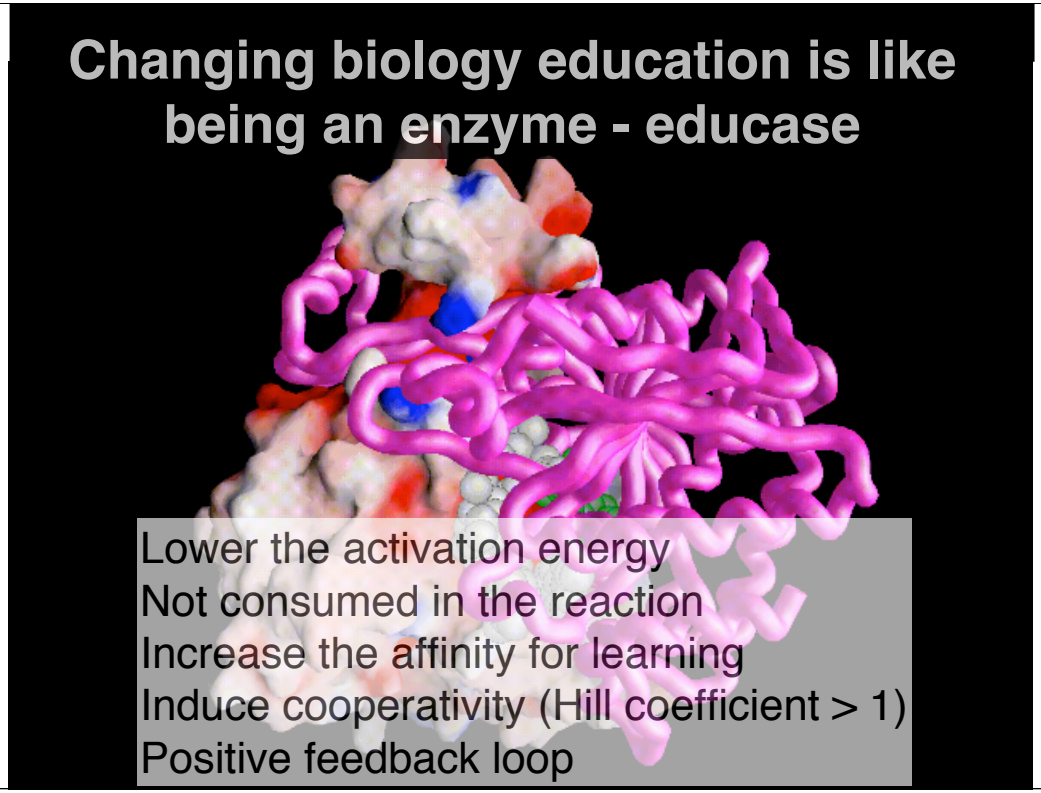
Educase: Catalytic Biology Reform

A. Malcolm Campbell — Biology Dept. & **GCAT**
Laurie J. Heyer — Mathematics Dept. & **GCAT**

DAVIDSON

Beyond BIO2010: Celebration and Opportunities
May 22, 2010

Changing biology education is like being an enzyme - educase

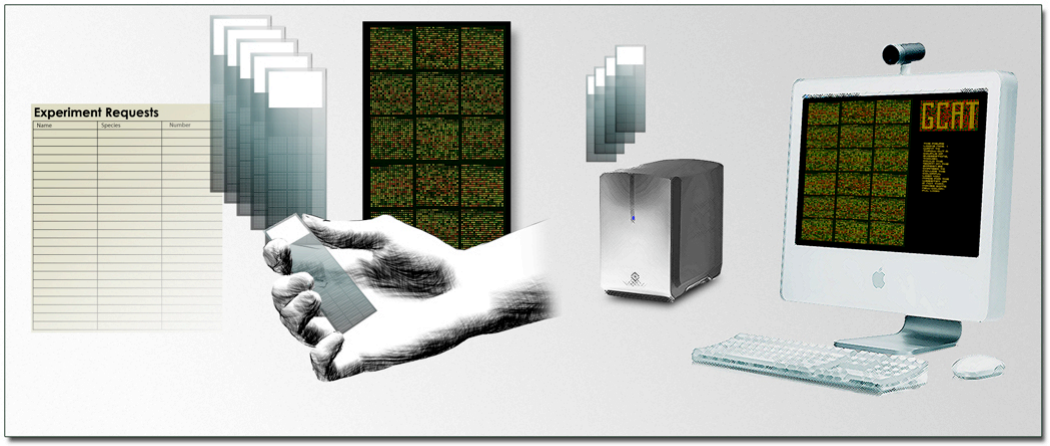


Lower the activation energy
Not consumed in the reaction
Increase the affinity for learning
Induce cooperativity (Hill coefficient > 1)
Positive feedback loop

2000-2010

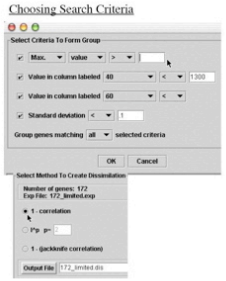
GCAT

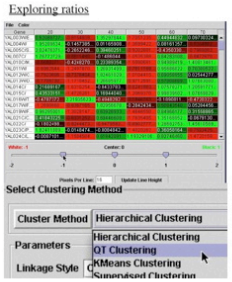
Genome Consortium for Active Teaching

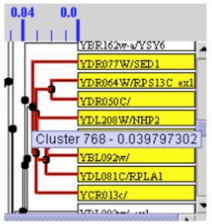


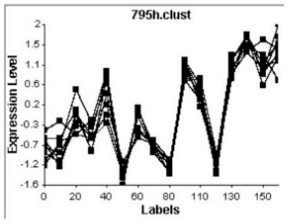
Started in 2000
Focused on DNA microarrays

