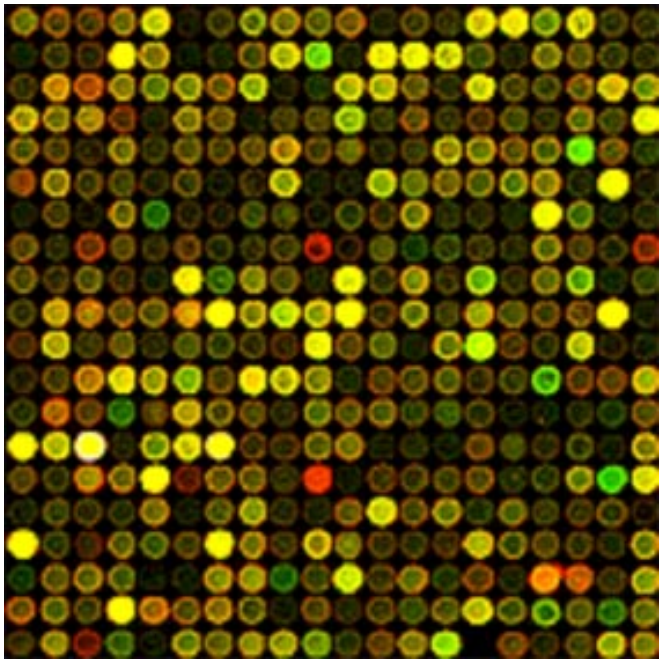
If students only study in their majors, then their options will be limited.

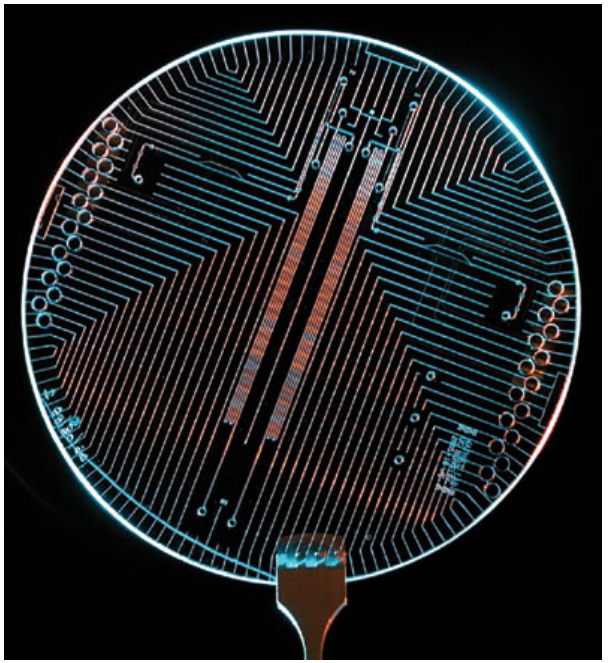
Will your students be multi-dimensional?



Why hire three people, when one will do?

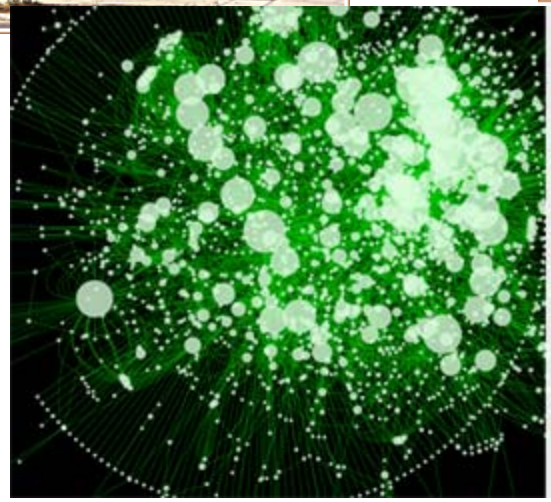
Do you use methods learned after graduate school?





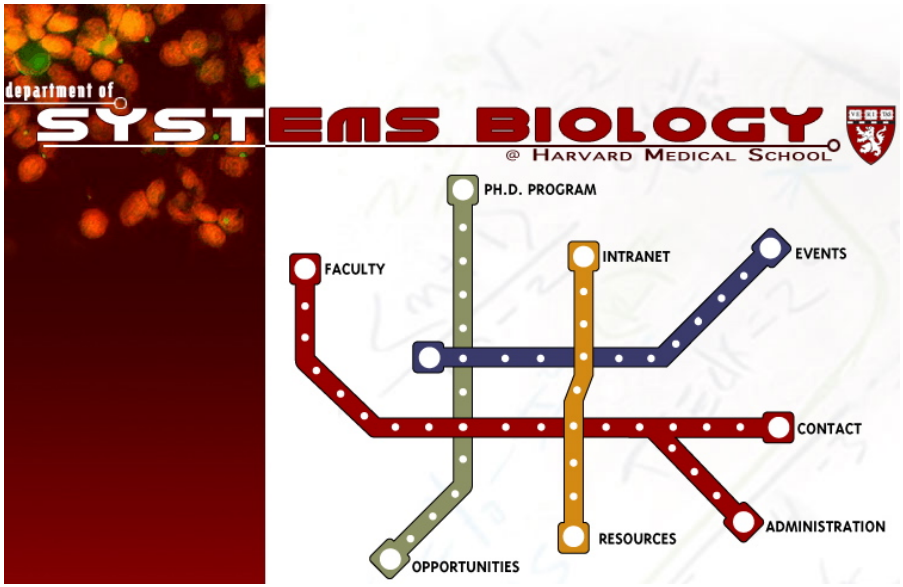
We need to prepare our students for a new landscape that changes like a screen saver.

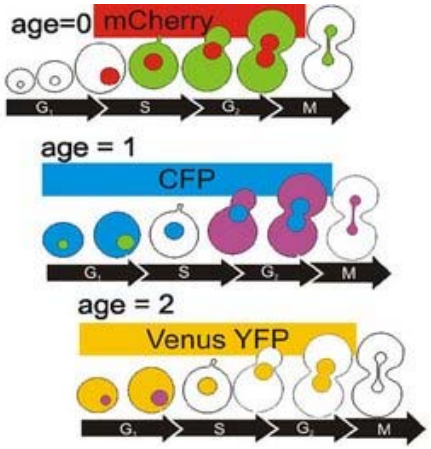
Where will your students go to graduate school?



Cytoscape

An Open Source Platrorm for
Network Analysis and Visualization





SynBERC
Synthetic Biology Engineering Research Center

Investigators

Jay Keasling, Director
University of California, Berkeley
Department of Chemical Engineering
Department of Bioengineering

Wendell Lim, Deputy Director
University of California, San Francisco
Department of Cellular and Molecular Pharmacology
Department of Biochemistry and Biophysics

Thrust Leaders			
Parts	Wendell Lim	Cellular & Molecular Pharmacology, Biochemistry & Biophysics	UCSF
Devices	Drew Endy	Biological Engineering	MIT
Chassis	George Church	Genetics	Harvard
Human Practices	Kenneth Oye	Political Science, Engineering Systems	MIT
	Paul Rabinow	Anthropology	UCB

