I Taught My Dog to Whistle, and Other Lessons from Student Research

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DAVIDSON

North Georgia College & State University
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Outline of Presentation

Why did you come to college?

What is the value of an education?

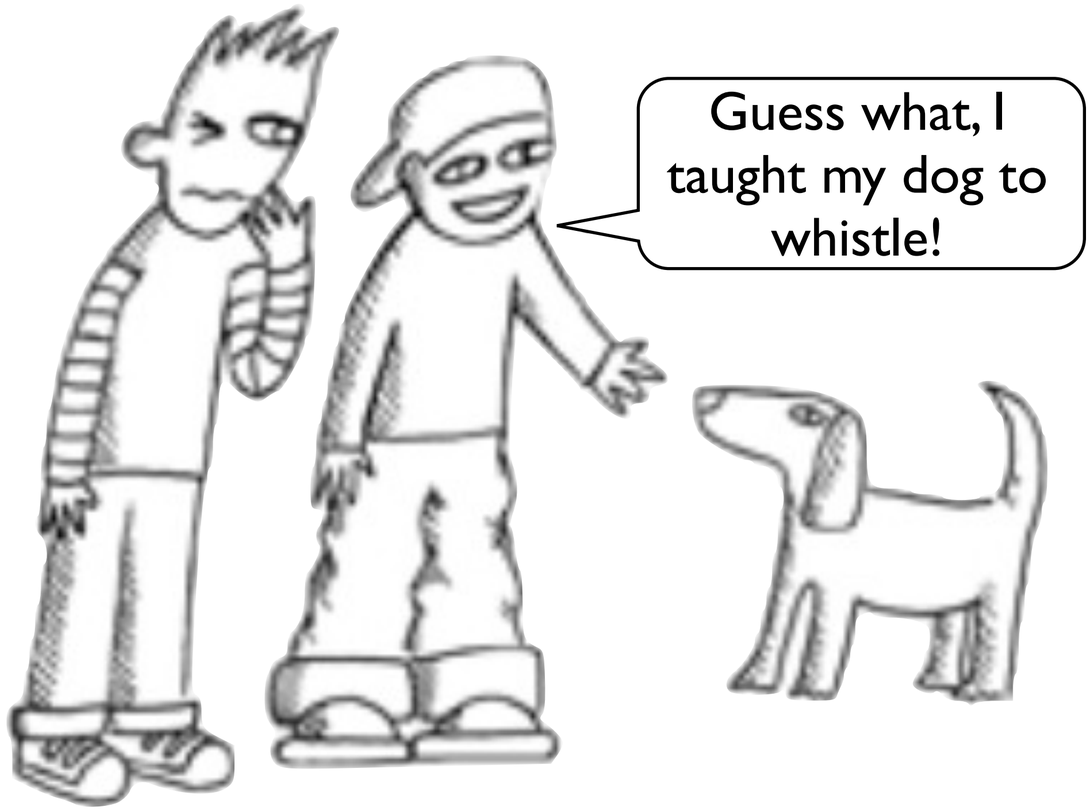
Why is research important?

Give examples of student research

New approach to intro bio as a model for other courses.

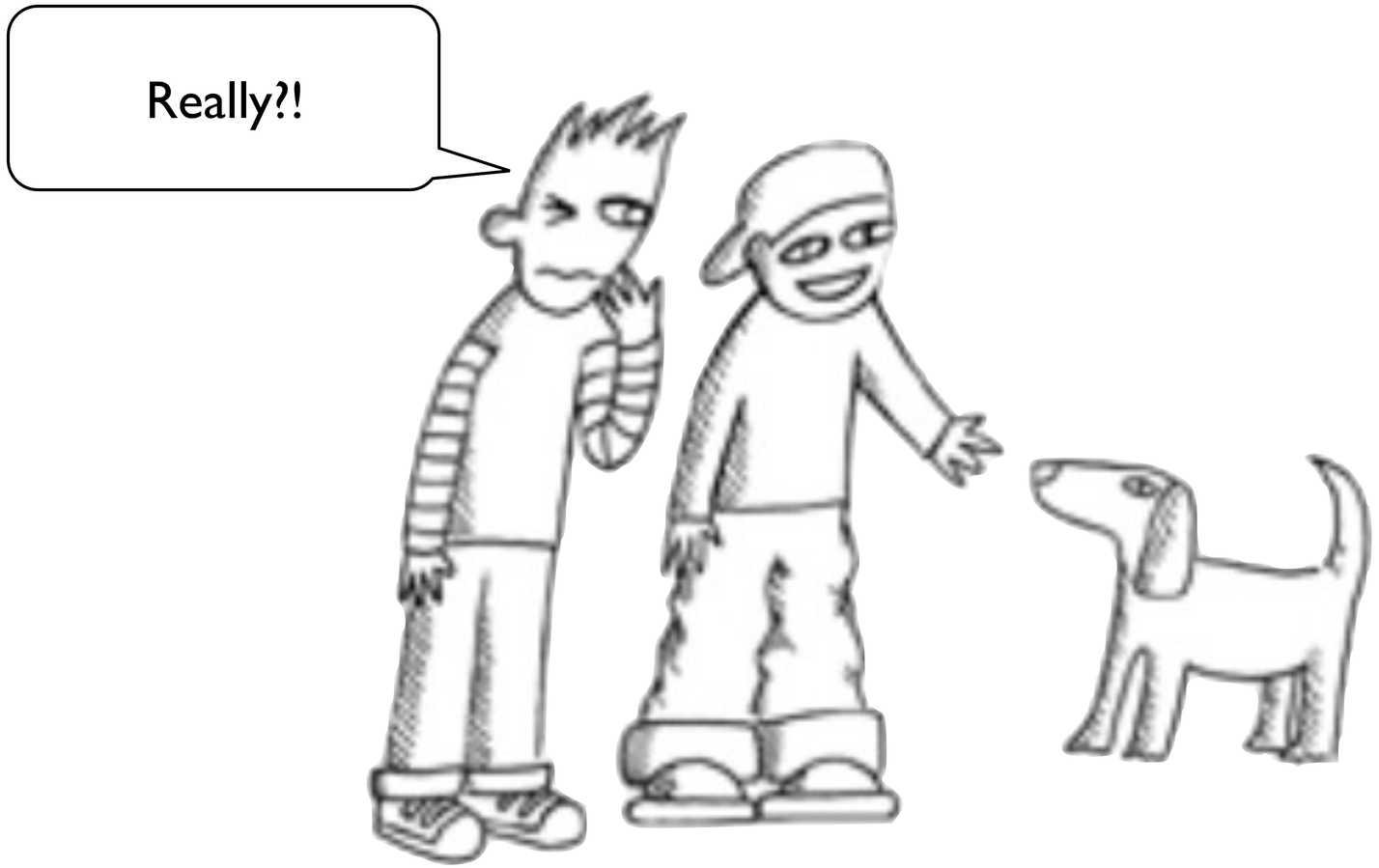
What does it take to become educated?

Teaching *vs* Learning



http://thegoodpeople.se/blog/?p=208

Teaching *vs* Learning



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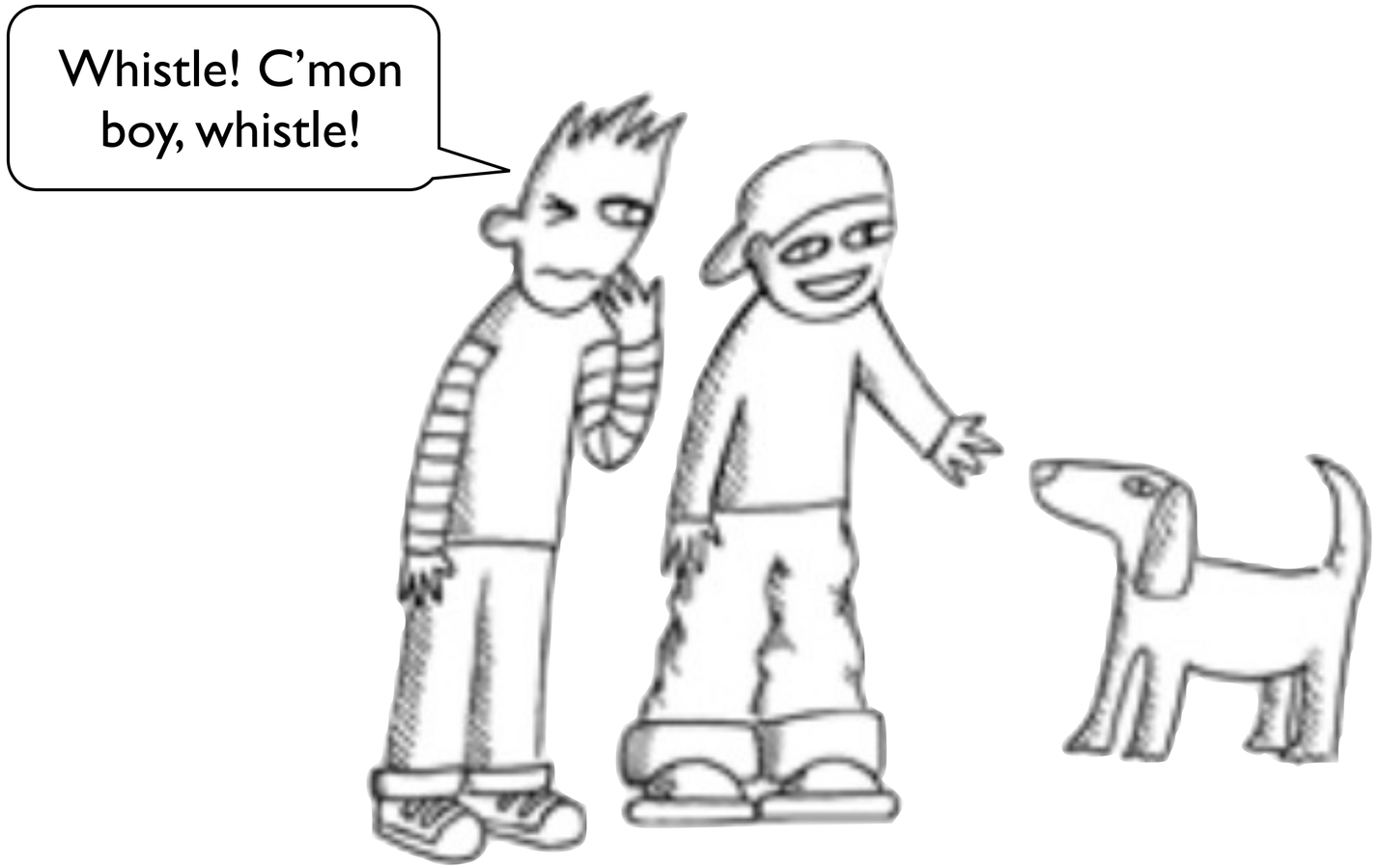