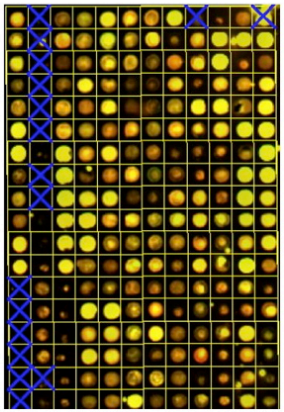
Open Source and Free Software











www.bio.davidson.edu/MAGIC

GCAT

Faculty Development

NSF funded

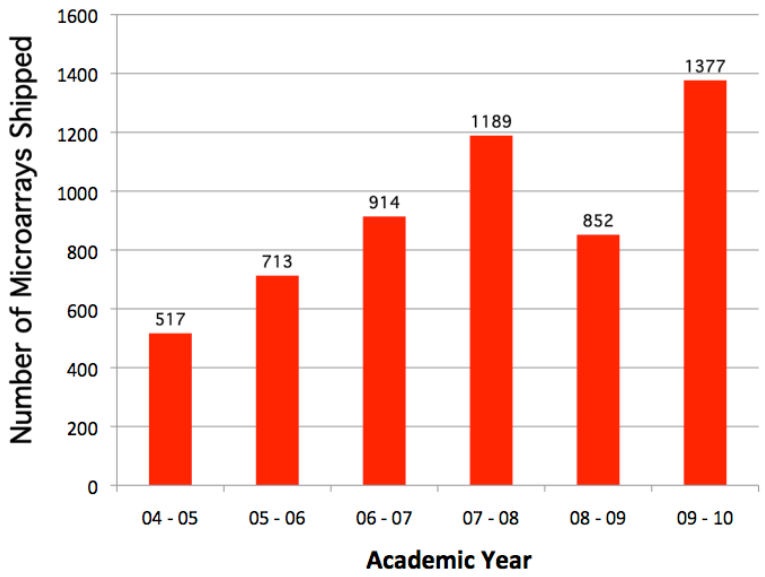
GCAT

Faculty Development

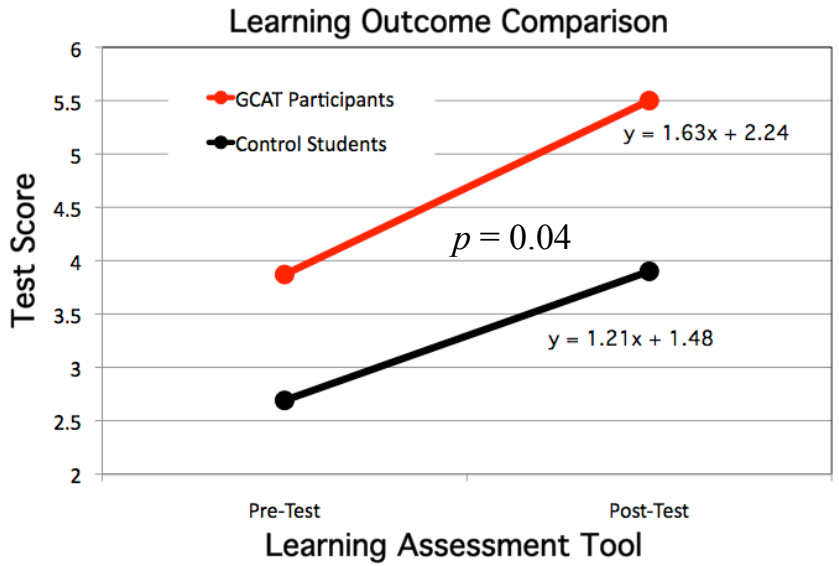
9 workshops, 360 faculty

Genome Consortium for Active Teaching

over 20,000 undergraduates



Genome Consortium for Active Teaching



Research grants funded

Published basic research

Published learning gains

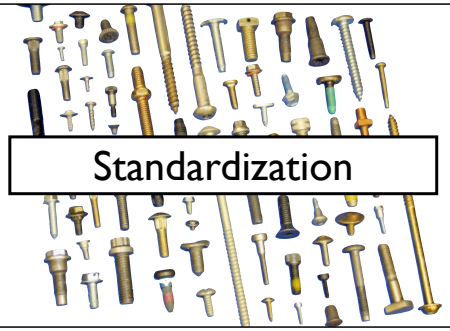
Teaching awards

2005-present
Synthetic Biology

Synthetic Biology

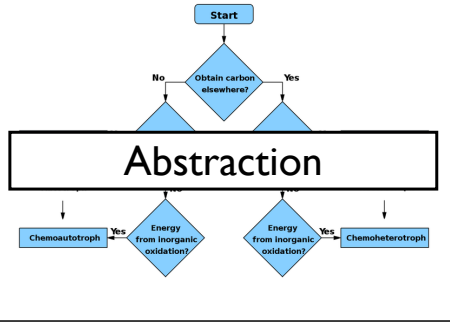
Application of engineering principles and mathematical modeling to the design and construction of biological parts, devices, and systems with applications in energy, medicine, and technology.

How is Synthetic Biology Different?

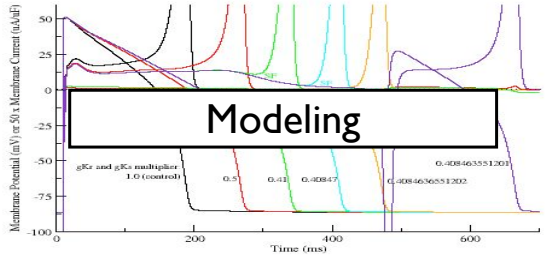


Standardization

Modularity



Abstraction



Modeling

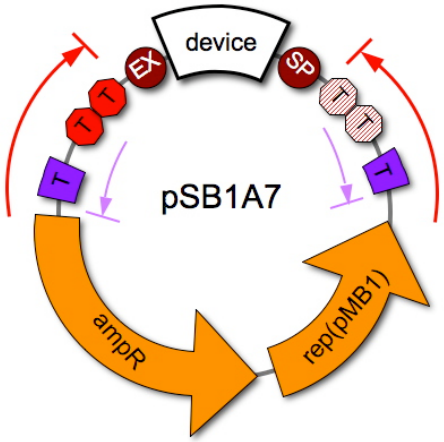
How is Synthetic Biology Different?

Abstraction

Modularity

Standards

Designing and modeling



iGEM 2009

How is Synthetic Biology Different?

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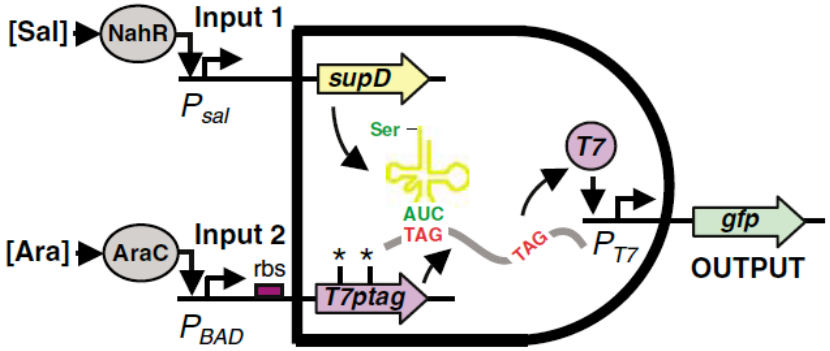
Designing and modeling



AND Logic Gate

iGEM 2009

How is Synthetic Biology Different?

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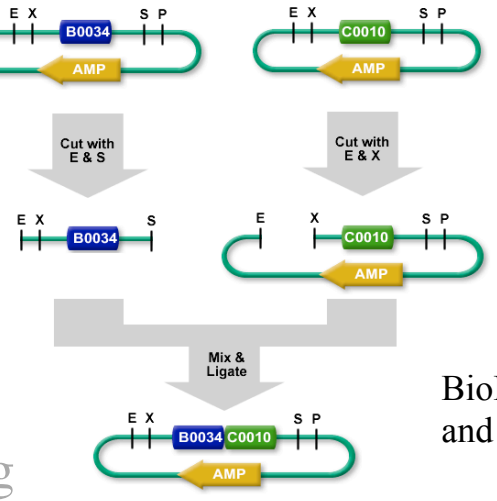


BioBrick Ends and Ligation

iGEM 2009

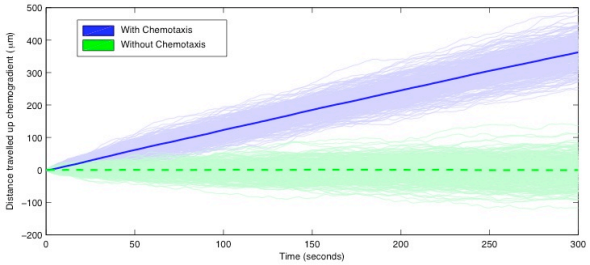
How is Synthetic Biology Different?

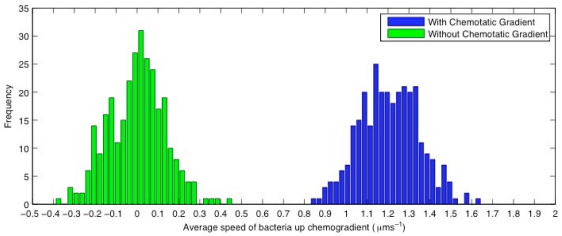
Abstraction

Modularity

Standards

Designing and modeling





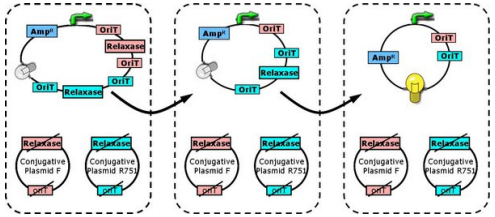
iGEM 2009

What is iGEM?