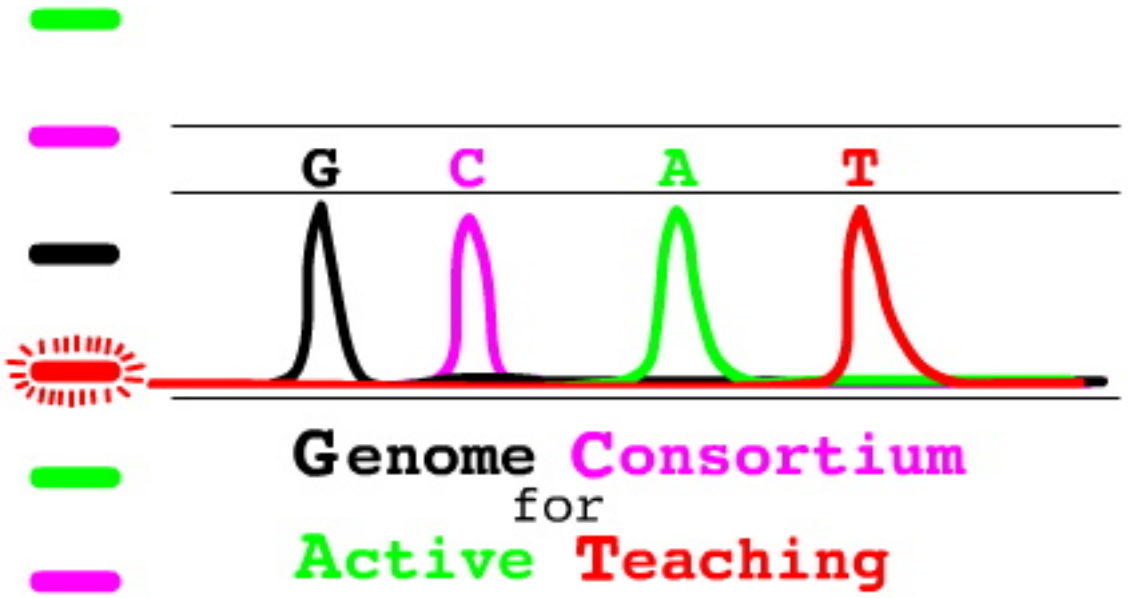
Research Members

P = parts *D* = devices *C* = chassis *H* = human practices

name	*department*	*institution*
J. Chris Anderson *P D C*	Bioengineering	UCB
Adam Arkin *P D C*	Bioengineering	UCB
Carlos Bustamante *P D*	Physics, Molecular & Cell Biology, Chemistry	UCB
George Church *C*	Genetics	Harvard
Raul Cuero *D*	Chemical Engineering	PVAMU
Drew Endy *P D C*	Biological Engineering	MIT
Michael Gyamerah *P D*	Chemical Engineering	PVAMU
Kristala Jones Prather *D C*	Chemical Engineering	MIT
Jay Keasling *D C*	Chemical Engineering	UCB
Thomas Knight *P D C*	Computer Science and Artificial Intelligence, Electrical Engineering and Computation	MIT

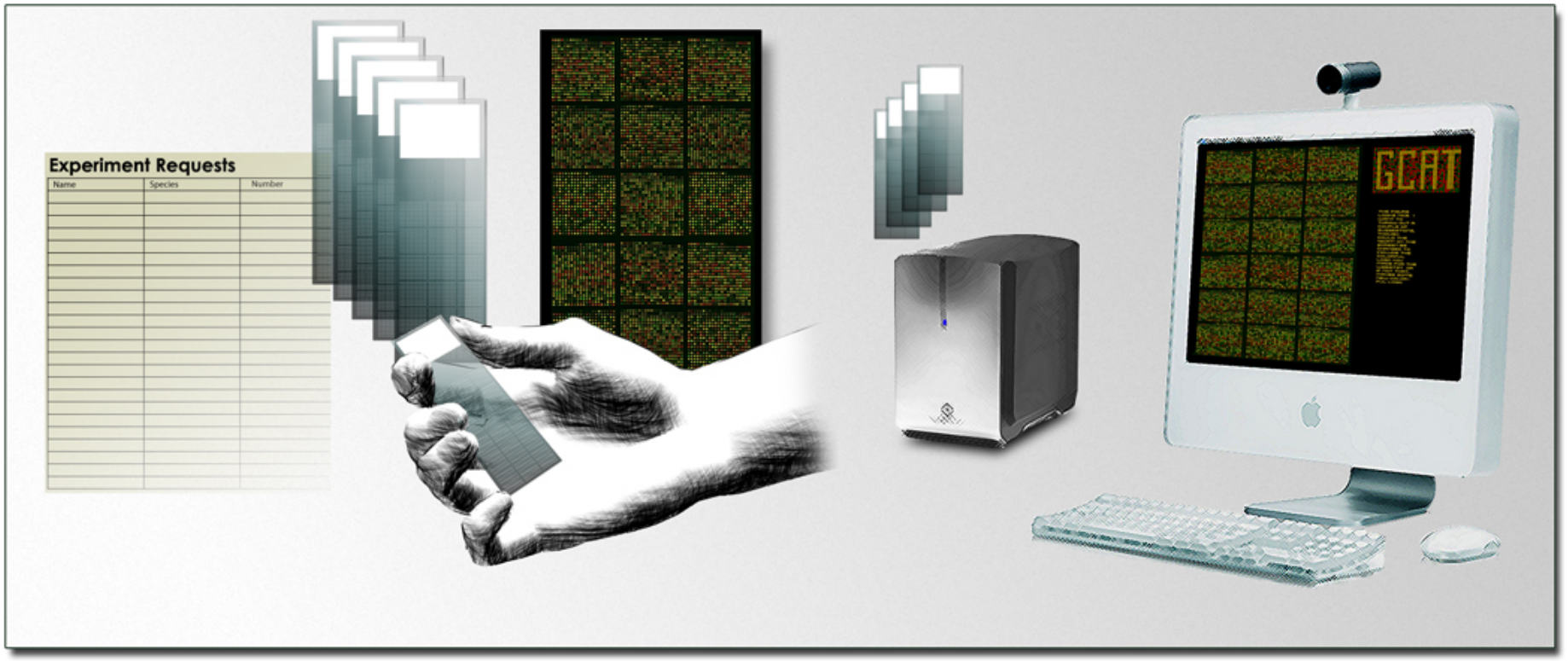
Biology has matured to the point where math and computer science are needed to make sense of the vast datasets.