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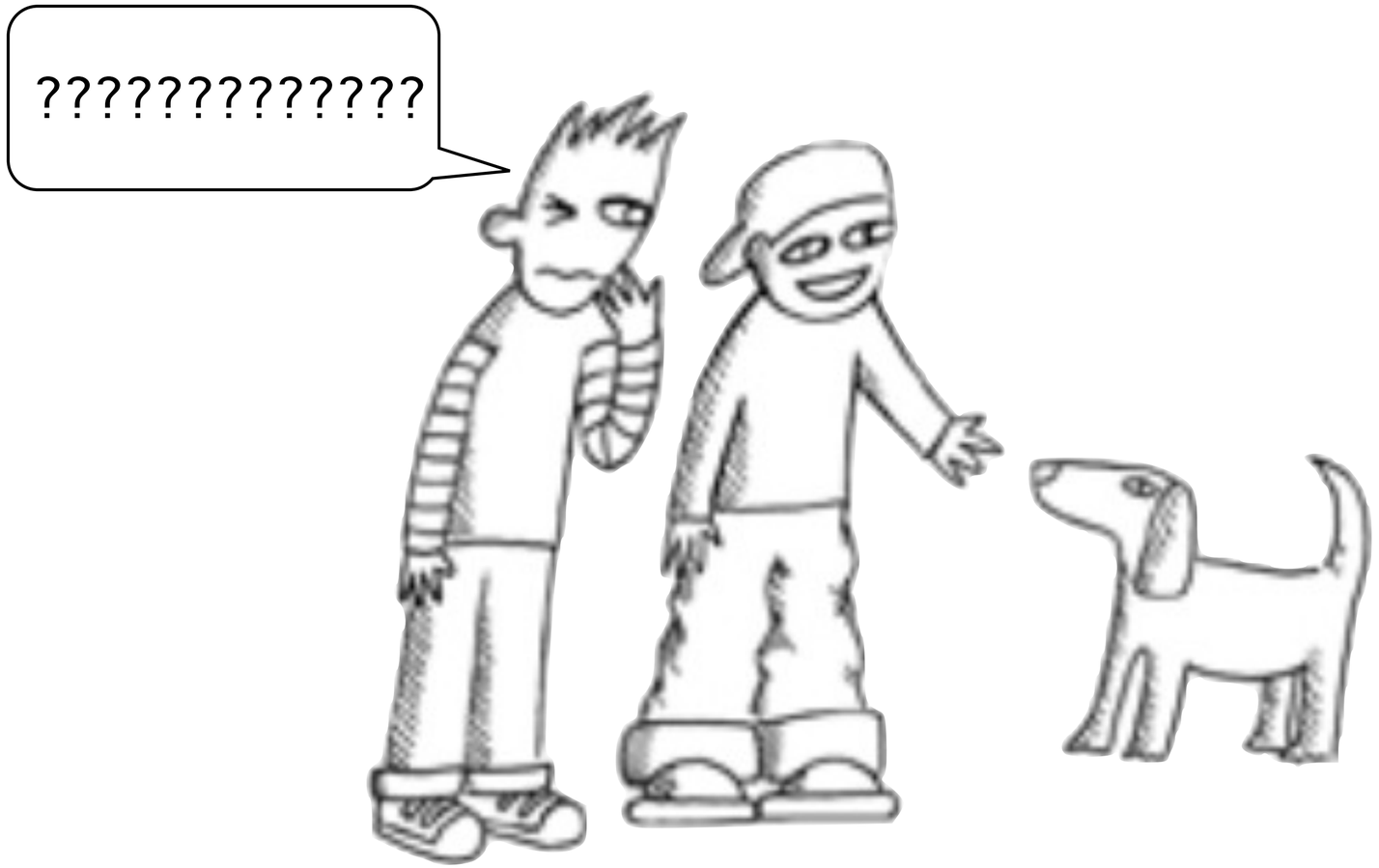

Teaching *vs* Learning

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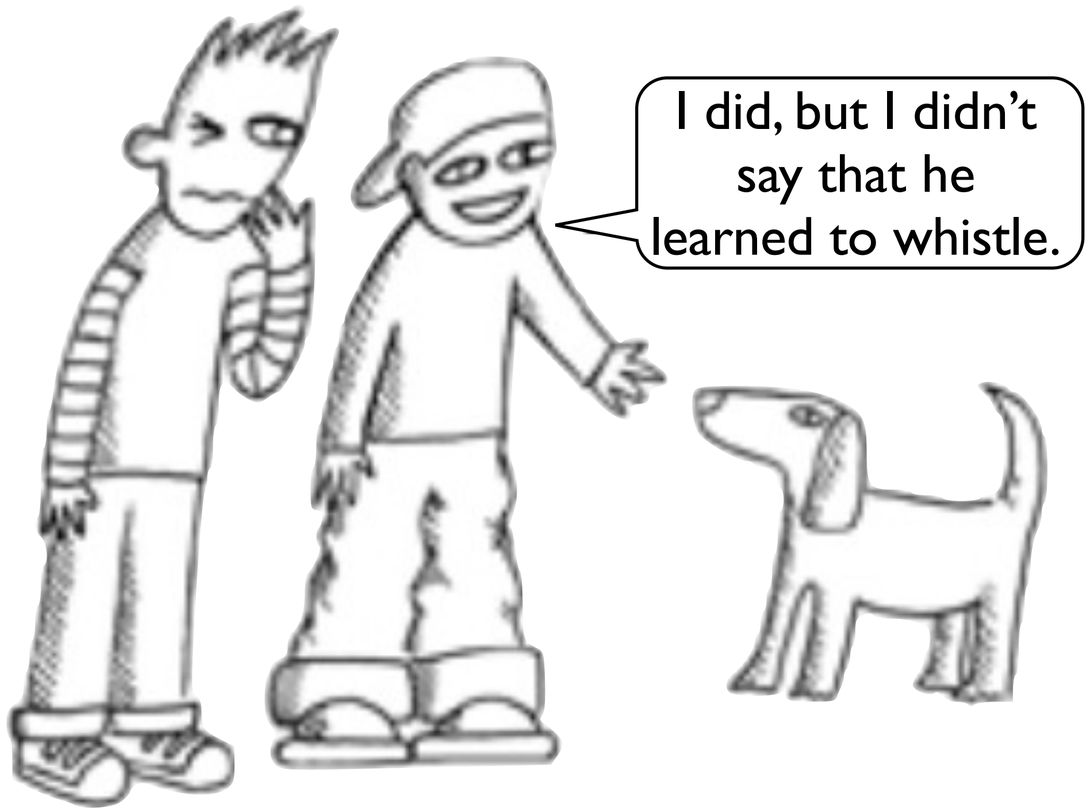


Why did you come to college?

http://www.creditnet.com/blog/miscellaneous/how-to-manage-student-loans

Are you training for one job?

"Number of Jobs Held, Labor Market Activity, and Earnings Growth among the Youngest Baby Boomers: Results from a Longitudinal Survey"

http://www.officefurniturepics.com/tag/used-office-cubicles/

Are you training for one job?

Bureau of Labor Statistics, 2008

- born in the years 1957 to 1964
- jobs from age 18 to age 42
- average of 10.8 jobs
- more jobs ages 18 - 24 than 36 - 42
- 23% held at least 15 jobs
- 14% held zero to four jobs

"Number of Jobs Held, Labor Market Activity, and Earnings Growth among the Youngest Baby Boomers: Results from a Longitudinal Survey"

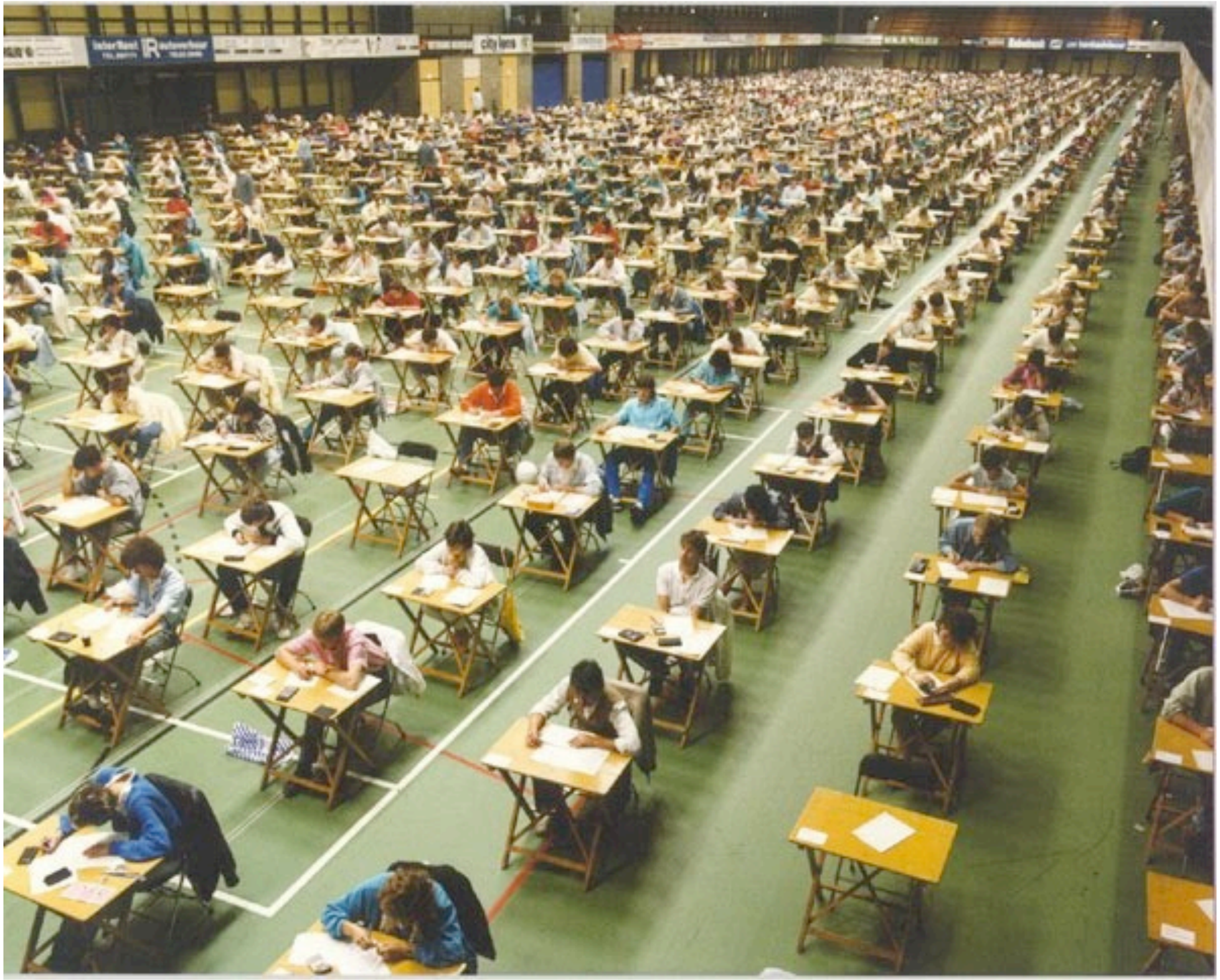
No one *gives* you an education.

If you want one, you have to take it.