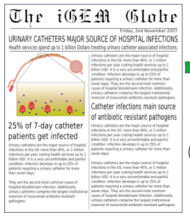
at a glance:

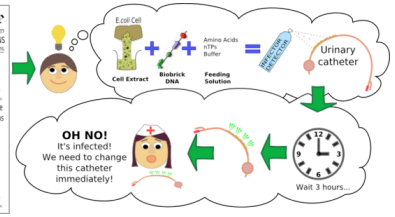
1925	minutes of talks	77	presentations
1200	participants	24	awards
825	jamboree attendees	22	weeks of work
84	teams	21	countries

http://2009.igem.org/Main_Page



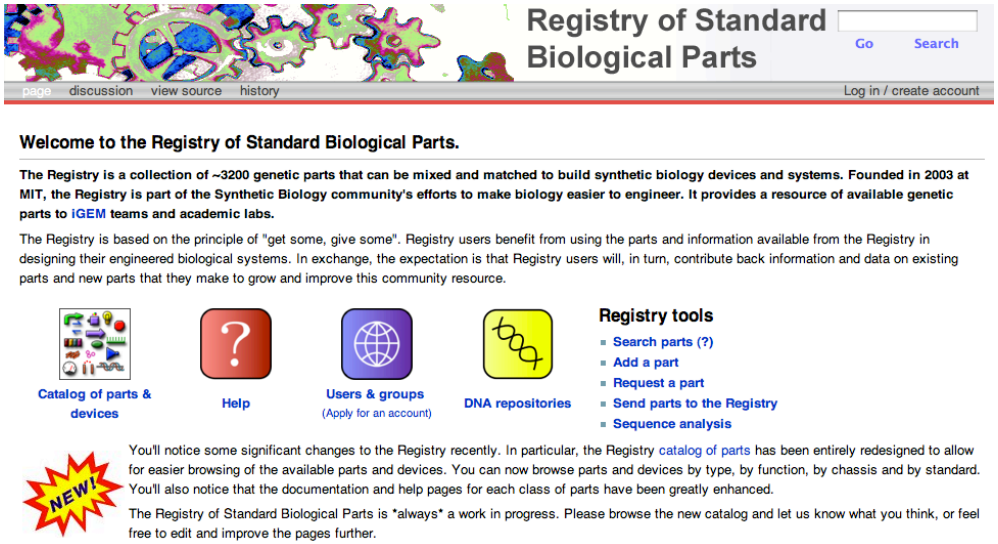
Peking University





Imperial College

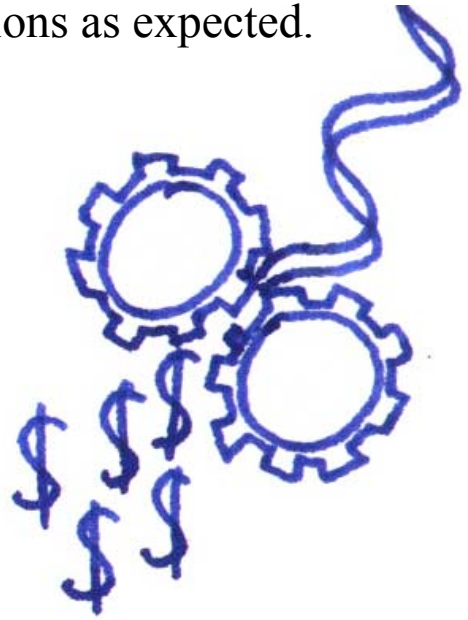
Standardized and Modular DNA



Think of Radio Shack for DNA parts.

Synthetic Biology: Win-Win Research

Win #1: your design functions as expected.



Synthetic Biology: Win-Win Research

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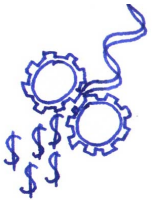
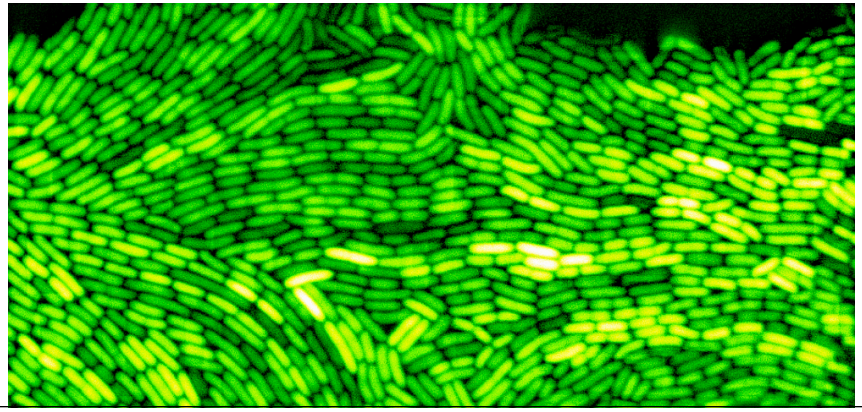


Win #2: your design fails but you uncover basic biology



Synthetic Biology
at
Davidson College

building bacterial computers

Majority this year's group are students of color.

2006 Team

Davidson College Synthetic Biologists

Majority this year's group are students of color.

Burnt Pancake Problem

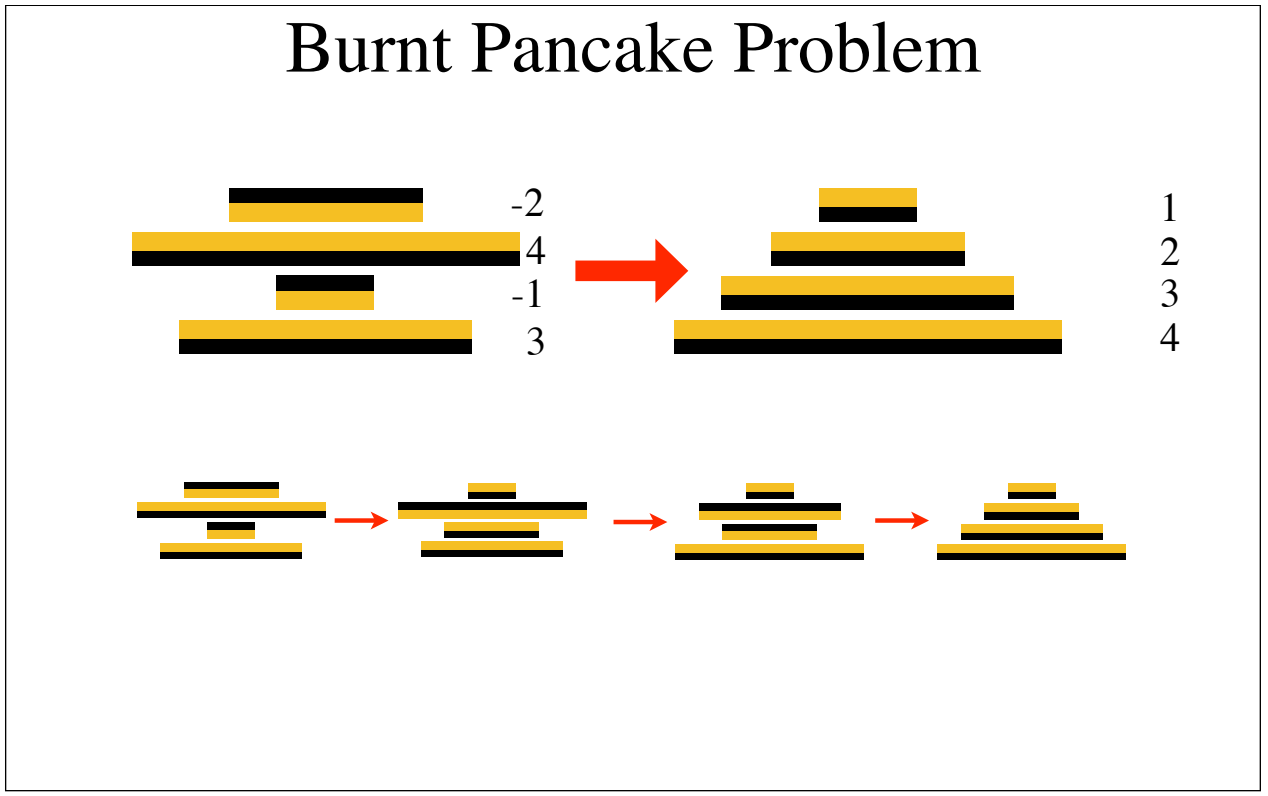
E. HOP
We Flip Them For You!

DAVIDSON

HAMPTON UNIVERSITY

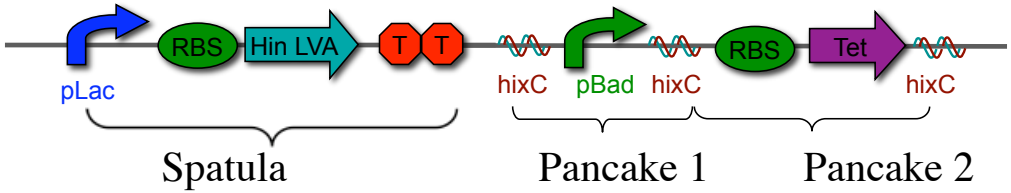
Discover Gold WESTERN

Only academic publication by Bill Gates.