Seven Year Collaboration; Three Countries



www.bio.davidson.edu/GCAT

GCAT Makes DNA Chips Affordable for ALL Students

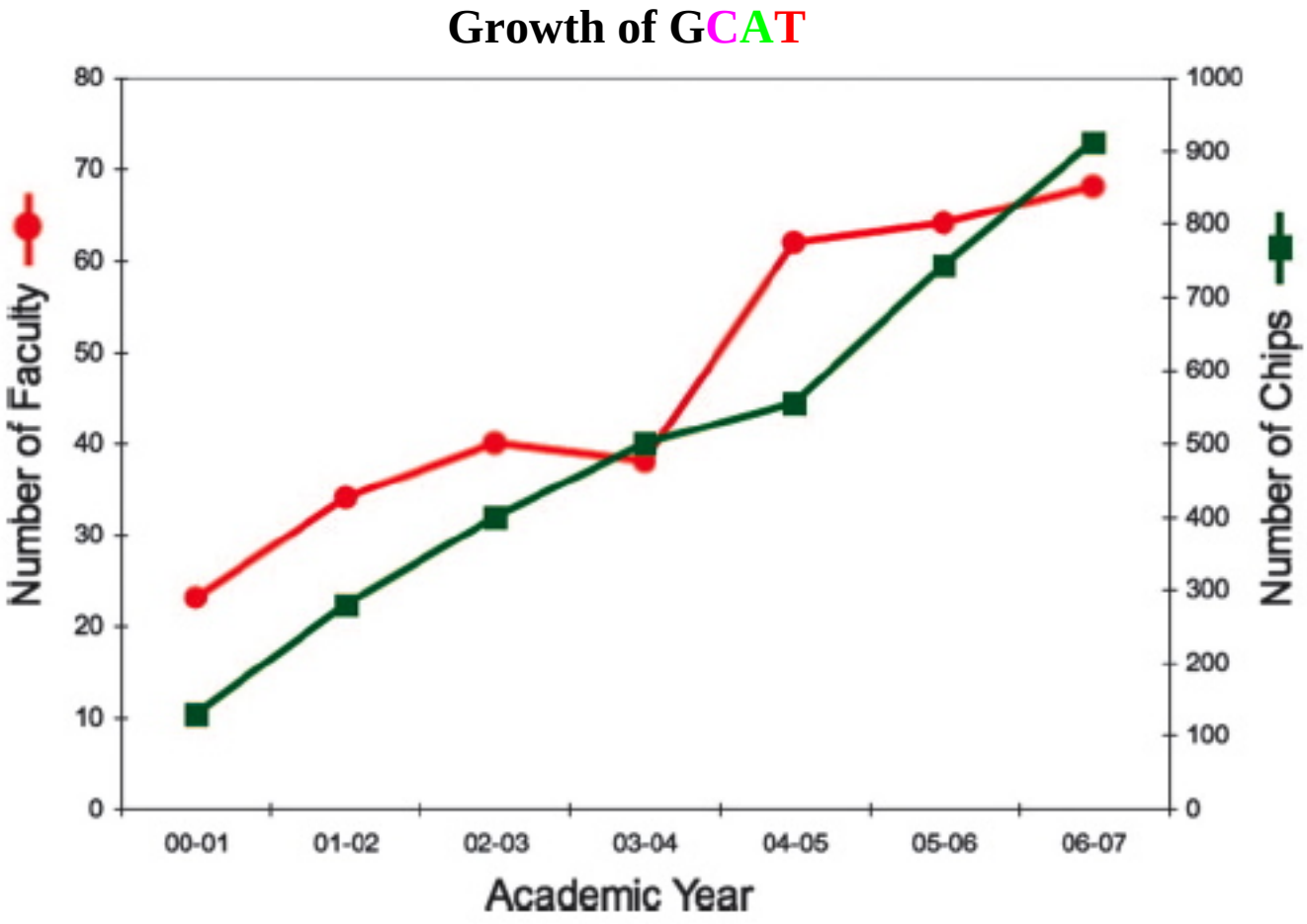


Vita Per Scientiam HHMI

Waksman Foundation for Microbiology

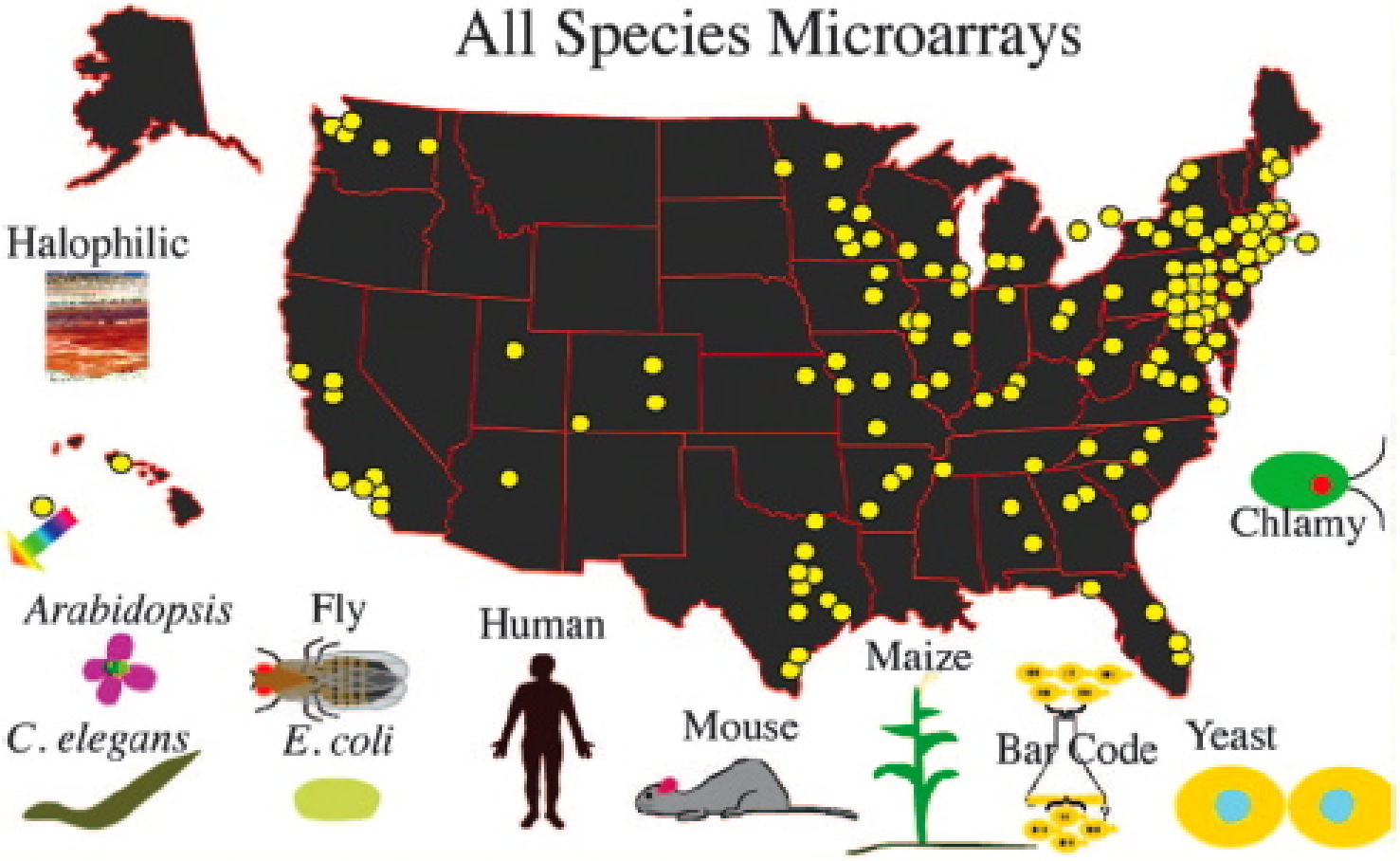
National Science Foundation

Steady Growth Over Time



10,000^{+} Undergraduates and Counting

Distribution of **GCAT** Members

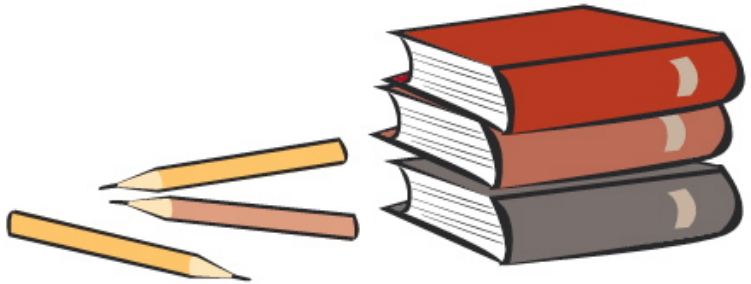


GCAT Publication of Outcomes

EDUCATIONFORUM

COLLABORATIVE PROGRAMS

Genome Consortium for Active Teaching (GCAT)



A. Malcolm Campbell,[1,2*†] Todd T. Eckdahl,[2,4] Edison Fowlks,[2,5] Laurie J. Heyer,[2,3] Laura L. Mays Hoopes,[2,6] Mary Lee Ledbetter,[2,7] Anne G. Rosenwald[2,8]

A supportive network of scientists and faculty brings sophisticated microarray experiments to the undergraduate lab and classroom.

Basic Research Publications

2008: 4 peer-reviewed publications
2007: 2 peer-reviewed publications
2006: 1 peer-reviewed publication

Student Learning Outcomes

Question	Topic	Increase (%)
1.	Microarray experimental error–dye bias	+ 36.2*
2.	Microarray experimental error–gradient	+ 10.5*
3.	Microarray negative controls	+ 10.3*
4.	Microarray experimental design	+ 38.2*
5.	Gene expression ratios using a graph	+ 5.8*
6.	Gene expression–probability	+ 0.2
7.	Gene expression–gene clusters	+ 22.3*
8.	Gene expression–regulatory cascade	+ 14.9*
9.	Gene expression–gene circuit graphs	+ 11.8*
10.	Interpreting microarray results	+ 19.0*
11.	Diagnosis with microarrays	+ 12.5*

* indicates $p < 0.05$; N = 409

Synthetic Biology
Synergistic Math

Synthetic Biology is
A) the design and construction of new biological parts, devices, and systems, and
B) the re-design of existing, natural biological systems for useful purposes.

Home About Conferences Labs Courses Resources FAQ

What is synthetic biology?