John Taylor Gotto

http://nccueagles.yuku.com/topic/6441#.T1o5-pjufqE

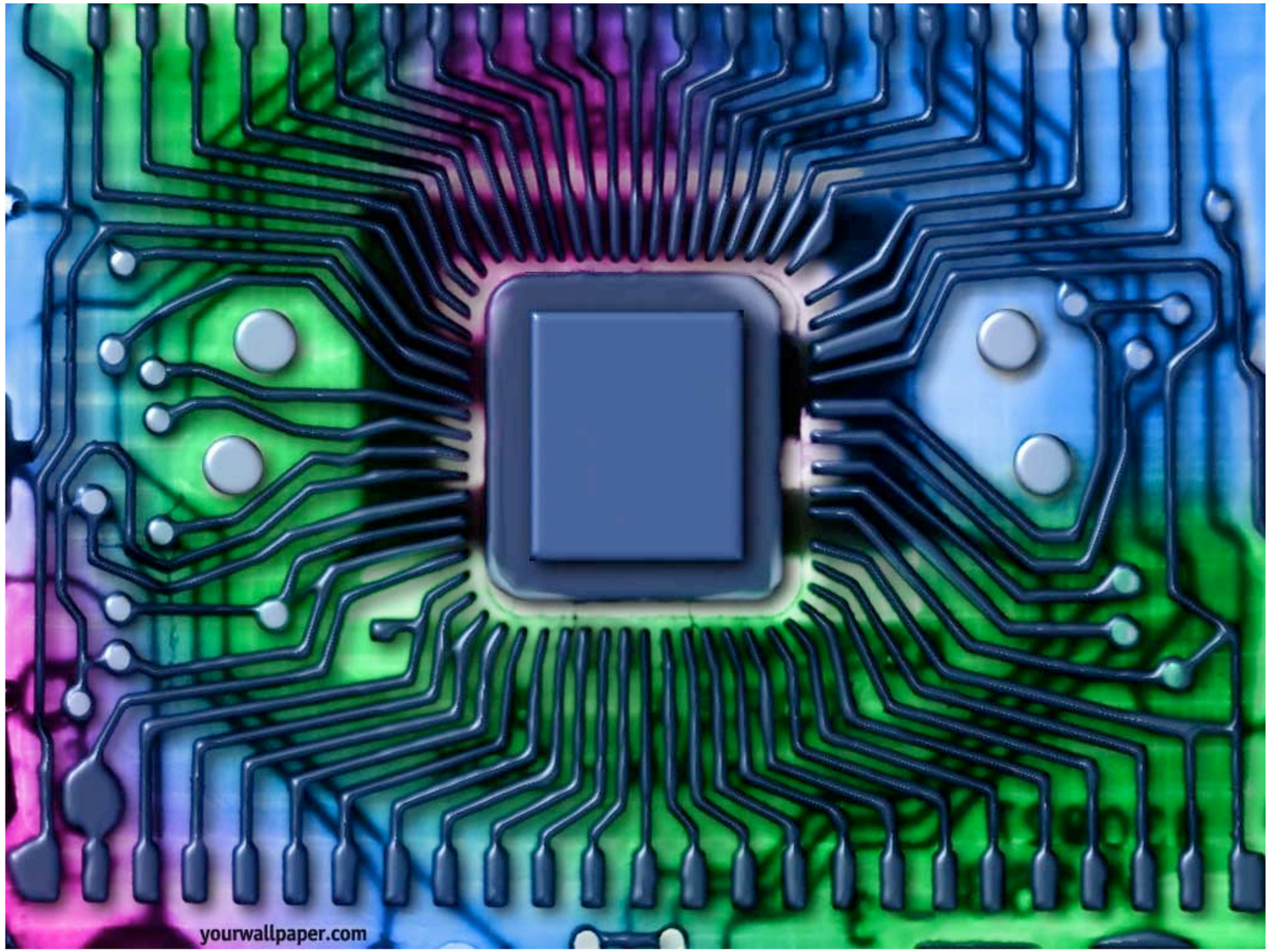
Describe the best learning experience you've had outside of schools.



http://confessionsofahighbrow.com/tag/standardized-tests/

List jobs that pay you to memorize information that you don't use….

Who thinks they can remember more factoids than a computer?

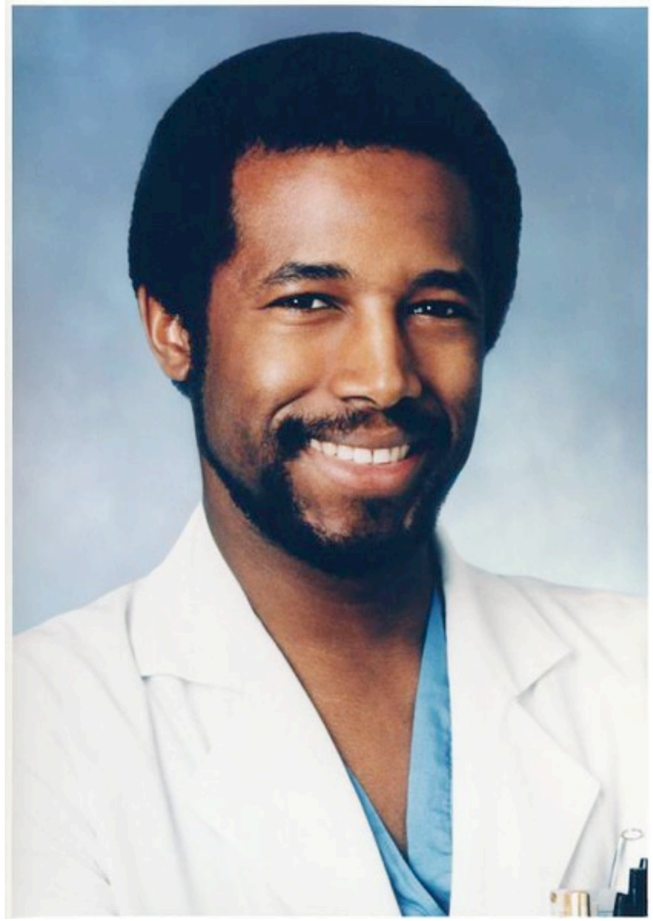


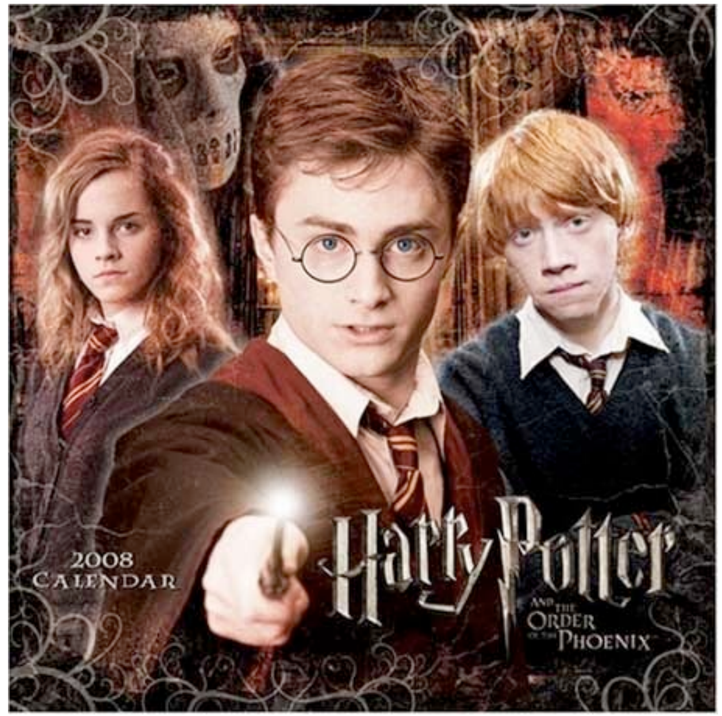
http://yourwallpaper.com/abstract/circuitboard01-1024.phtml

Why try to compete with computers by memorizing?

http://9to5mac.com/2011/12/08/apple-makes-its-2001-picks-for-the-app-store/

What can humans do that computers cannot?





Describe the best educational experience you've had in school.

Education is the only industry where customers never complain when they get less product for their money.

Percent Americans 25+ with Bachelor's Degree

30.4 % overall

14.1% Hispanics

19.9% African Americans

34.0% Caucasians

http://www.nytimes.com/2012/02/24/education/census-finds-bachelors-degrees-at-record-level.html

Average Annual Earnings Workers 18+

advanced degree	$74,602
bachelors degrees	$51,206
high school diploma	$27,915
no high school diploma	$18,734.

http://usgovinfo.about.com/od/censusandstatistics/a/collegepays.htm

Who is John Taylor Gotto?

(prize for first correct answer)

Why is it that you can look up this,
but if you hit a word in class,
you ask the teacher what it means?

Take charge of your own education.

Raise your hand if you learned a lot by doing your research.

Raise your hand if you learned a lot by doing your research.

How many tests did you take on your research?

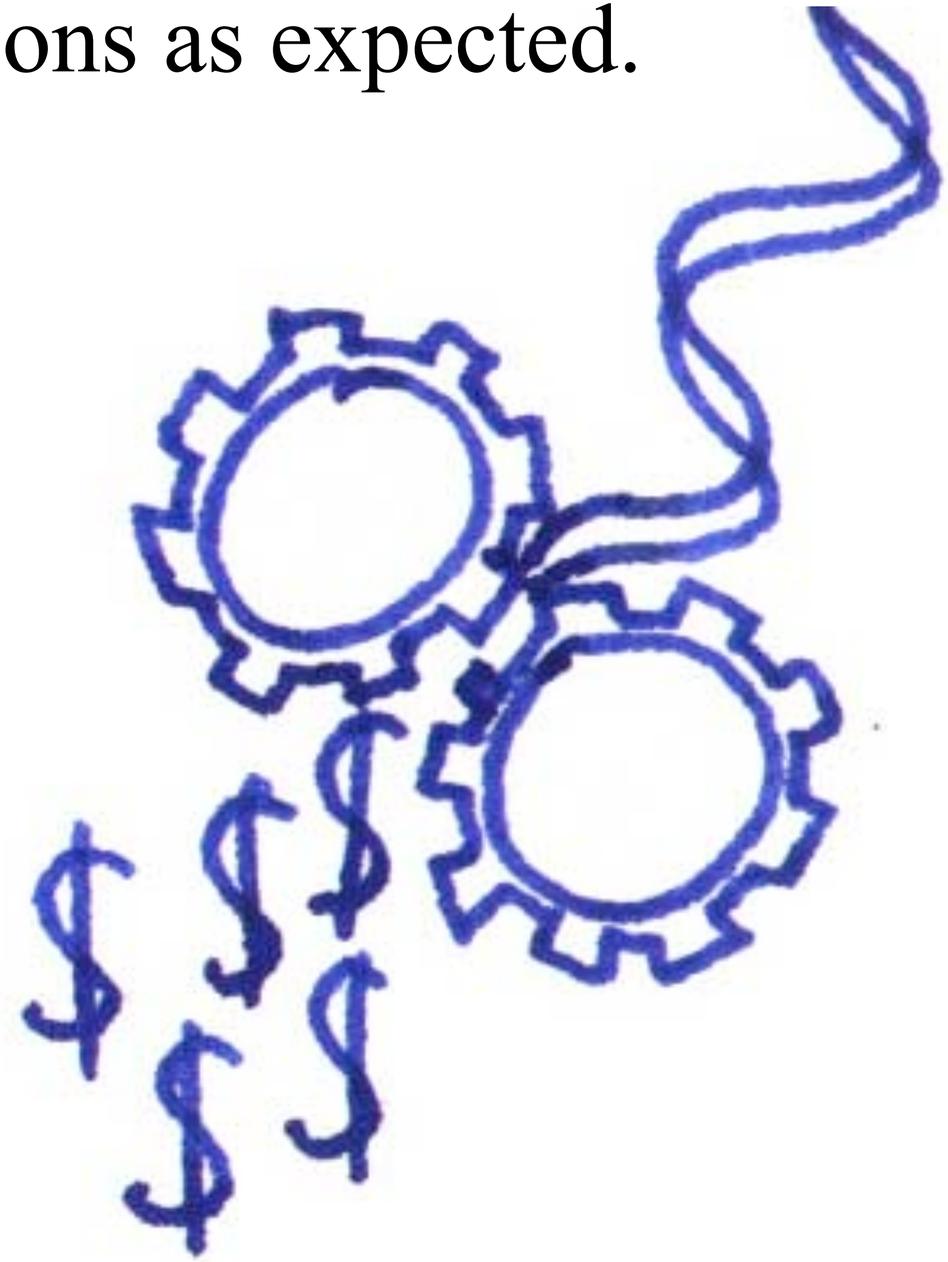
How many times did you have to memorize factoids?