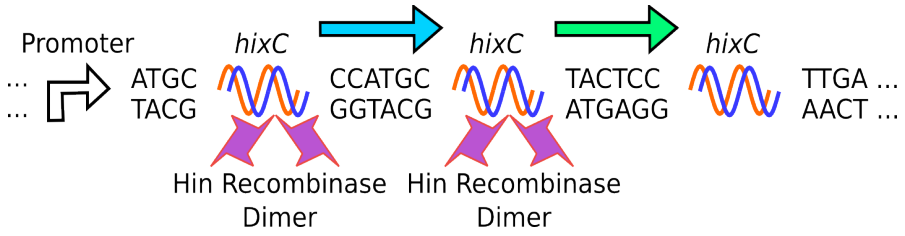
Using two spatulas, one to lift and the other to flip.

DNA Burnt Pancakes



abstractions of DNA parts

Flipping DNA with Hin/*hixC*



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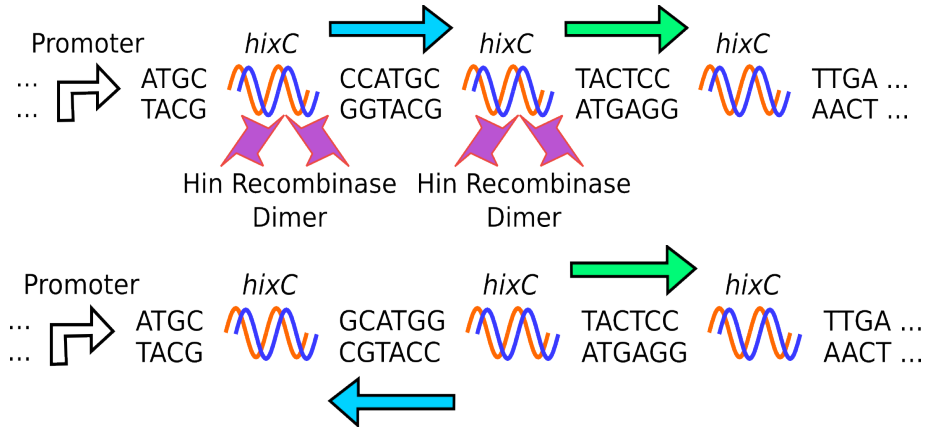

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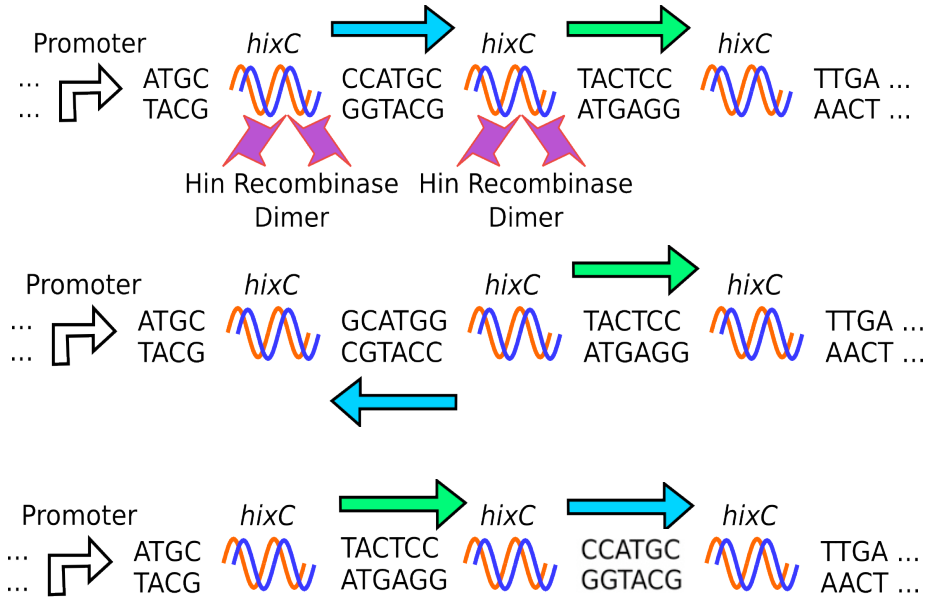


Top 10 most accessed articles of all time

JOURNAL OF BIOLOGICAL ENGINEERING

Top 10 most accessed articles for last 30 days / past year / all time

1. Research Open Access Highly accessed

Accesses 28057 evaluated on F1000 BIOLOGY

Solving a Hamiltonian Path Problem with a bacterial computer

Jordan Baumgardner, Karen Acker, Oyinade Adefuye, Samuel Thomas Crowley, Will DeLoache, James O Dickson, Lane Heard, Andrew T Martens, Nickolaus Morton, Michelle Ritter, Amber Shoecraft, Jessica Treece, Matthew Unzicker, Amanda Valencia, Mike Waters, A Malcolm Campbell, Laurie J Heyer, Jeffrey L Poet, Todd T Eckdahl

Journal of Biological Engineering 2009, **3**:11 (24 July 2009)

[Abstract] [Full Text] [PDF] [PubMed] [Related articles] [F1000 Biology]

2. Research Open Access Highly accessed

Accesses 23354

Engineering bacteria to solve the Burnt Pancake Problem

Karmella A Haynes, Marian L Broderick, Adam D Brown, Trevor L Butner, James O Dickson, W Lance Harden, Lane H Heard, Eric L Jessen, Kelly J Malloy, Brad J Ogden, Sabriya Rosemond, Samantha Simpson, Erin Zwack, A Malcolm Campbell, Todd T Eckdahl, Laurie J Heyer, Jeffrey L Poet

Journal of Biological Engineering 2008, **2**:8 (20 May 2008)

[Abstract] [Full Text] [PDF] [PubMed] [Related articles]

3. Methodology Open Access Highly accessed

Accesses 11794

Engineering BioBrick vectors from BioBrick parts

Reshma P Shetty, Drew Endy, Thomas F Knight Jr

Journal of Biological Engineering 2008, **2**:5 (14 April 2008)

Increased Student Diversity

37 undergraduates in 5 years

African American	Hispanic	First Generation	Asian Minority	Asian
11	2	5	2	4

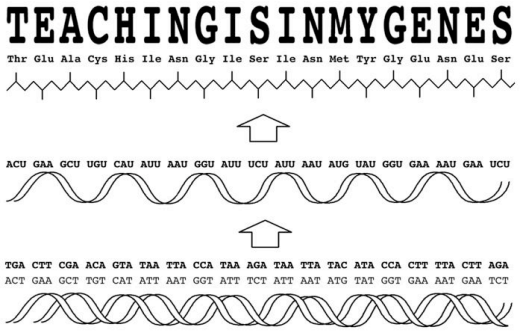
PhD	Dual degree	MD	MPH	Jobs	
9	2	2	3	4	7

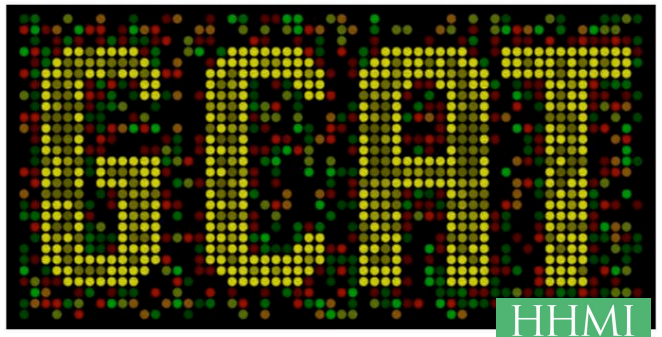
campus: 74% Caucasian **biology majors: 87% Caucasian**

27 students are seniors or have graduated
10 are still in school and undecided

GCAT Faculty Workshop
Synthetic Biology

15 pairs of faculty
1 Bio + 1 Other
July 8 - 10, 2010





HHMI
HOWARD HUGHES
MEDICAL INSTITUTE

2010-2020

Integrated Systems Biology

What's Wrong with Biology Education Now?