- Synthetic biology refers to both:
  - the design and fabrication of biological components and systems that do not already exist in the natural world
  - the re-design and fabrication of existing biological systems.

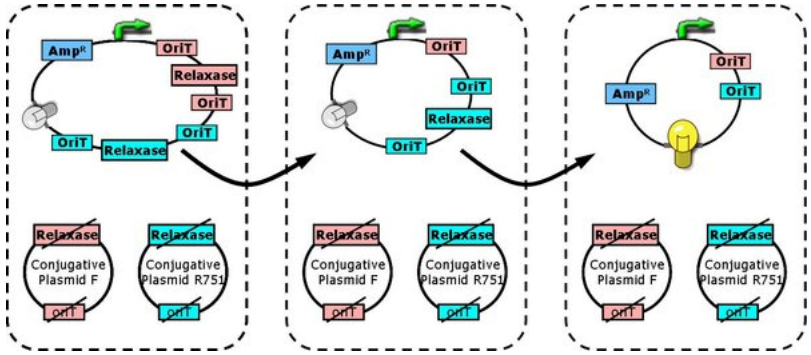
What is the difference between synthetic biology and systems biology?

- Systems biology studies complex biological systems as integrated wholes, using tools of modeling, simulation, and comparison to experiment. The focus tends to be on natural systems, often with some (at least long term) medical significance.
- Synthetic biology studies how to build artificial biological systems for engineering applications, using many of the same tools and experimental techniques. But the work is fundamentally an engineering application of biological science, rather than an attempt to do more science. The focus is often on ways of taking parts of natural biological systems, characterizing and simplifying them, and using them as a component of a highly unnatural, engineered, biological system.

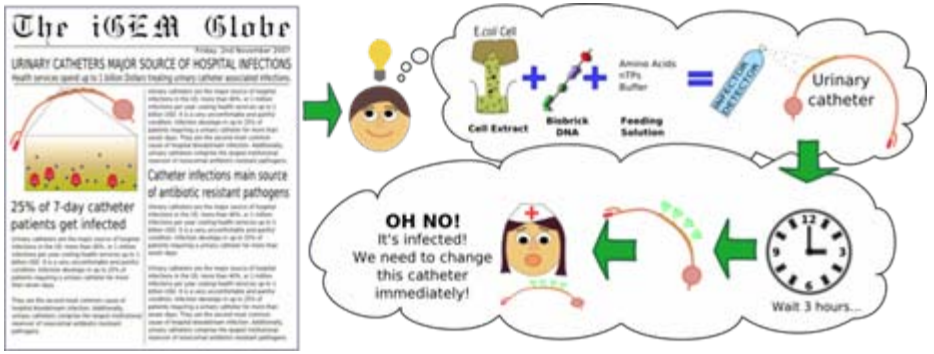
BioBrick Registry of Standard Parts

http://parts.mit.edu/registry/index.php/Main_Page

iGEM: international Genetically Engineered Machines



Peking University



Imperial College

Student Success at iGEM

DAVIDSON

HAMPTON UNIVERSITY

Discover Gold WESTERN

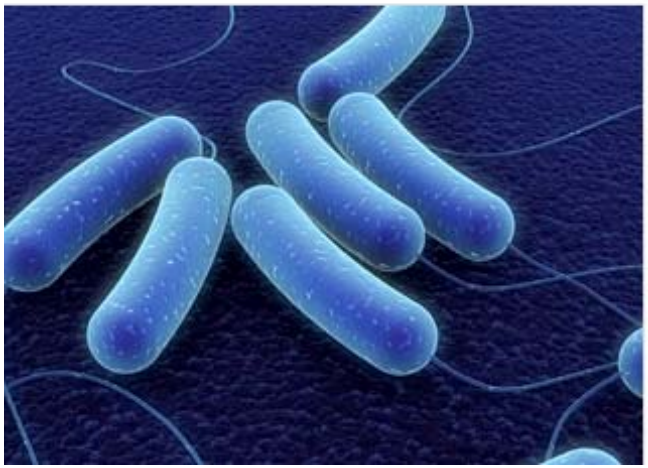
Student Publication and Notoriety

May 30, 2008

DNA Computer Puts Microbes to Work as Number Crunchers

Study shows genetic material in bacteria can be harnessed to solve complex math problems

By Nikhil Swaminathan



It's not your normal, electronic silicon-based machine, but scientists have made a computer from a small, circular piece of DNA, then inserted it into a living bacterial cell and unleashed the microbe to solve a mathematical sorting problem.

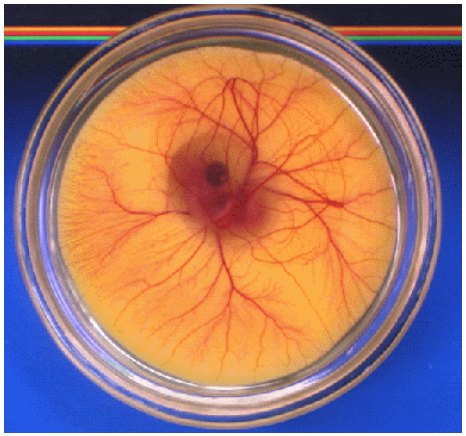
"A computer is any system that can read some input and give some readable output," says Karmella Haynes, a biologist at Davidson College in North Carolina and co-author of a new study appearing in the *Journal of Biological Engineering*. Haynes and her team looked to harness the power of DNA recombination to solve the so-called "burnt pancake problem": a puzzle about how to stack different-size flapjacks that are burned on one side and perfectly cooked on the other using the fewest number of flips

Genomics is the new molecular biology.

If a student seeks a research career, he or she had better pursue an education that enhances his or her quantitative skills.

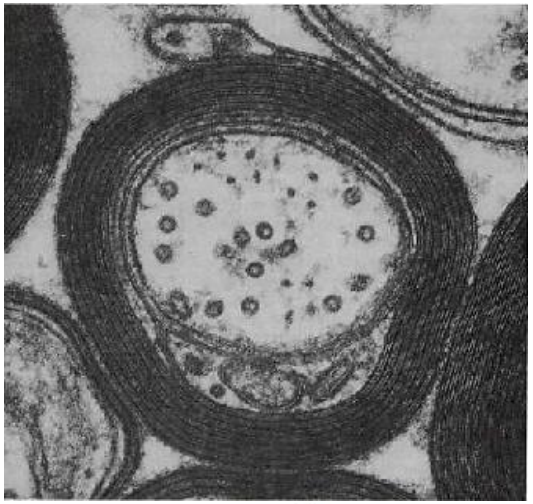
Math is the New Microscope

What is the optimum branching angle?

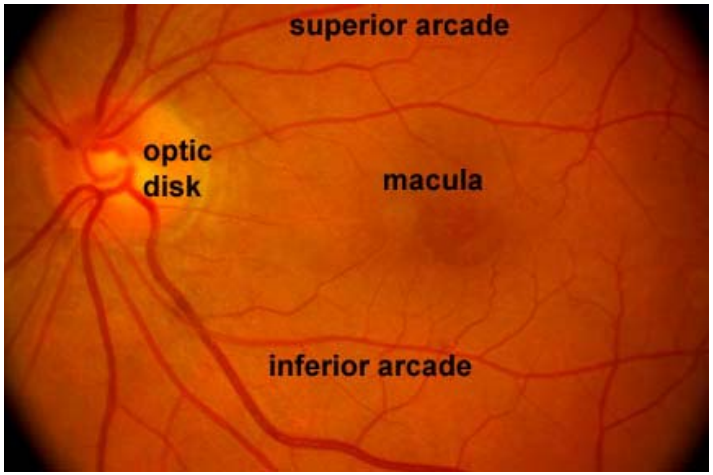


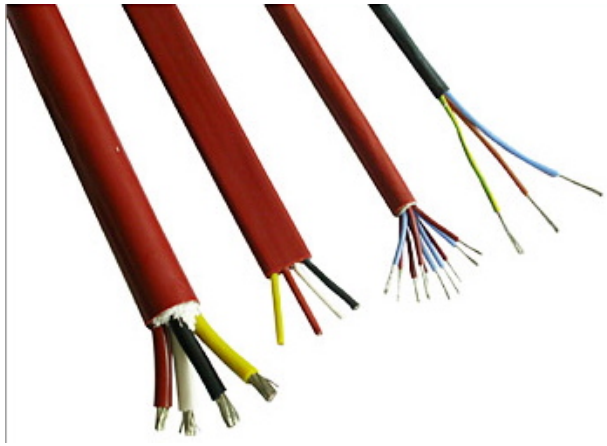
$$f(x) = k\left(\frac{x}{r_1^4} + \frac{\sqrt{(d-x)^2+y^2}}{r_2^4}\right)$$

How much myelin is best?