Why should course work be any different than research?

Synthetic Biology Research at Davidson College

Synthetic Biology: Win-Win

Win #1: your design functions as expected.



Synthetic Biology: Win-Win Research

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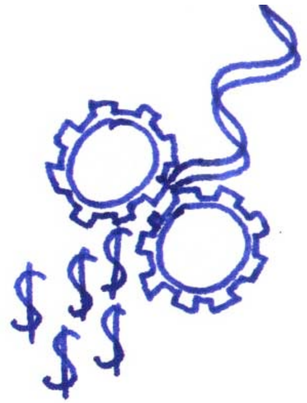
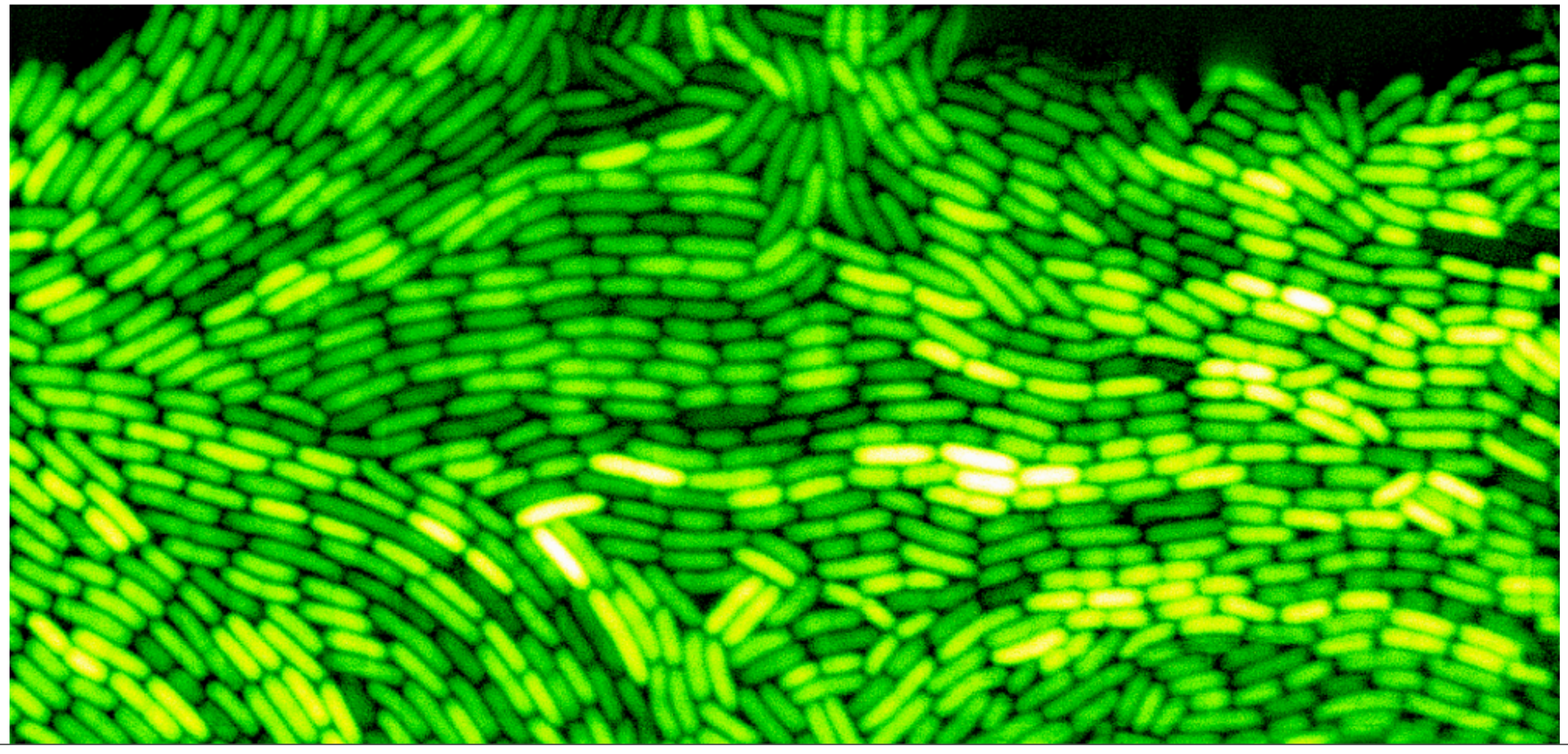
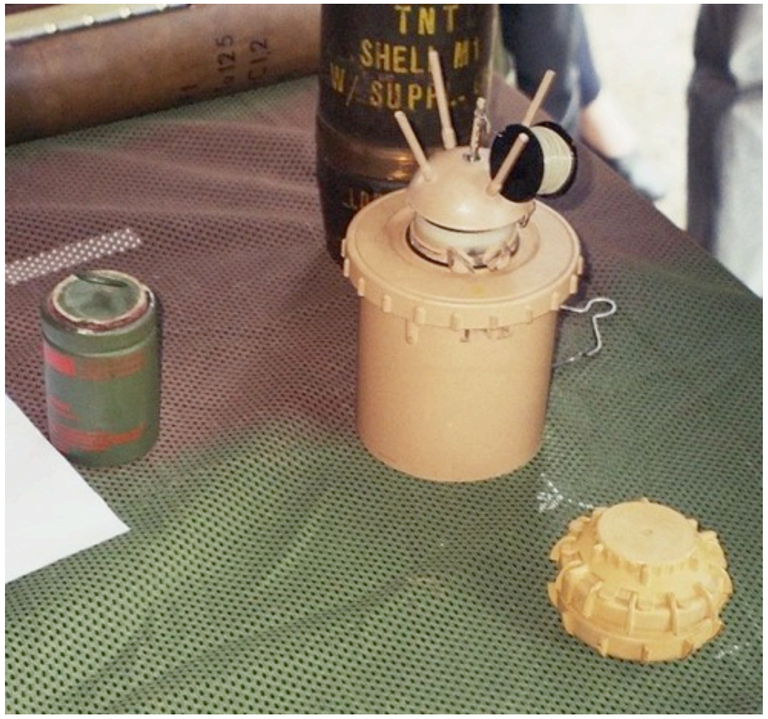


Win #2: your design fails but you uncover basic biology

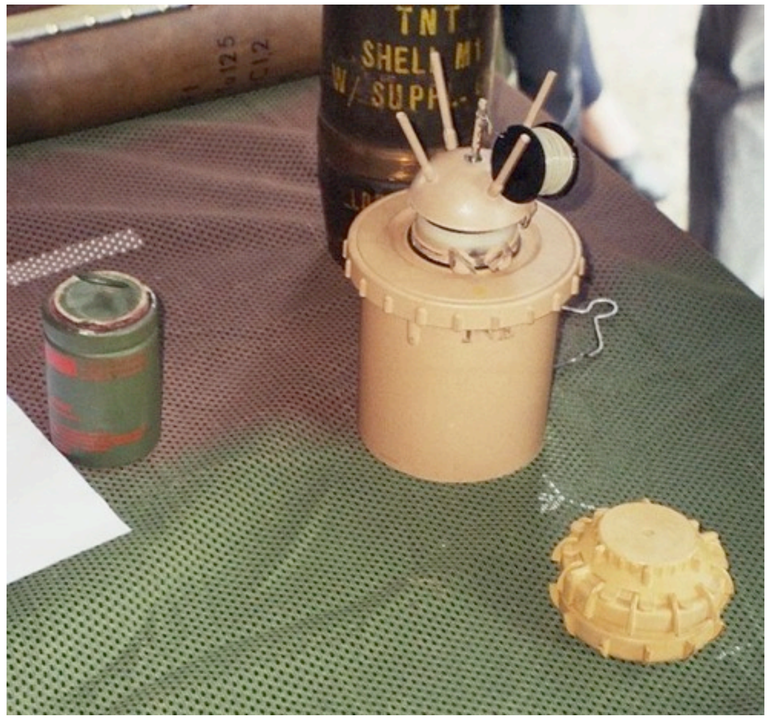


Real World Applications of Synthetic Biology

Land Mine Detection



Land Mine Detection



Synthetic Biology
Land Mine Detection

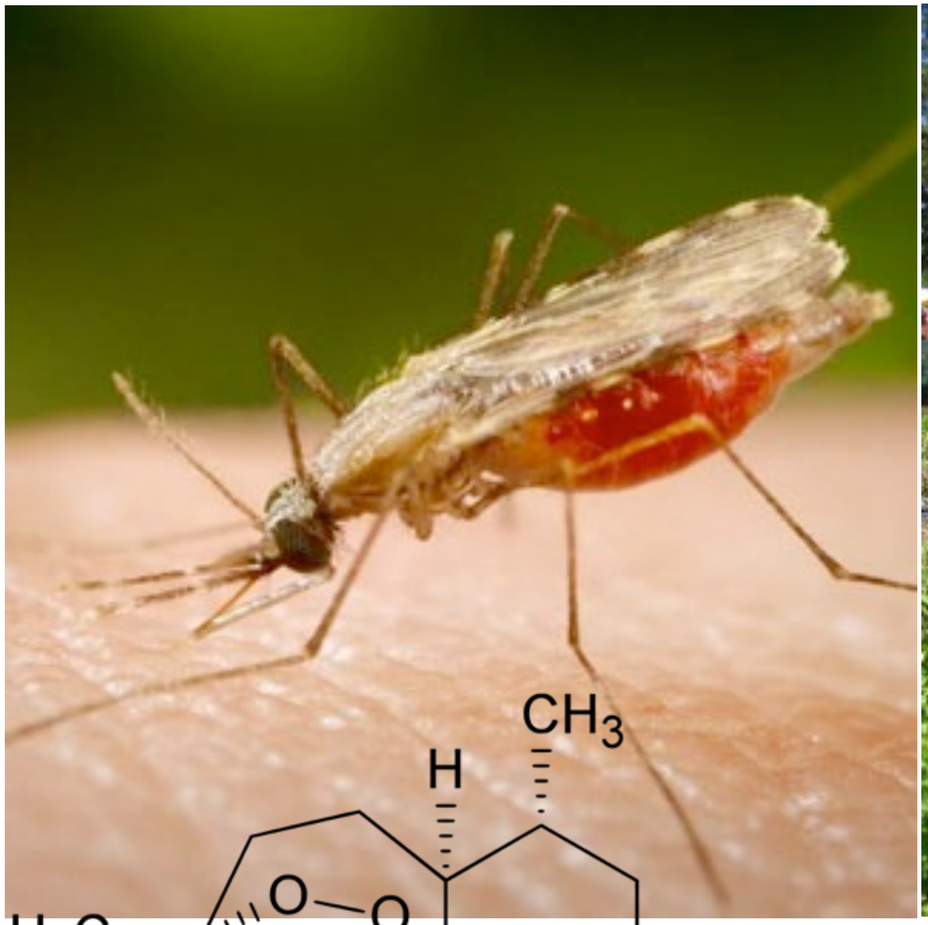
WARNING SIGN: The bioengineered Thales cress turns red when exposed to a mine byproduct.