- Vocabulary is emphasized
- Experimental approaches are minimized
- Math is absent
- Memorization is rewarded
- Critical thinking is discouraged
- Information is irrelevant to students

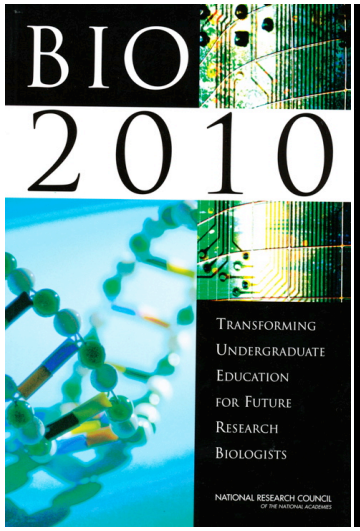
Too much content for the containers

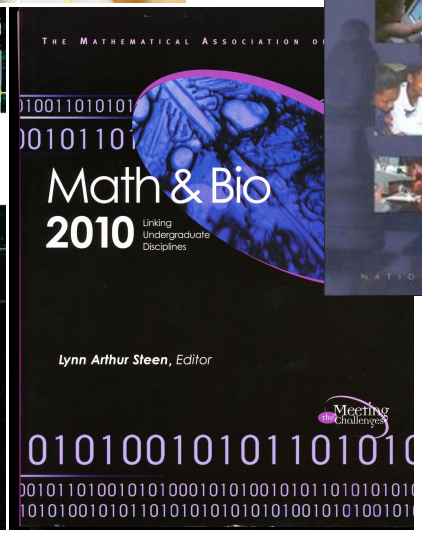
When you cram too much information into students, the outcome is unnatural and unpleasant to look at.

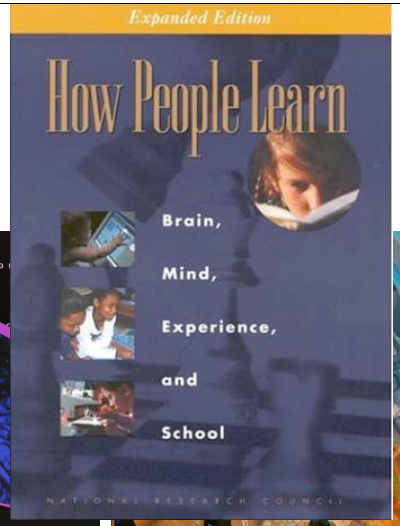
If we currently cover all the important stuff….

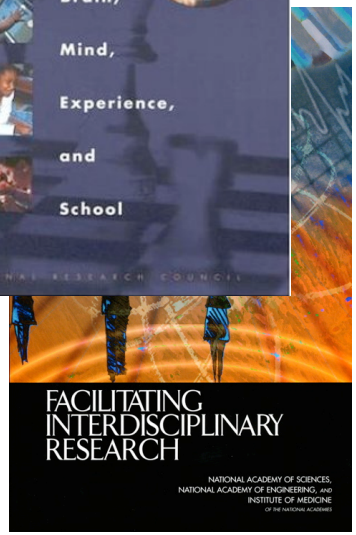
…how can we add more content?

Start with the literature…







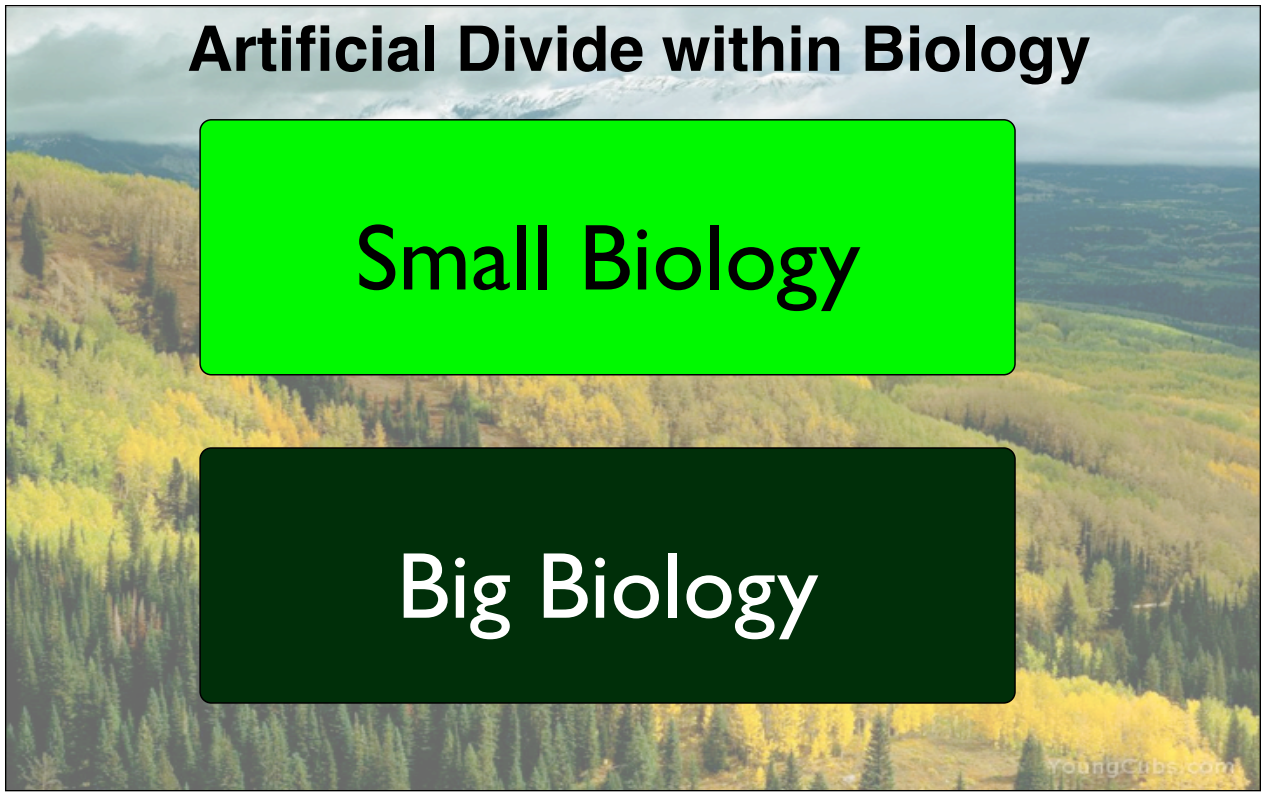


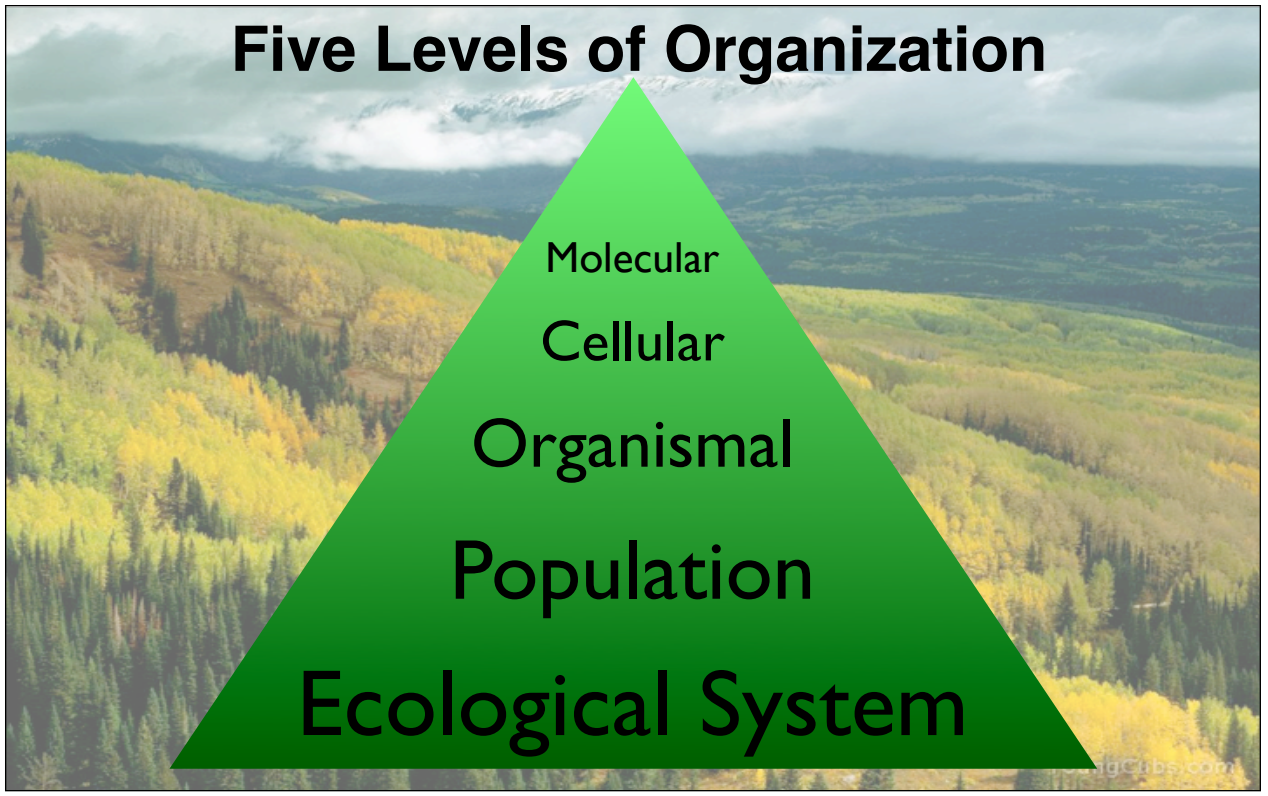
To fix biology education:

- Reduce the volume of information
- Facilitate construction of their own knowledge
- Use math repeatedly to illuminate biology
- Analyze real experimental data
- Reward thinking and creativity
- Discuss ethical, legal, social implications

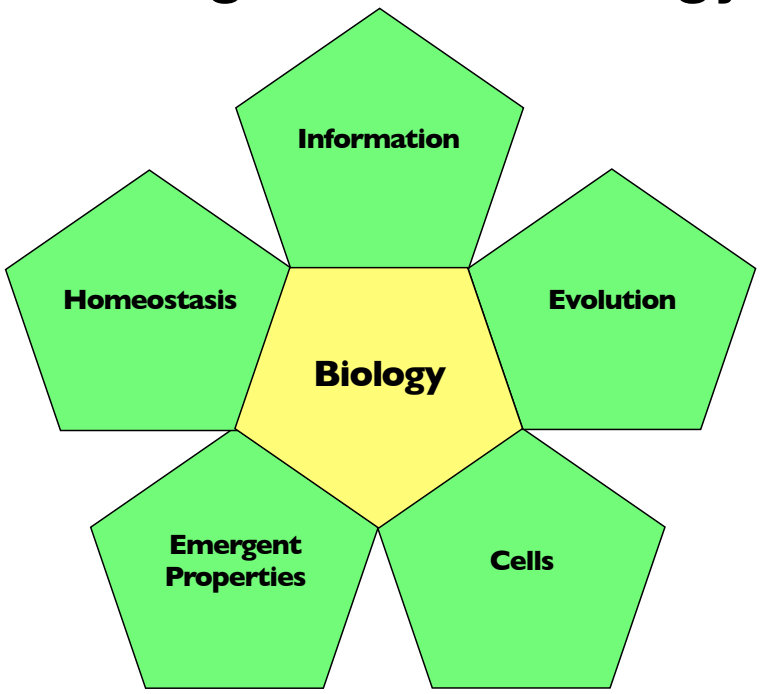
Present information and data…


… in the context of the big picture.
YoungCubs.com

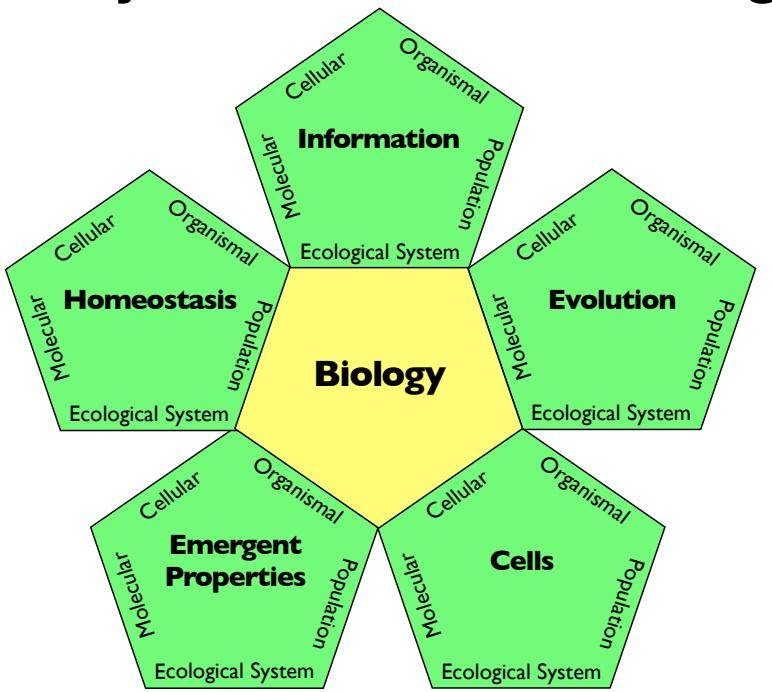

Artificial Divide within Biology
Small Biology
Big Biology


Five Levels of Organization
Molecular
Cellular
Organismal
Population
Ecological System

Five Big Ideas of Biology



Five by Five Matrix of Biology



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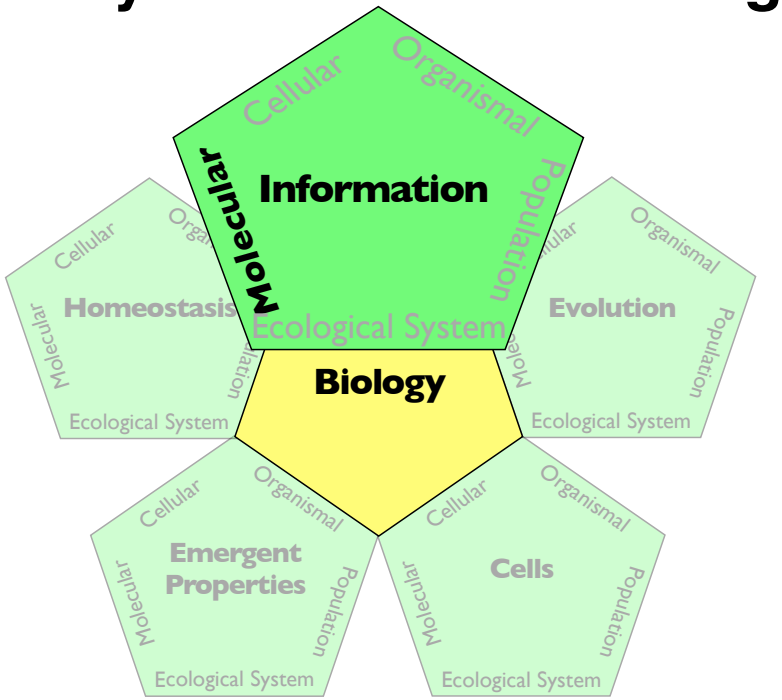

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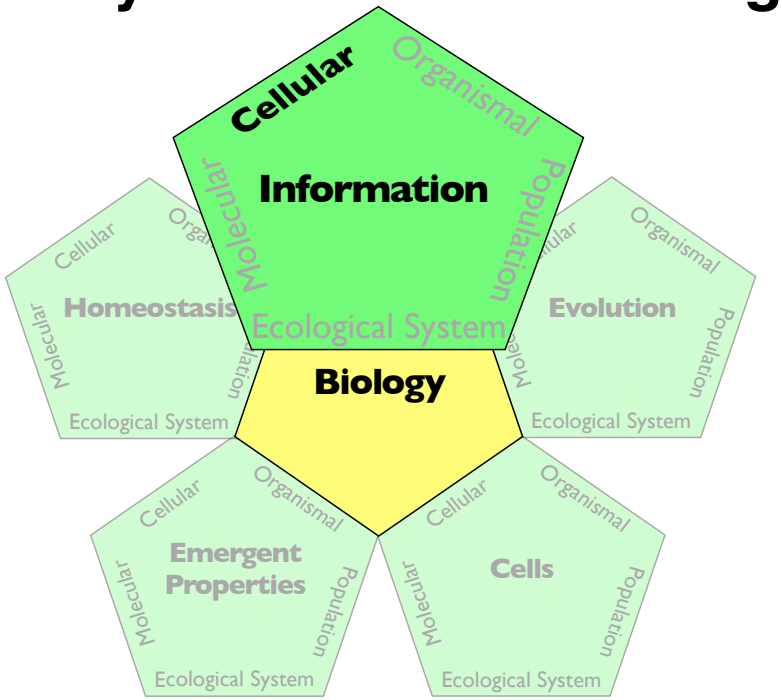