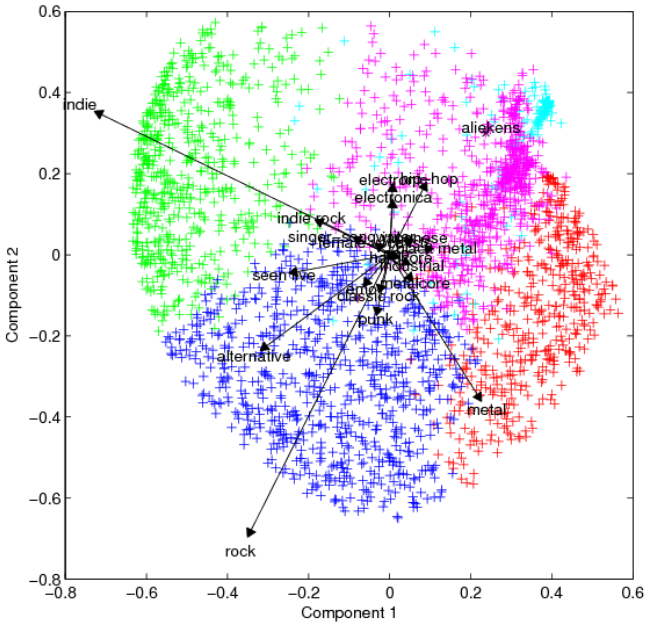


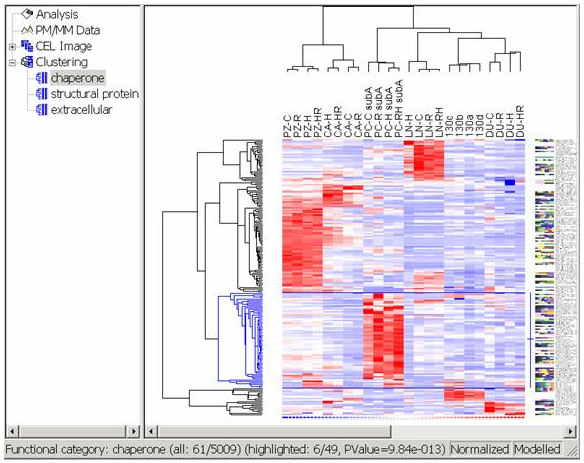
$$v = \alpha\left(\frac{r}{R}\right)^2 \ln\left(\frac{r}{R}\right)$$



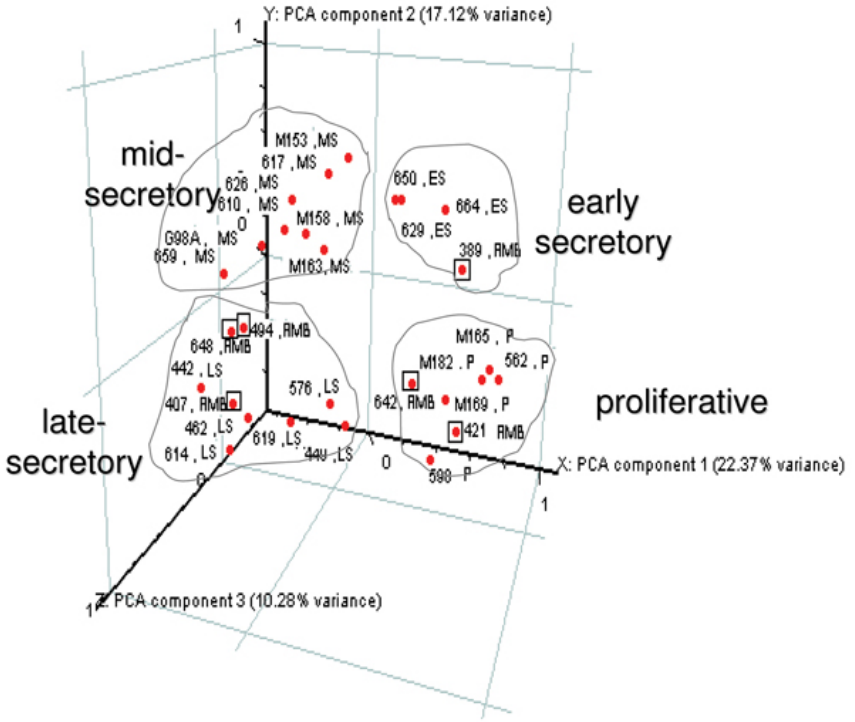


Clustering





Principle Component Analysis

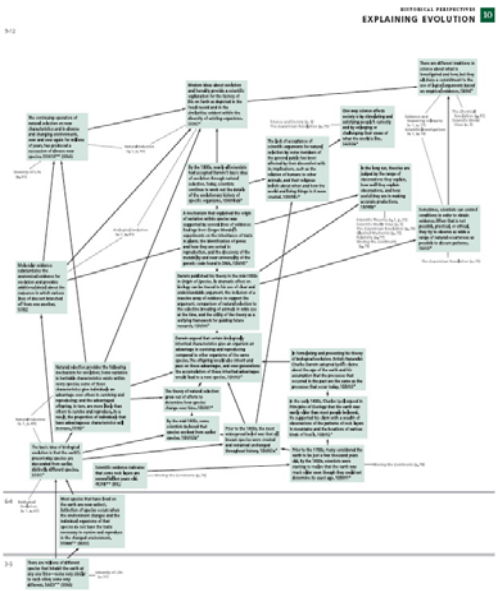


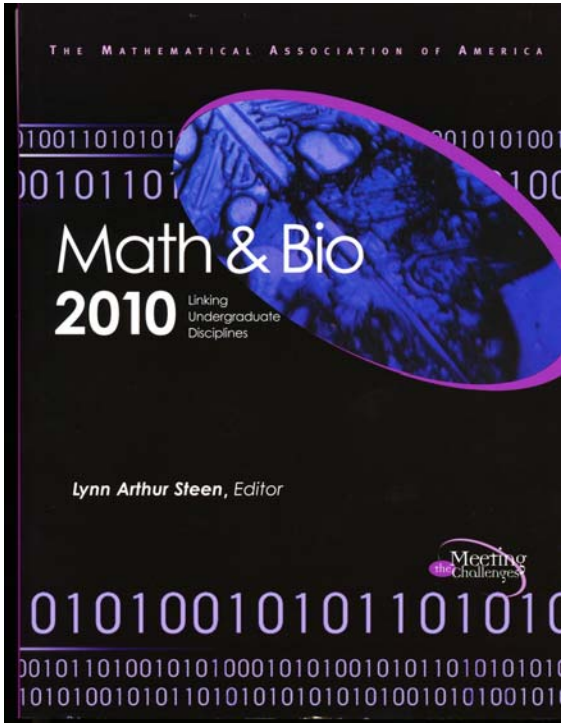
$$u[m] = \frac{1}{N}\sum_{n=1}^{N} X[m,n]$$

$$\mathbf{w}_1 = \arg\max_{\|\mathbf{w}\|=1} \operatorname{var}\{\mathbf{w}^T\mathbf{x}\} = \arg\max_{\|\mathbf{w}\|=1} E\left\{\left(\mathbf{w}^T\mathbf{x}\right)^2\right\}$$

Since our students’ needs are changing, what must we do as their teachers to keep up with the changing demands?