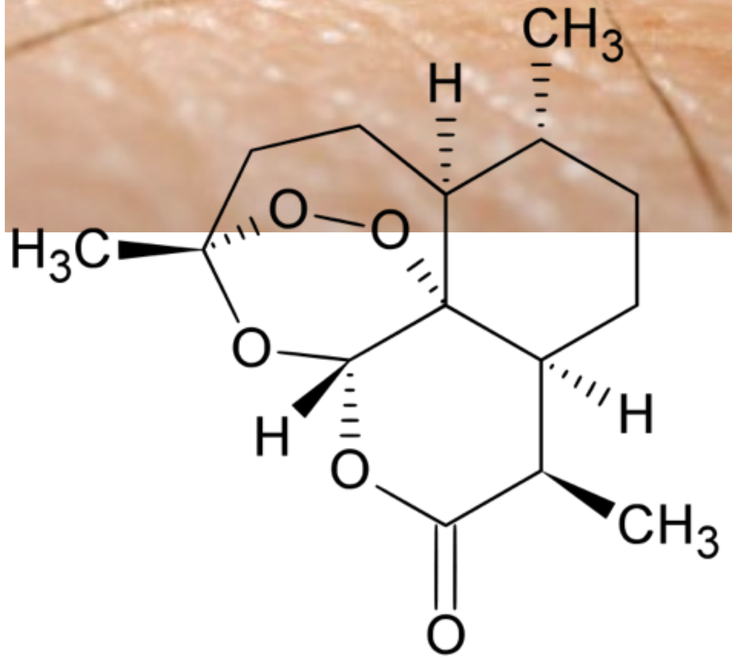
COURTESY OF ARESA BIODETECTION

New weed may flag land mines

By John K. Borchardt | *Contributor to The Christian Science Monitor*

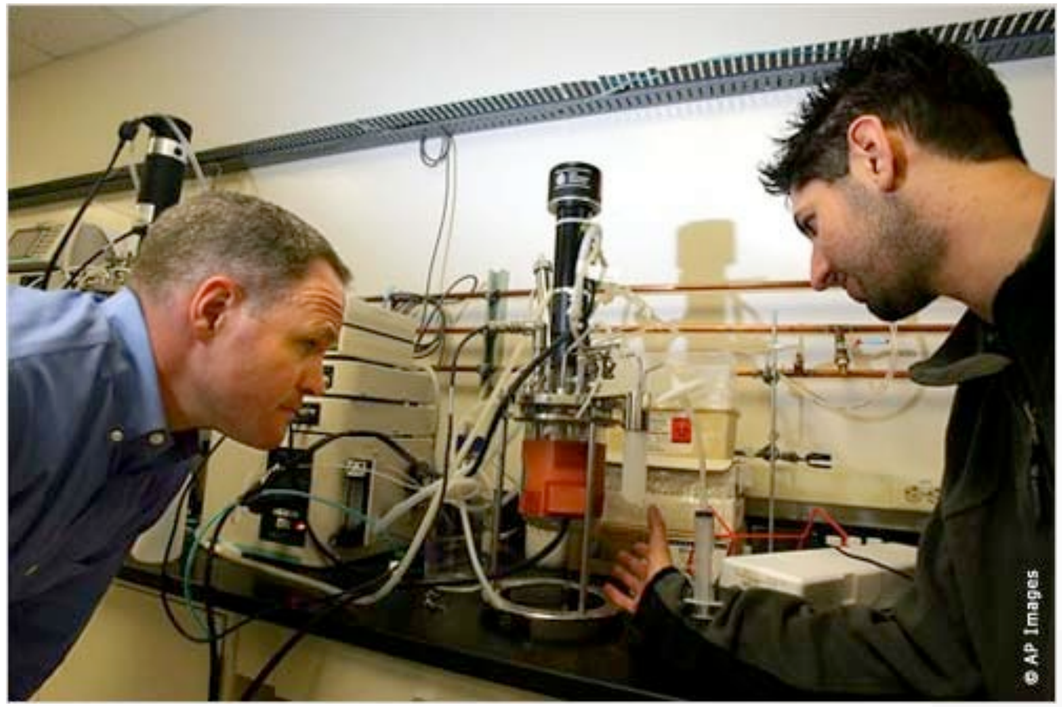
Production of Medicines

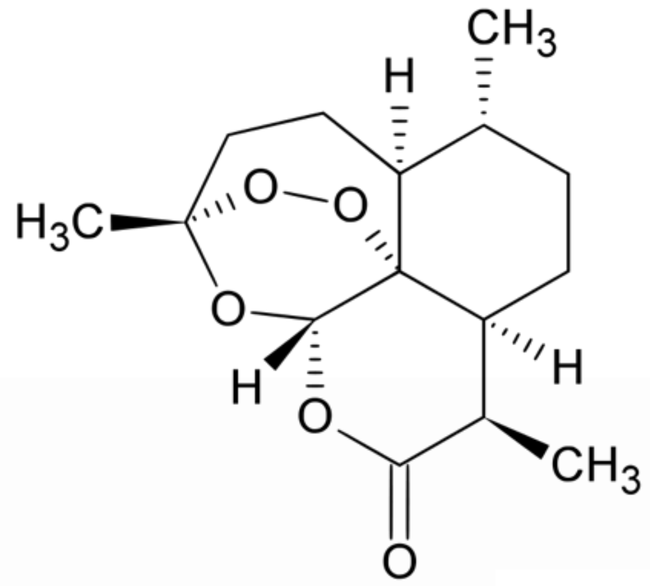




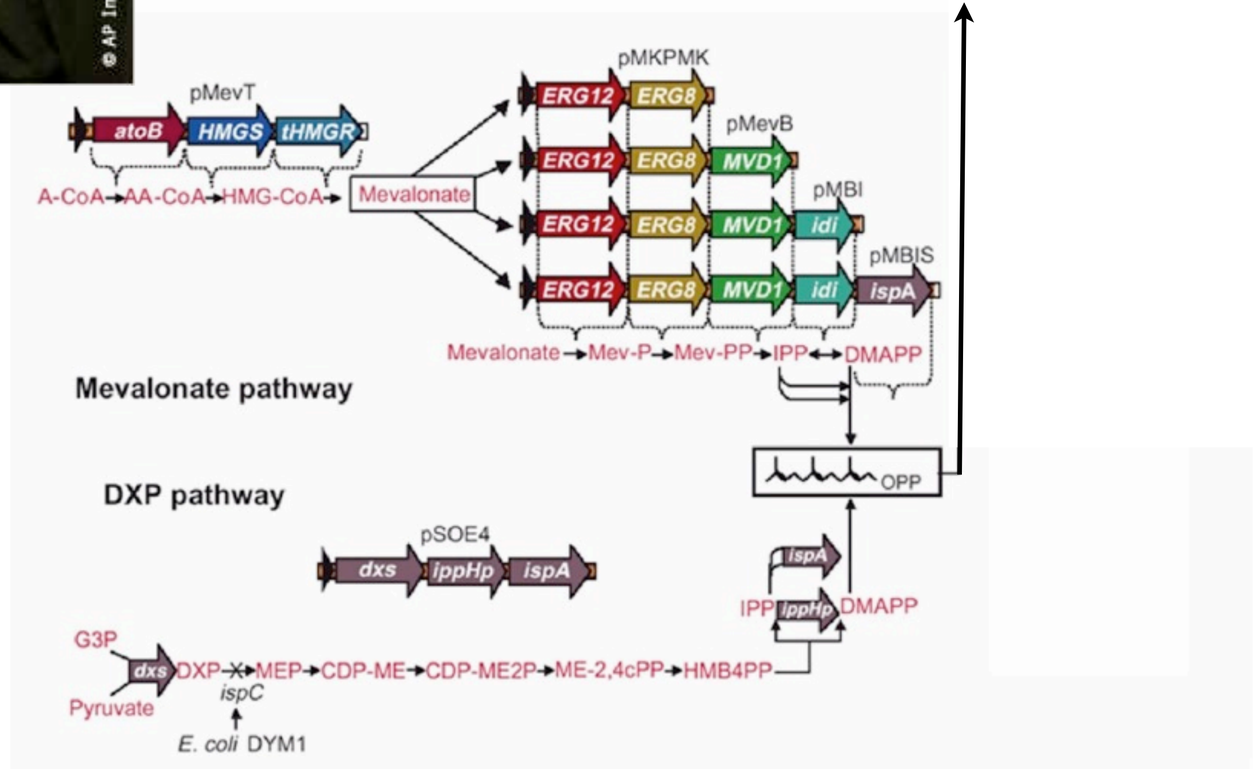
$1 per pill

Production of Medicines

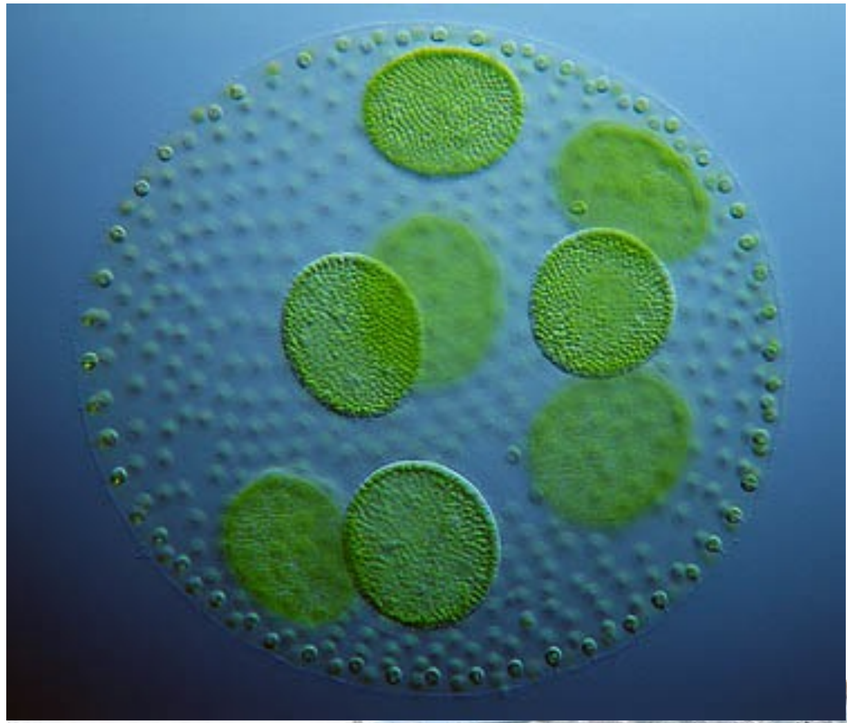




10¢ per pill



Biofuels from Algae



CO_2-neutral

1,000,000 gallons in 2008

Laurie Heyer, Todd Eckdahl & Jeff Poet

DAVIDSON

Discover Gold WESTERN