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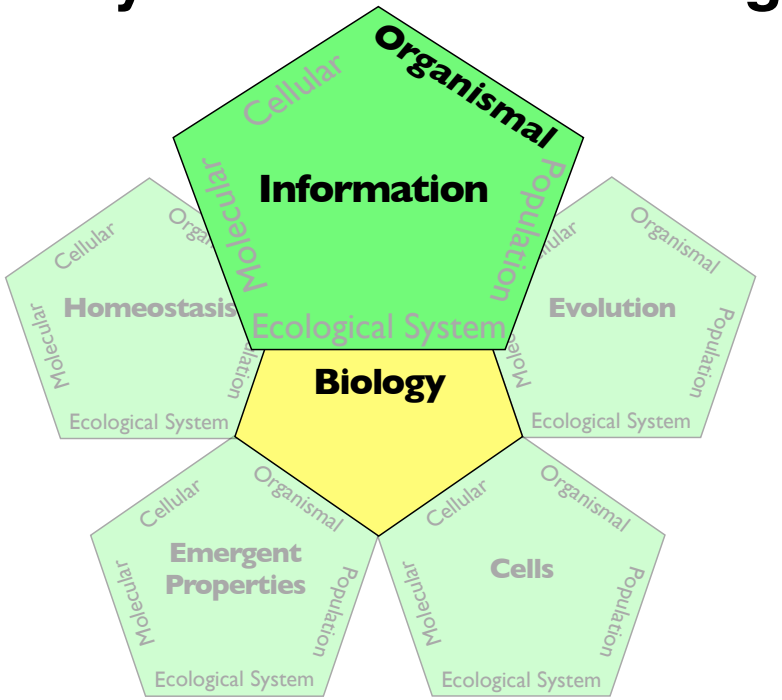

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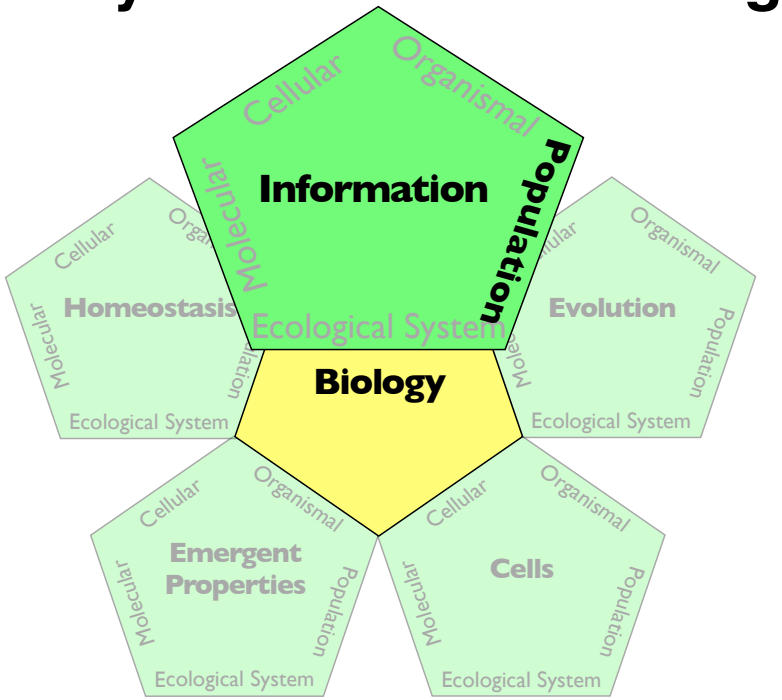

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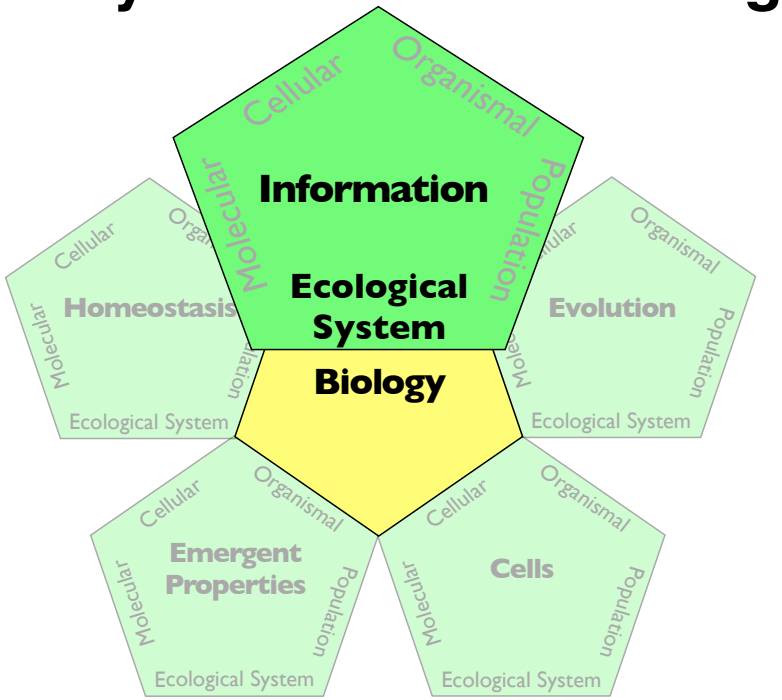

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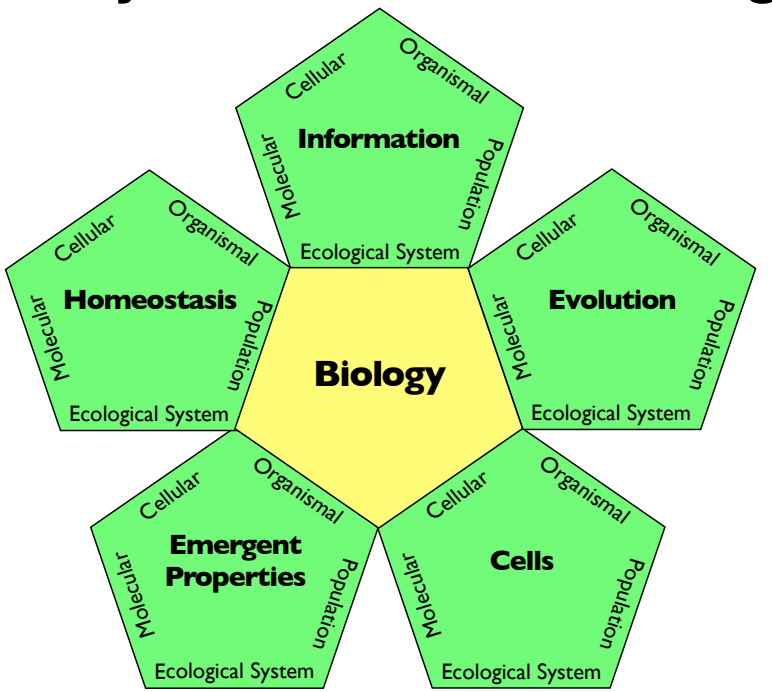
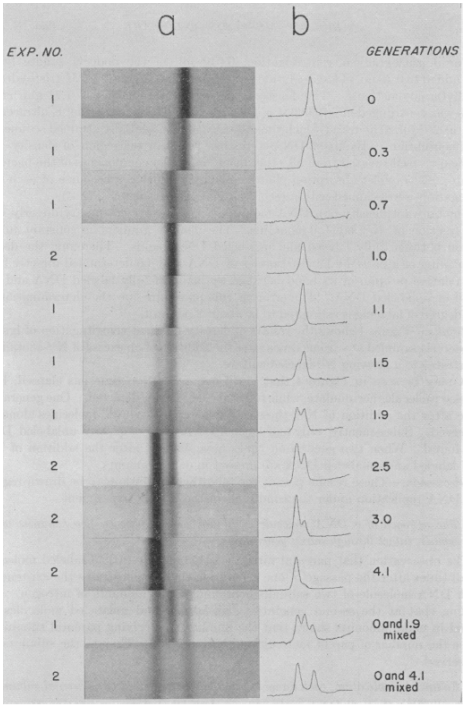