PROJECT
2061
CONNECTIONS


EXPLAINING EVOLUTION


THE MATHEMATICAL ASSOCIATION OF AMERICA
Math & Bio
2010
Linking
Undergraduate
Disciplines
Lynn Arthur Steen, Editor
Meeting the Challenges
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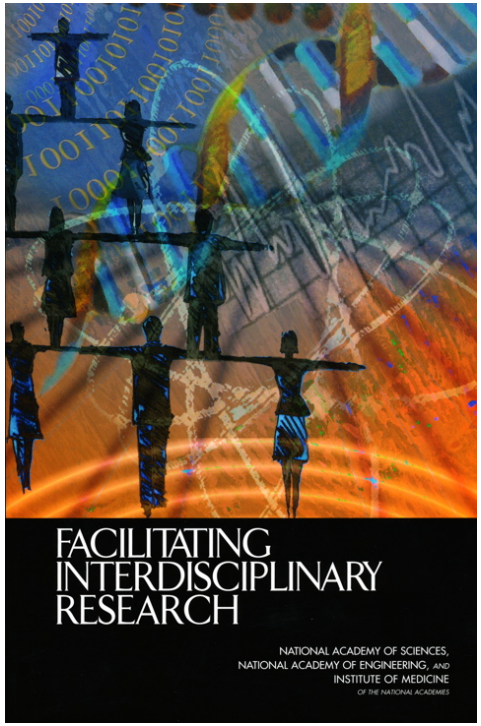
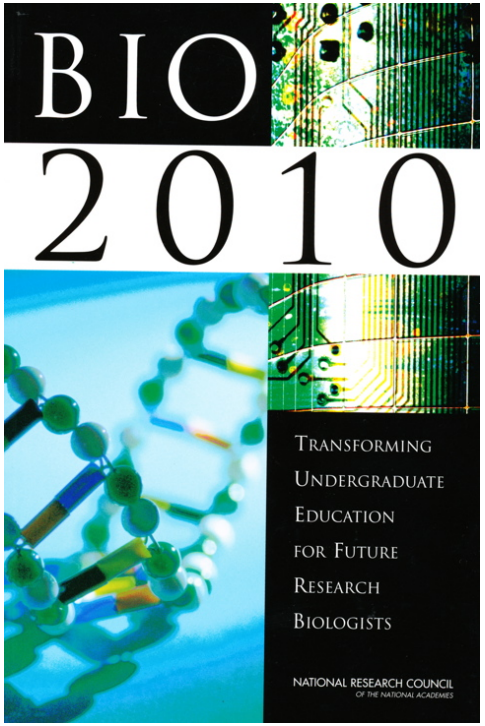

FACILITATING
INTERDISCIPLINARY
RESEARCH
NATIONAL ACADEMY OF SCIENCES,
NATIONAL ACADEMY OF ENGINEERING, AND
INSTITUTE OF MEDICINE
OF THE NATIONAL ACADEMIES


BIO
2010
TRANSFORMING
UNDERGRADUATE
EDUCATION
FOR FUTURE
RESEARCH
BIOLOGISTS
NATIONAL RESEARCH COUNCIL
OF THE NATIONAL ACADEMIES

How can we retool ourselves and our courses?

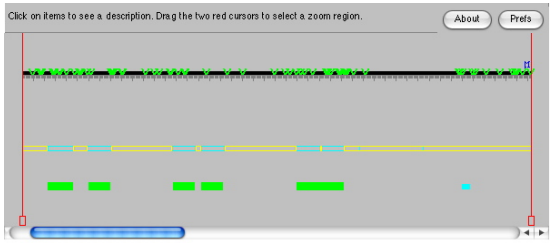
Faculty Development - free & hands on.

How can we modify existing courses?

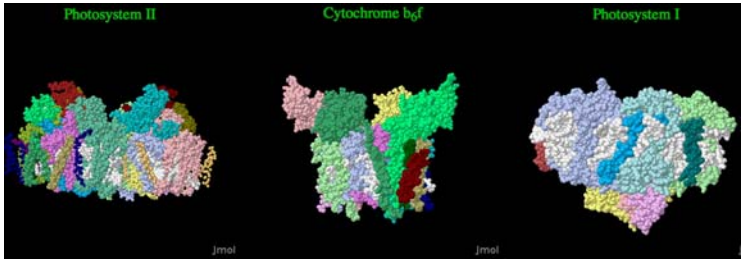
What is the probability of having HIV given a positive test?

$$P(HIV_{pos} \mid +) = \frac{P(+ \mid HIV_{pos})\, P(HIV_{pos})}{P(+ \mid HIV_{pos})\, P(HIV_{pos}) + P(+ \mid HIV_{neg})\, P(HIV_{neg})}$$

What is the topology of the encoded protein?



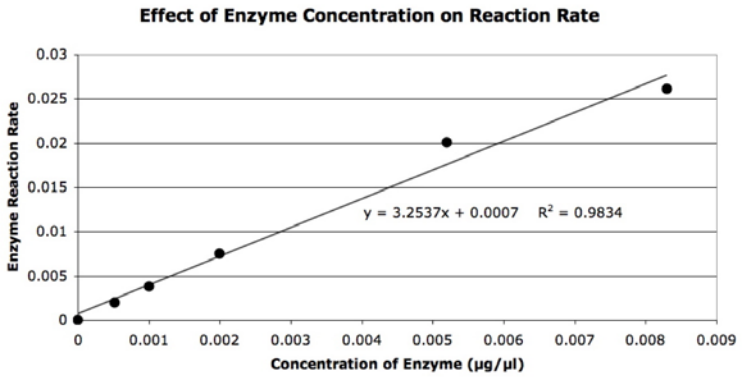
What is the 3D shape of this protein?

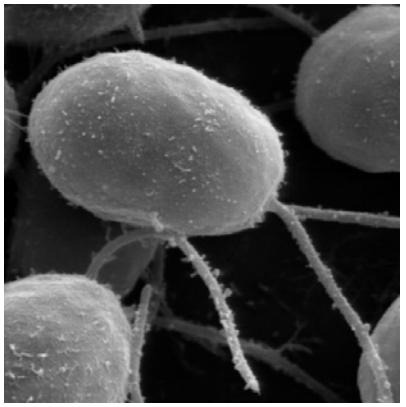


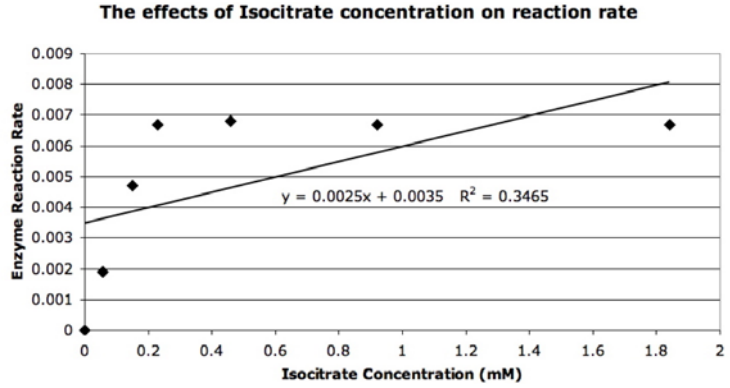
Overhaul Introductory Biology

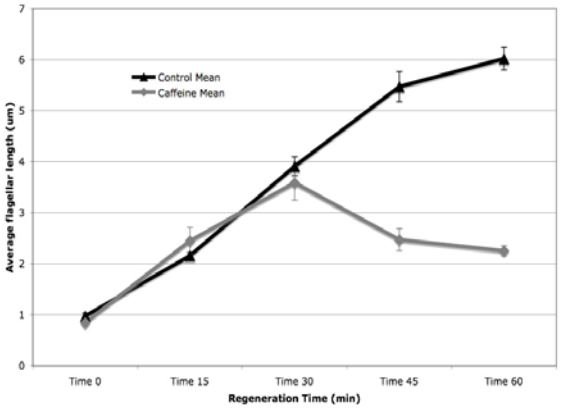
- ✓ Focus on 5 main concepts
- ✓ Use fewer examples
- ✓ Students construct their knowledge
- ✓ Provide data to support claims
- ✓ Connect content to what they know
- ✓ **Include math throughout**
- ✓ Incorporate ELSI throughout
- ✓ Dissolve false division of big and small biology
- ✓ Write in comfortable style

Update labs. Include statistics and probability.