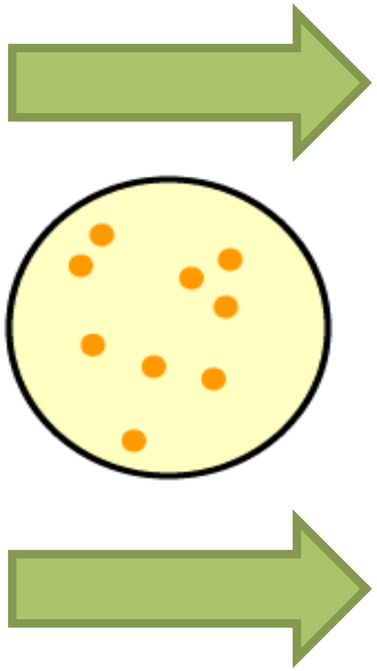
Building Bacterial Computers

Can we build a bacterial cryptographic hash function?

What is a hash function?

HGTf34$2

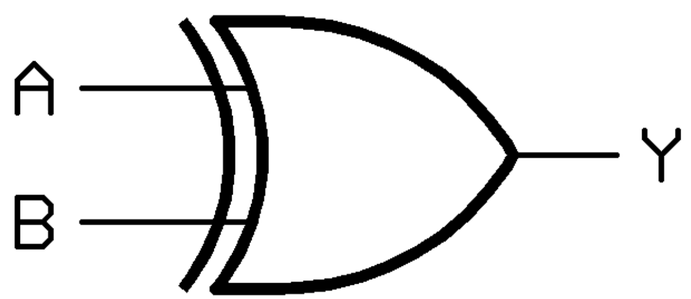
Can Bacteria Perform a Hash Function?



HGTf34$2

Use XOR Logic Gate for Hash Function

Input 1	Input 2	Output
0	0	0
0	1	1
1	0	1
1	1	0



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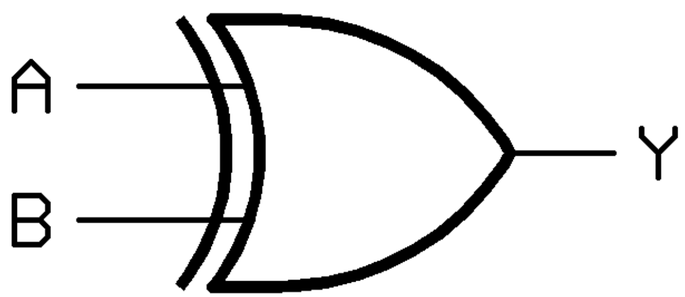

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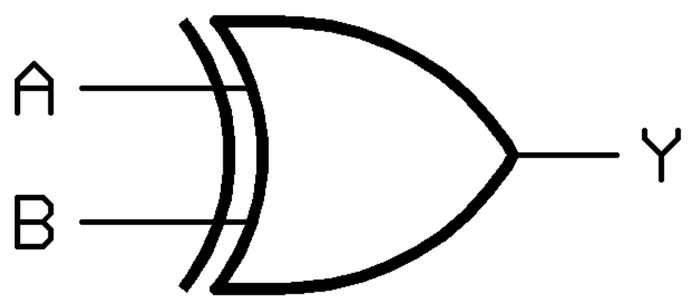
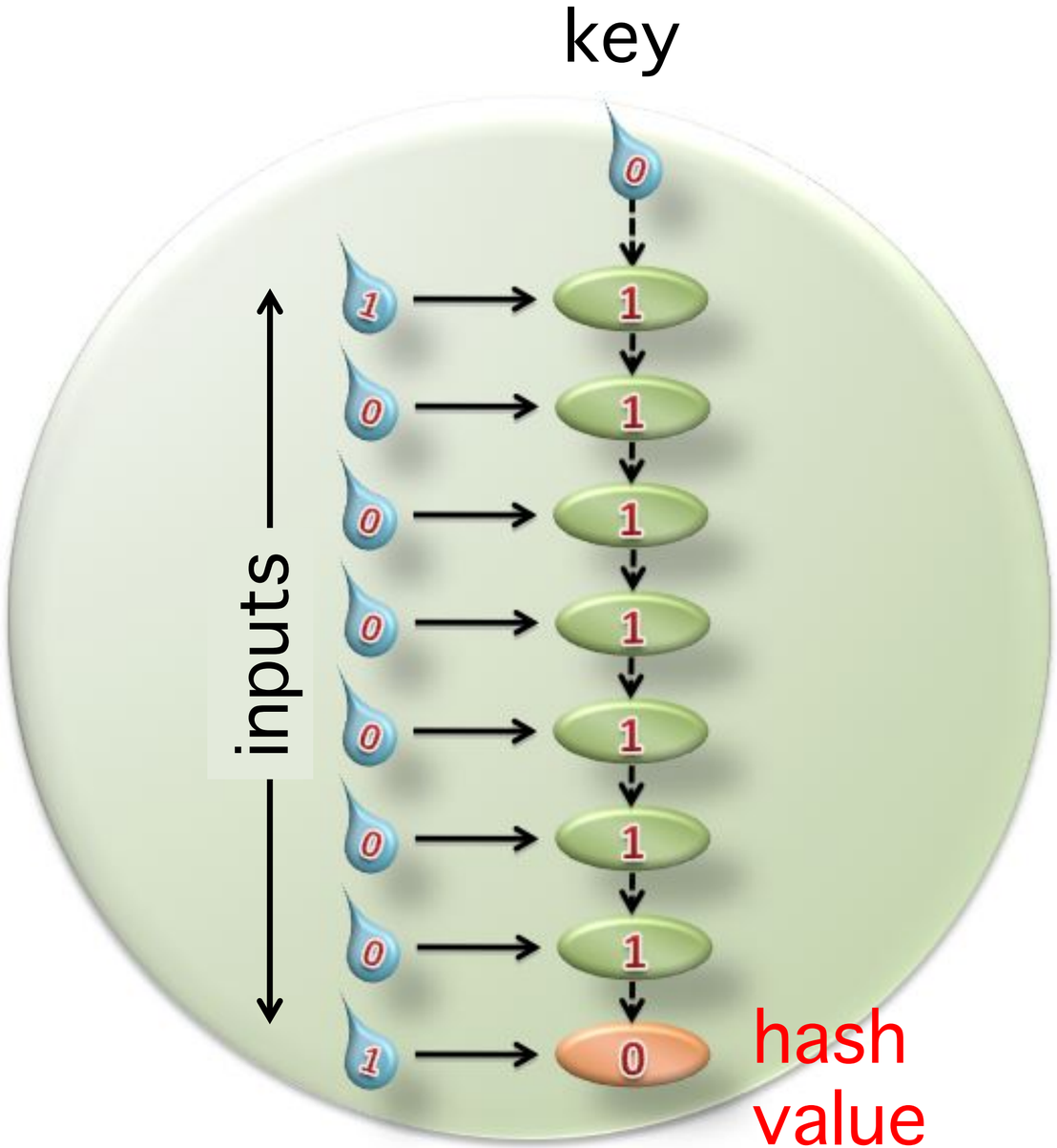