BioMath Explorations



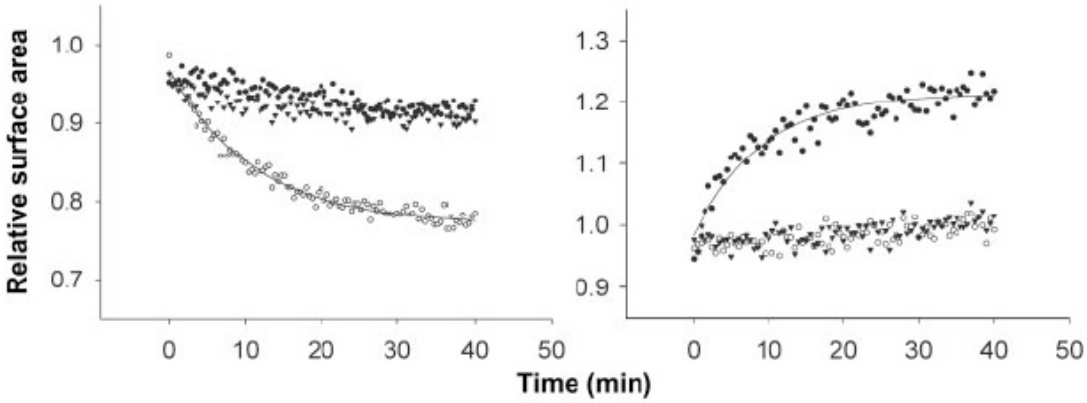
Bio-Math Exploration 1.2

How much DNA is in each band?

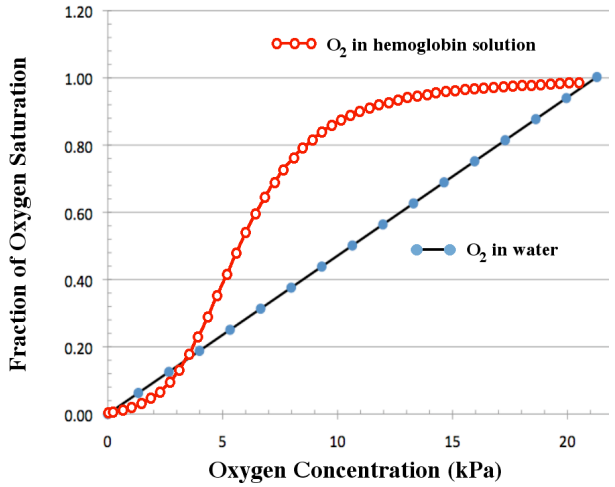
BioMath Explorations

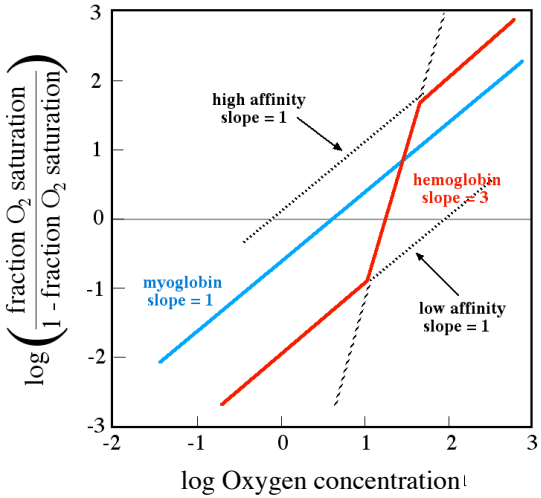
BioMath Exploration 6.3

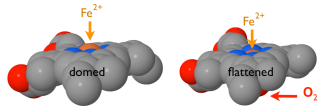
How can you fit exponential curves to data?



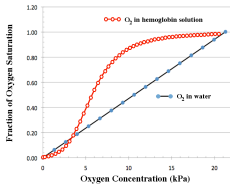
Real Data and Integrating Questions

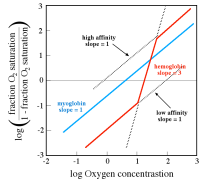


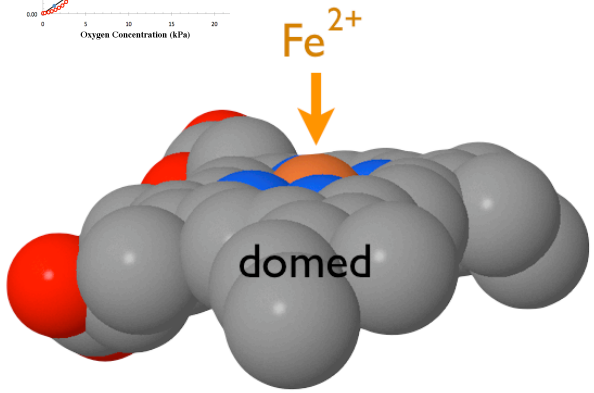


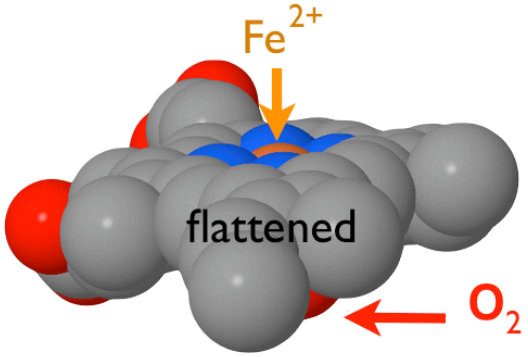


Real Data and Integrating Questions

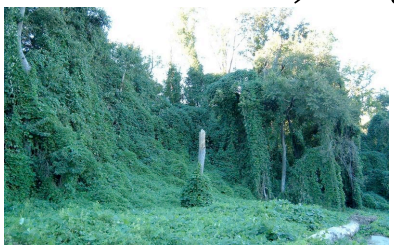


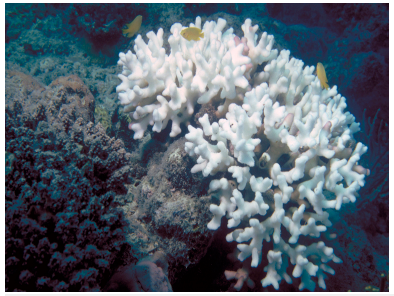


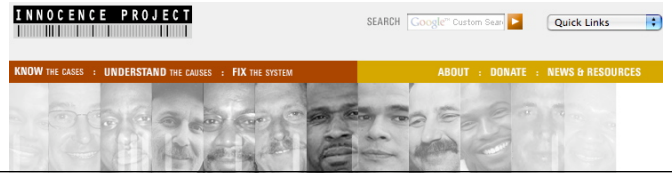




Ethical, Legal and Social Implications







Are religion and evolution compatible?

Is science possible if you are uncertain about what is true?

Does basic biology have any impact on the real world?

Who owns your DNA?

Acknowledgements

Faculty: Laurie Heyer, Jeff Poet, Todd Eckdahl, Karmella Haynes

Students: Romina Clemente, Clif Davis, A.J. Grant, Mary Gearing, Kin Lau, Olivia Ho-Shing, Shamita Punjabi, Eric Sawyer, Ashley Schooner, Siya Sun, Shashank Suresh, Bryce Szczepanik, Leland Taylor, Annie Temmink, Alyndria Thompson, Will Vernon, Oyinade Adefuye, Will DeLoache, Jim Dickson, Andrew Martens, Amber Shoecraft, Mike Waters, Jordan Baumgardner, Tom Crowley, Lane Heard, Nick Morton, Michelle Ritter, Karen Acker, Bruce Henschen, Jessica Treece, Matt Unzicker, Amanda Valencia, Lance Harden, Sabriya Rosemond, Samantha Simpson, Erin Zwack, Marian Broderick, Adam Brown, Trevor Butner, Lane Heard, Eric Jessen, Kelley Malloy, Brad Ogden, Kelly Davis, Alicia Allen, James Barron, Robert Cool, Kelly Davis, Will DeLoache, Erin Feeney, Andrew Gordon, John Igo, Aaron Lewis, Kristi Muscalino, Madeline Parra, Pallavi Penumetcha, Karlesha Roland, Max Win, Xiao Zhu, Kristen DeCelle, Matt Gemberling, Oscar Hernandez, Andrew Drysdale, Nick Cain, Tamar Odel, and Jackie Ryan.

The Duke Endowment, NSF, HHMI
Genome Consortium for Active Teaching (**G**CAT)
Davidson College James G. Martin Genomics Program
MWSU SGA, Foundation & Summer Research Institute