Get CCLI funding from NSF

Collaborate Wisely. Make Smart Hires.

E. Stevens (DC Chem)
D. Boye (DC Phys)
L. Heyer (DC Math)
V. Case (DC Bio)
D. Wessner (DC Bio)
J. Williamson (DC Bio)
D. Kimmel (DC Bio)
S. Sundby (Macalester Bio)
S. Tonidandel (DC Psych)
A. Ordman (Beloit Bio)

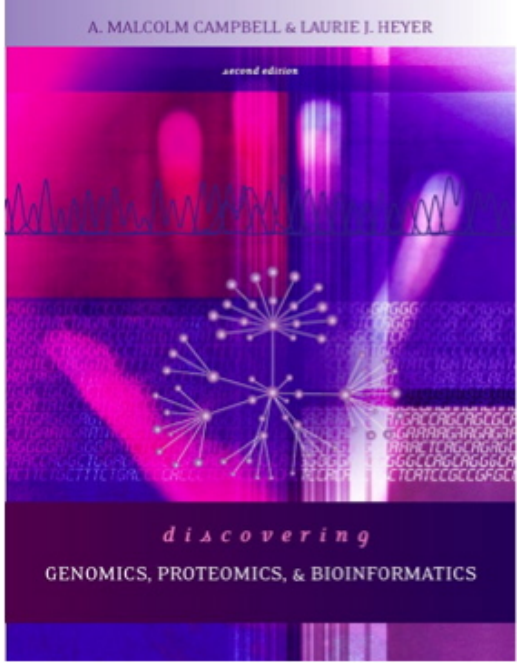
C. Paradise (DC Bio)
B. Lom (DC Bio)
B. Hatfield (DC Bio)
E. Fowlks (Hampton Bio)
A. Rosenwald (Georgetown Bio)
T. Eckdahl (MWSU Bio)
J. Poet (MWSU Math)
L. Hoopes (Pomona Bio)
M.L. Ledbetter (Holy Cross Bio)
V. Armbrust (UW Oceanography)

Smart Heyer

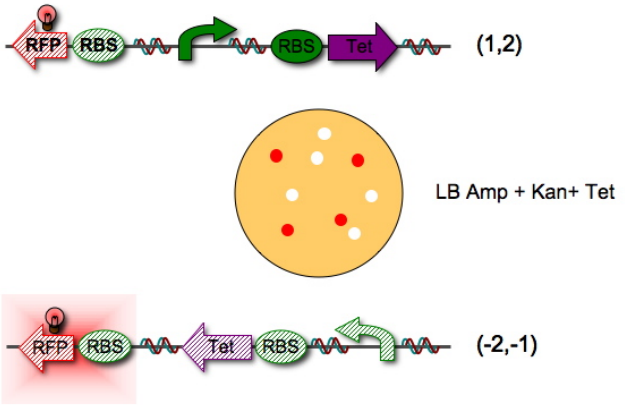
Students 2008

Students 2007

Genomics

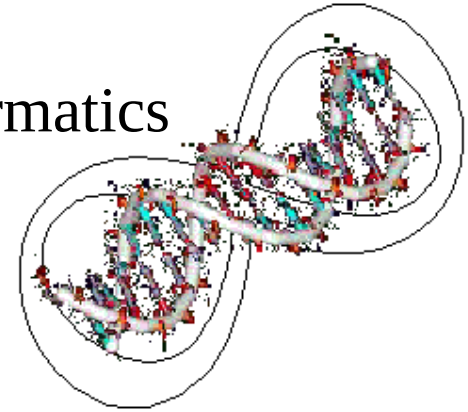


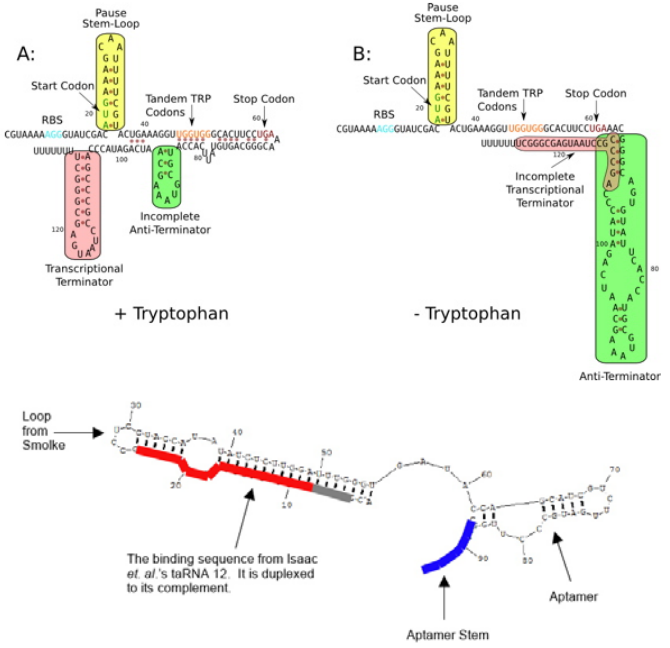
Synthetic Biology



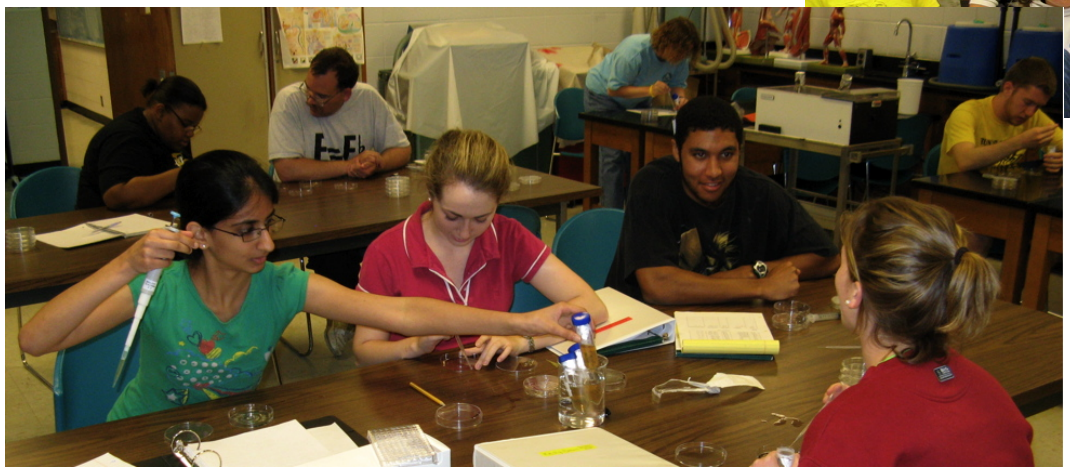
Do we need new courses?

Bioinformatics





Real research
is the curriculum.