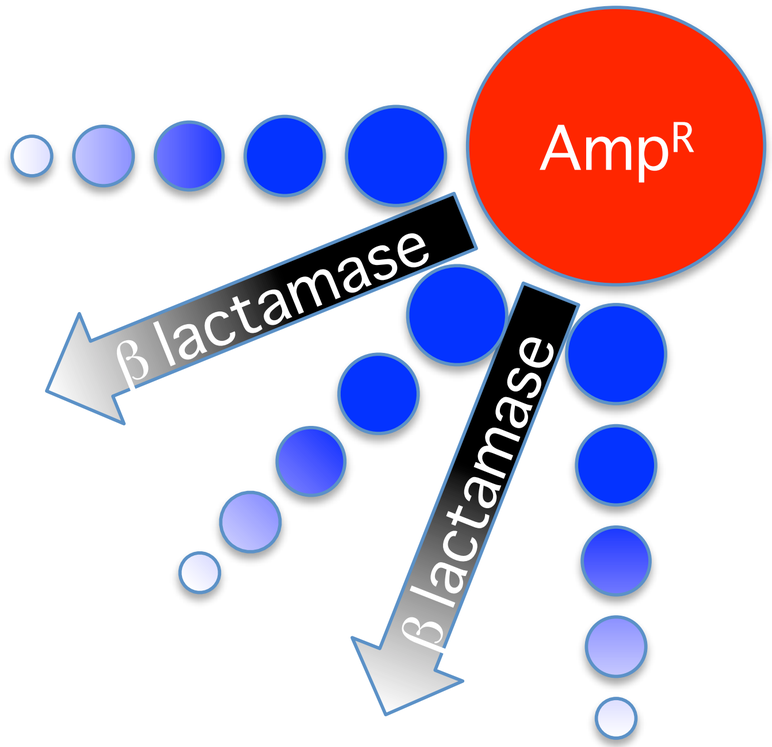
Design Linear Bacterial Hash Function

CAB = 010000001

HASH VALUE = 0



Time-Delayed Bacterial Growth



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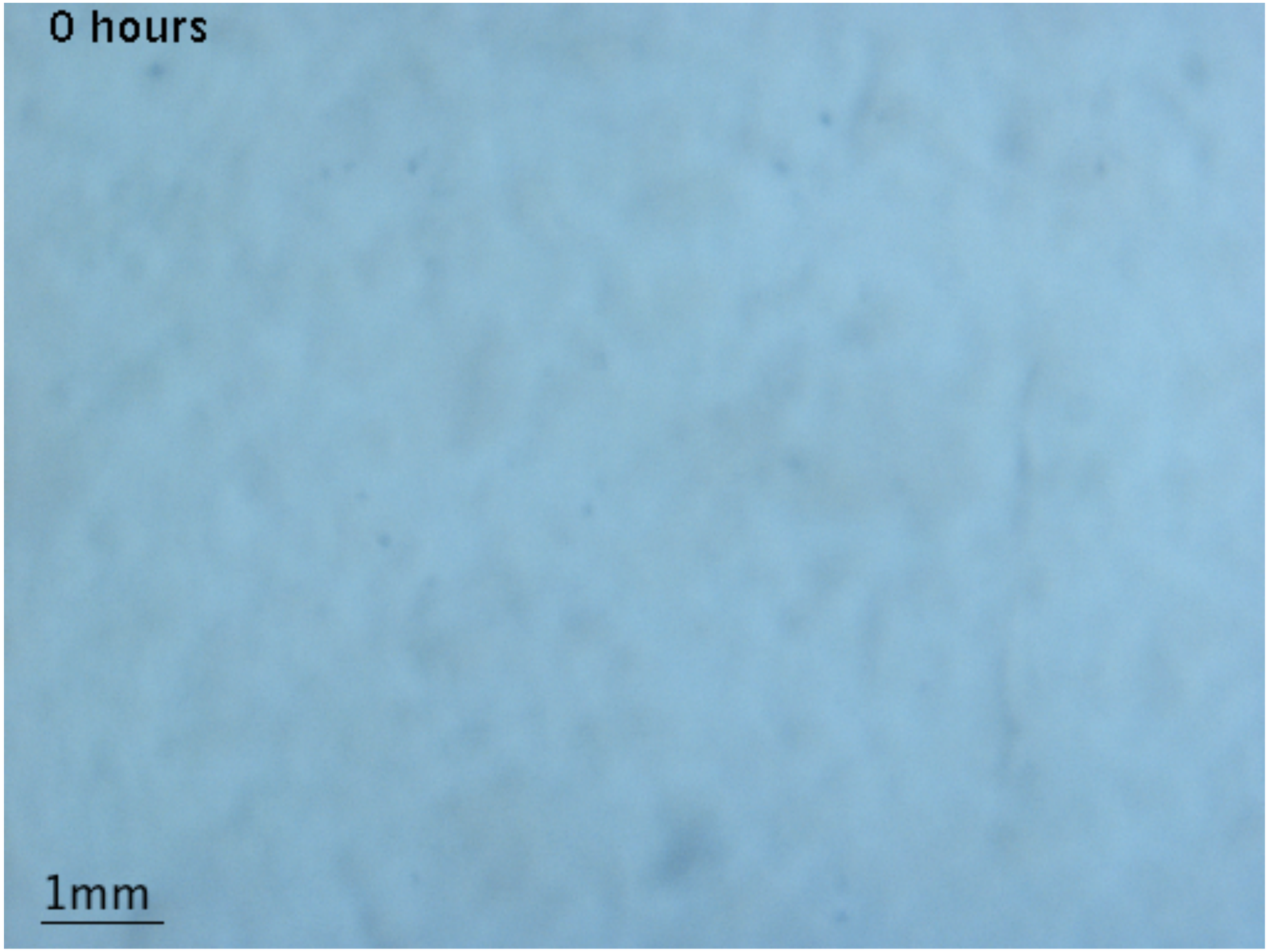
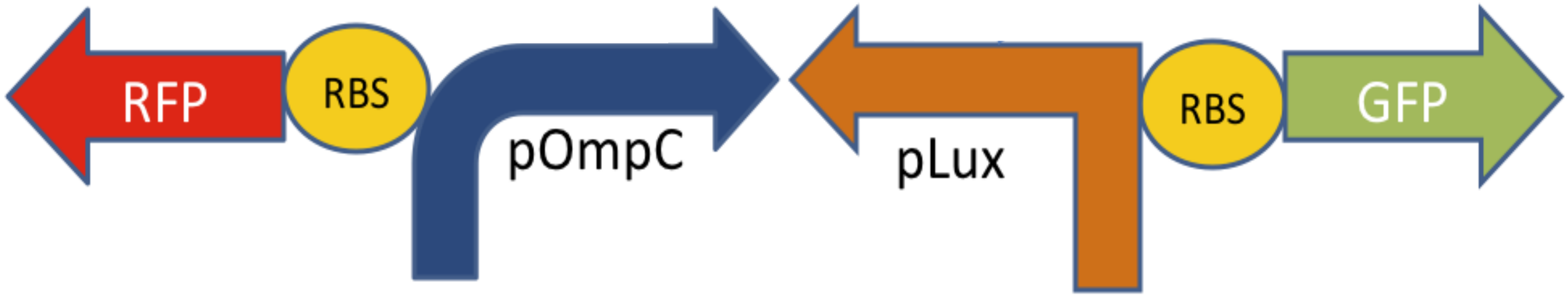


DNA-based XOR Logic Gate



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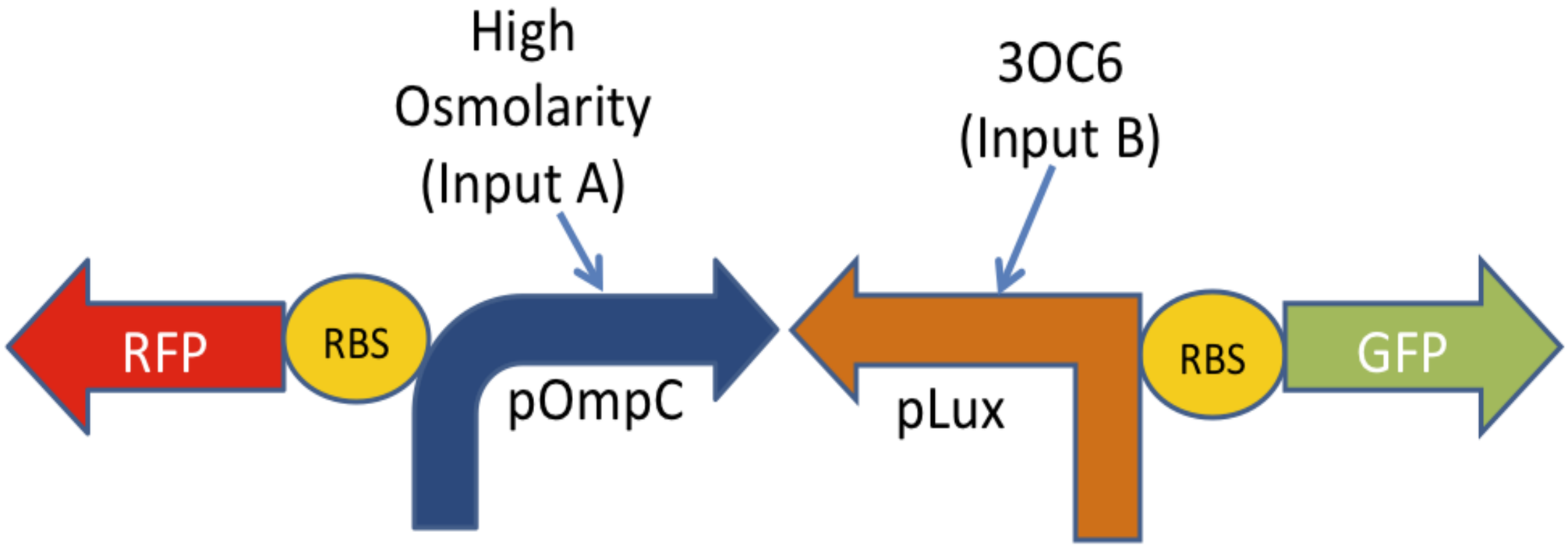

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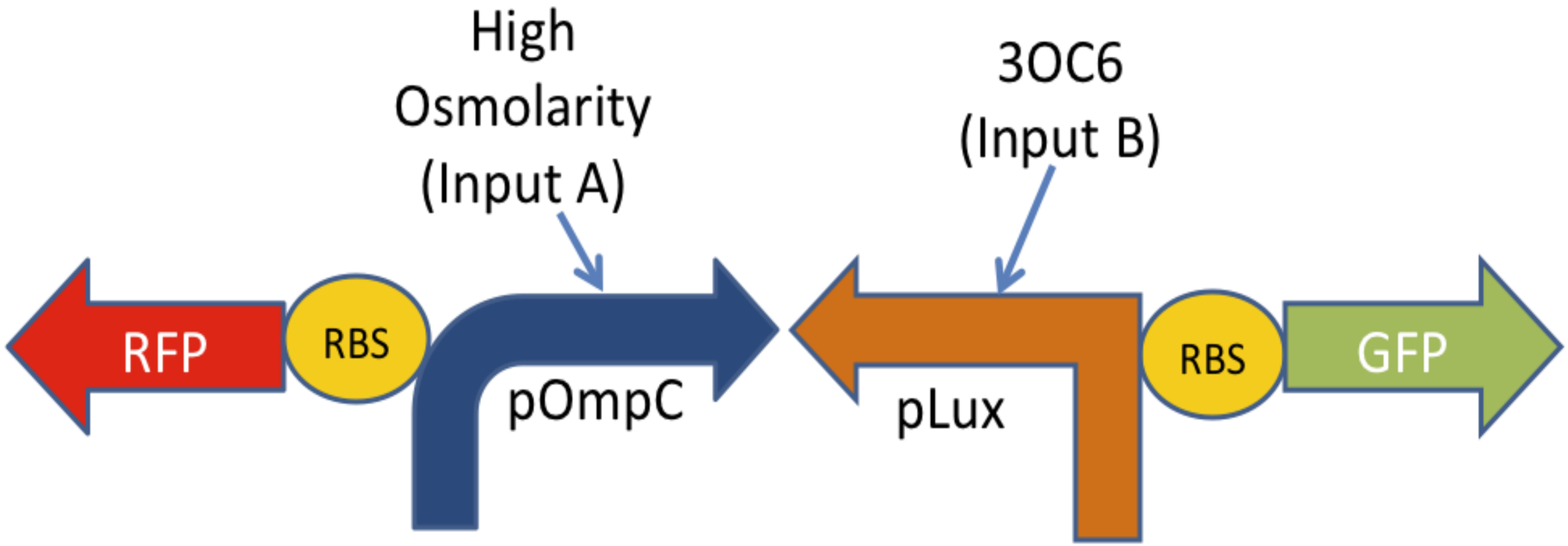
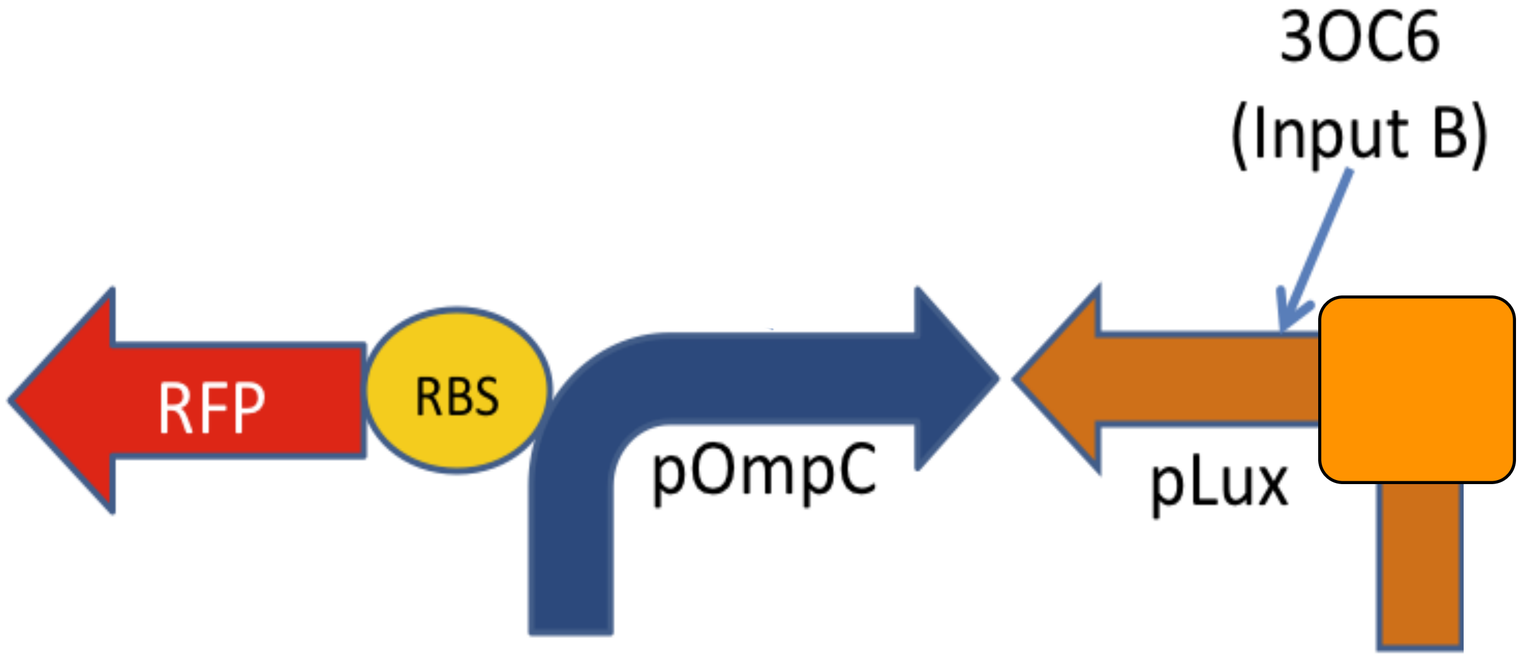