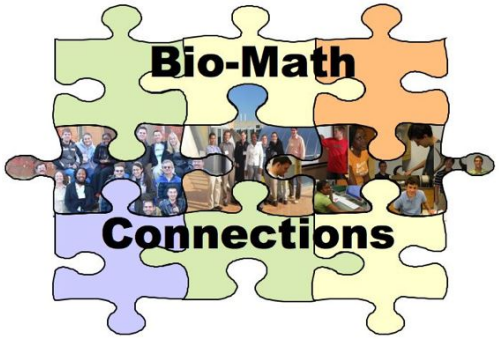


Interdisciplinary Training for Undergraduates in Biological and Mathematical Sciences (UBM)

PROGRAM SOLICITATION
NSF 06-541
***REPLACES DOCUMENT* NSF 04-546**

National Science Foundation
Directorate for Biological Sciences
Emerging Frontiers
Directorate for Education and Human Resources
Division of Undergraduate Education
Directorate for Mathematical and Physical Sciences
Division of Mathematical Sciences
Office of Multidisciplinary Activities

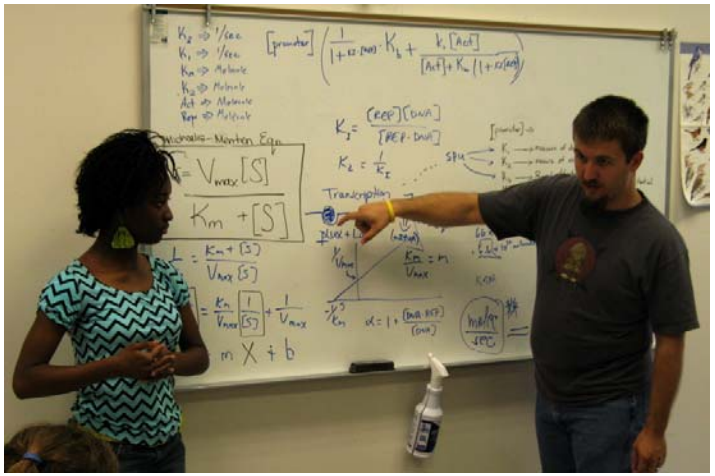
Why do we
reward
memorization is
our classes?

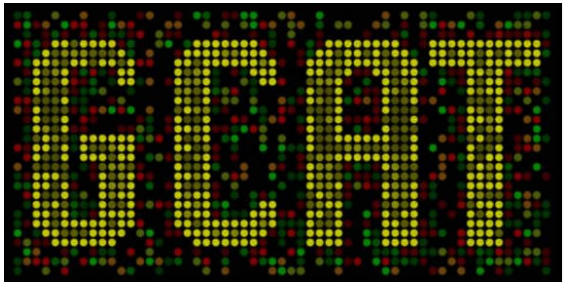


Teaching | Microarrays | Synthetic Biology | Textbook

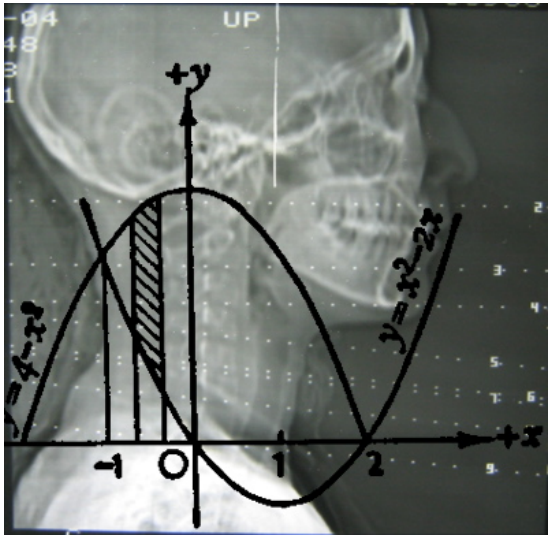
At Davidson, I have taught the following classes:

- MAT 130 Calculus I
- MAT 130 M Calculus & Modeling I
- MAT 137 Calculus & Modeling II
- MAT 135 Calculus II
- MAT 150 Linear Algebra
- MAT 210 Mathematical Modeling
- MAT 235 Differential Equations
- MAT 340 Probability
- MAT 341 Mathematical Statistics
- MAT 482 Introduction to Operations Research
- BIO / CSC 310 Bioinformatics



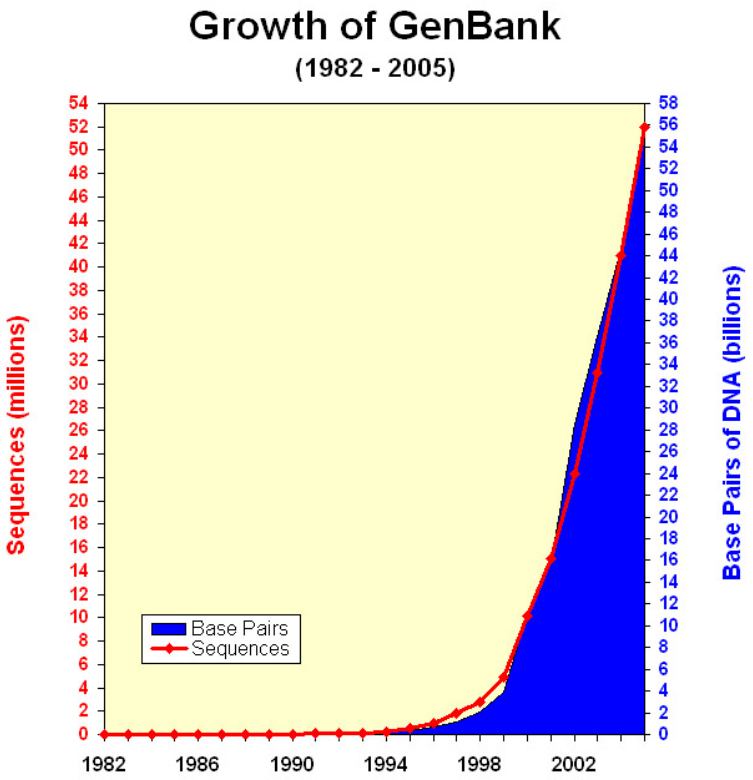


Should we team teach more?



Is more content better?

How much do your students remember now?



Neil Campbell's *Biology* 5th Edition 55 chapters, 1290 pages
Neil Campbell's *Biology* 6th Edition 55 chapters, 1175 pages
Neil Campbell's *Biology* 7th Edition 55 chapters, 1312 pages
Neil Campbell's *Biology* 8th Edition 55 chapters, 1393 pages

MAAIKE f Dutch
Dutch diminutive of **MARIA**

MAARIA f Finnish
Finnish form of **MARIA**

MAARIKA f Finnish, Estonian
Diminutive of **MAARIA** (Finnish) or **MAARJA** (Estonian).

MAARIT f Finnish
Finnish form of **MARGARET**

MAARJA f Estonian
Estonian form of **MARIA**

MAARTEN m Dutch
Dutch form of **MARTIN**

MAARTJE f Dutch
Dutch feminine form of **MARTIN**

MAAS m Dutch
Dutch short form of **THOMAS**

MAATA f Maori
Maori form of **MARTHA**

MAAYAN f Jewish
Means "spring of water" in Hebrew.

MABEL f English
Medieval form of **AMABEL**... [more]

MABELLA f English (Rare)
Elaborated form of **MABEL**

MABELLE f English
Variant of **MABEL**... [more]

MABLE f English
Variant of **MABEL**

MABON m Welsh, Welsh Mythology
Derived from Welsh *mab* meaning "son"... [more]

MABYN f Welsh
Means "youth" in Welsh... [more]

How would you respond if I gave you a list of 500 student names and required you to memorize them?

MAB	MACHA	MADELINA
MABEL	MACHIKO	MADELINE
MABLI	MACKENZIE	MADELYN
MABON	MACON	MADGE
MABYN	MACONAQUEA	MADISON
MAC	MACY	MADLAINA
MACADRIAN	MACYN	MADOG
MACARENA	MADA	MADONNA
MACARIA	MADAN	MADRA
MACARIO	MADDEN	MADRID
MACAWI	MADDOCK	MADRONA
MACAYLE	MADDOX	MAE
MACBETH	MADDY	MAEGAN
MACE	MADELEINE	MAEKO
MACEO	MADELIA	MAEL

The Star Fleet Academy Myth

Our students can learn more each year.

Can we tweak what we have and honestly meet the needs of our students?

If we currently cover all the important stuff….

…how can we add more content?

Base Your Teaching on Data

Triage based on educational goals!

1) List goals

2) What could students do if goals are met?

3) Measure if students can do #2

This presentation has offered some answers and now I invite you to an honest discussion.

Can I teach outside my area?

How do I cover more material?

Am I equally trained in math and biology?

Do I want students to be equally trained in both?

What happens if my students are smarter than me?!

Learning is the Primary Goal