High Osmolarity (Input A)	3OC6 (Input B)	Fluorescence (Output)
0	0	0
1	0	1(GFP)
0	1	1(RFP)
1	1	0

DNA-based XOR Logic Gate



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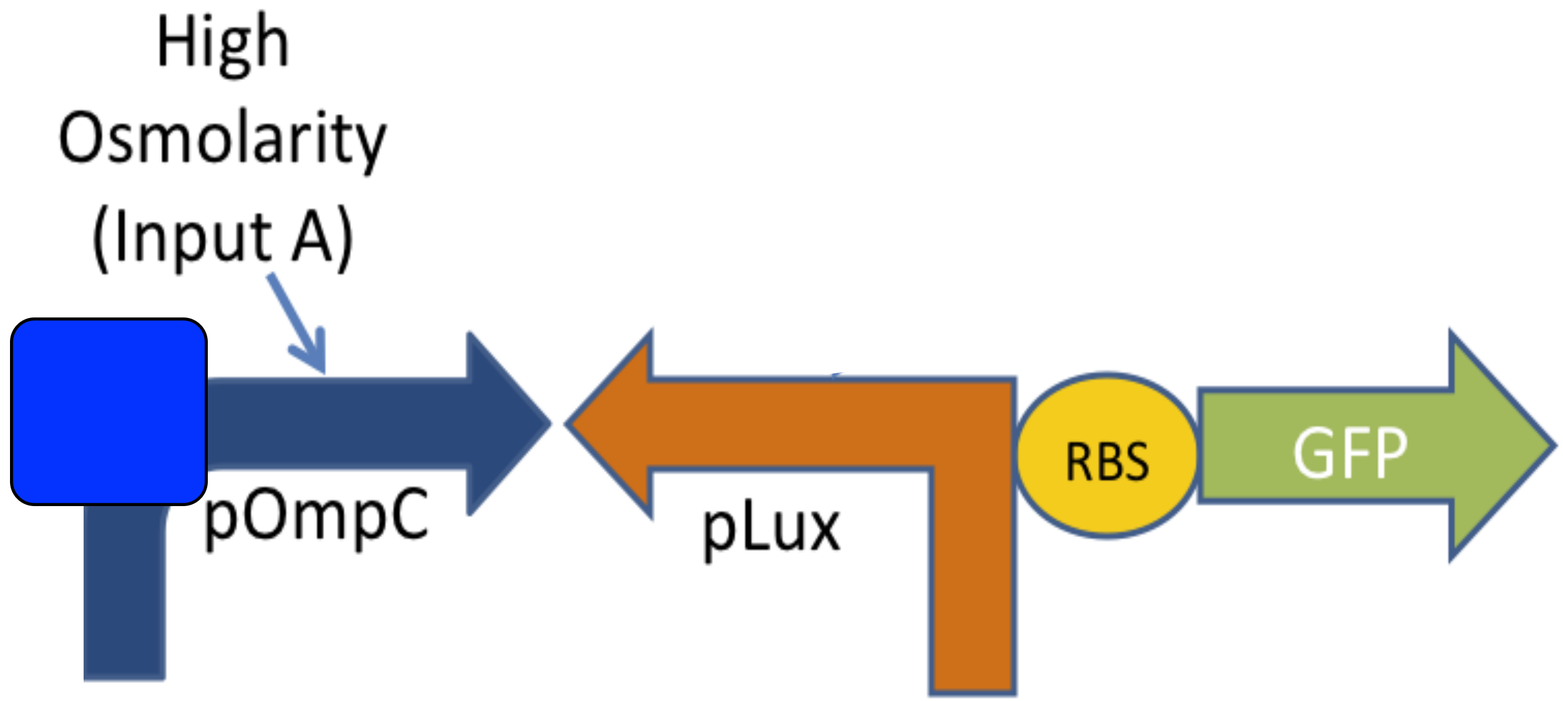

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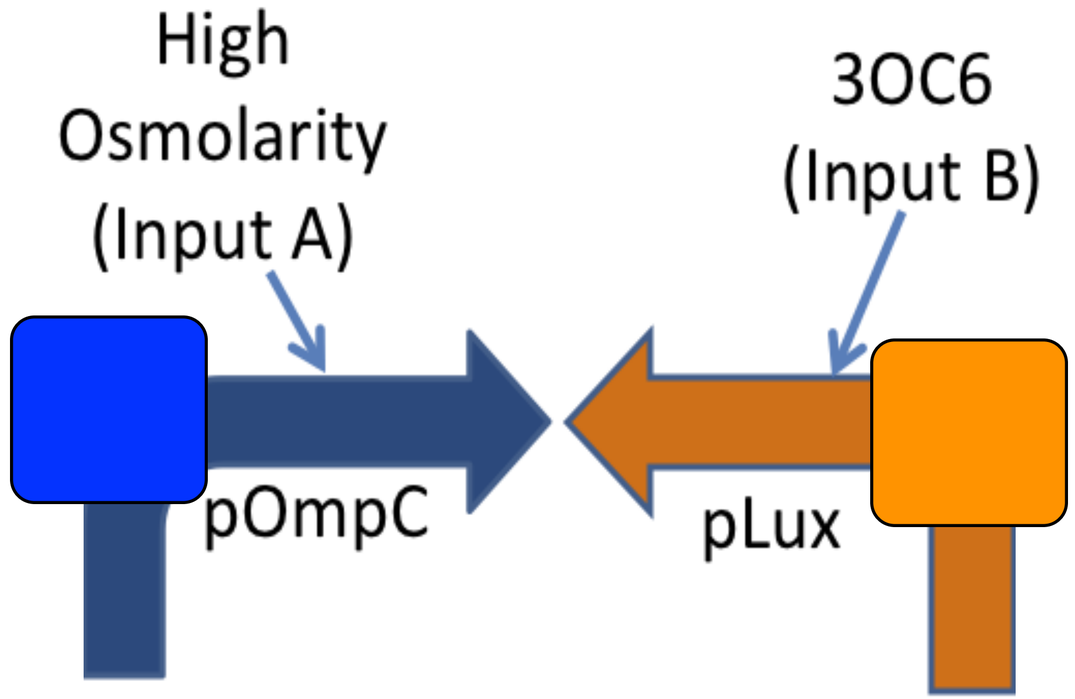

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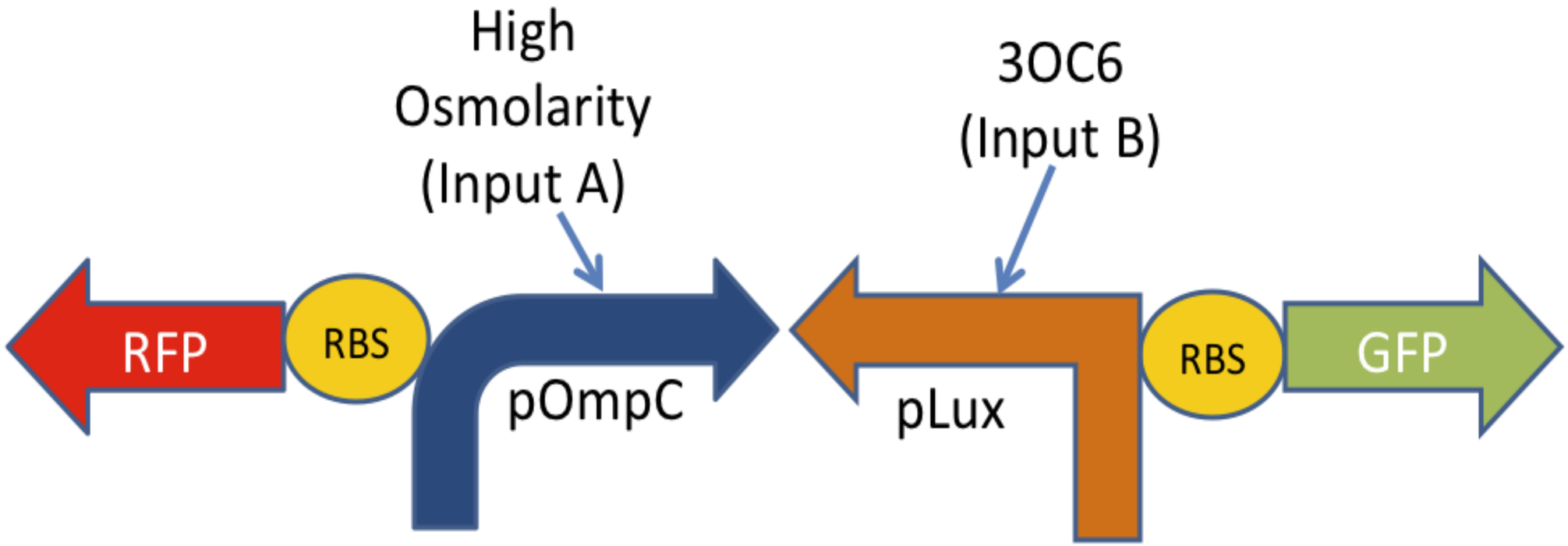

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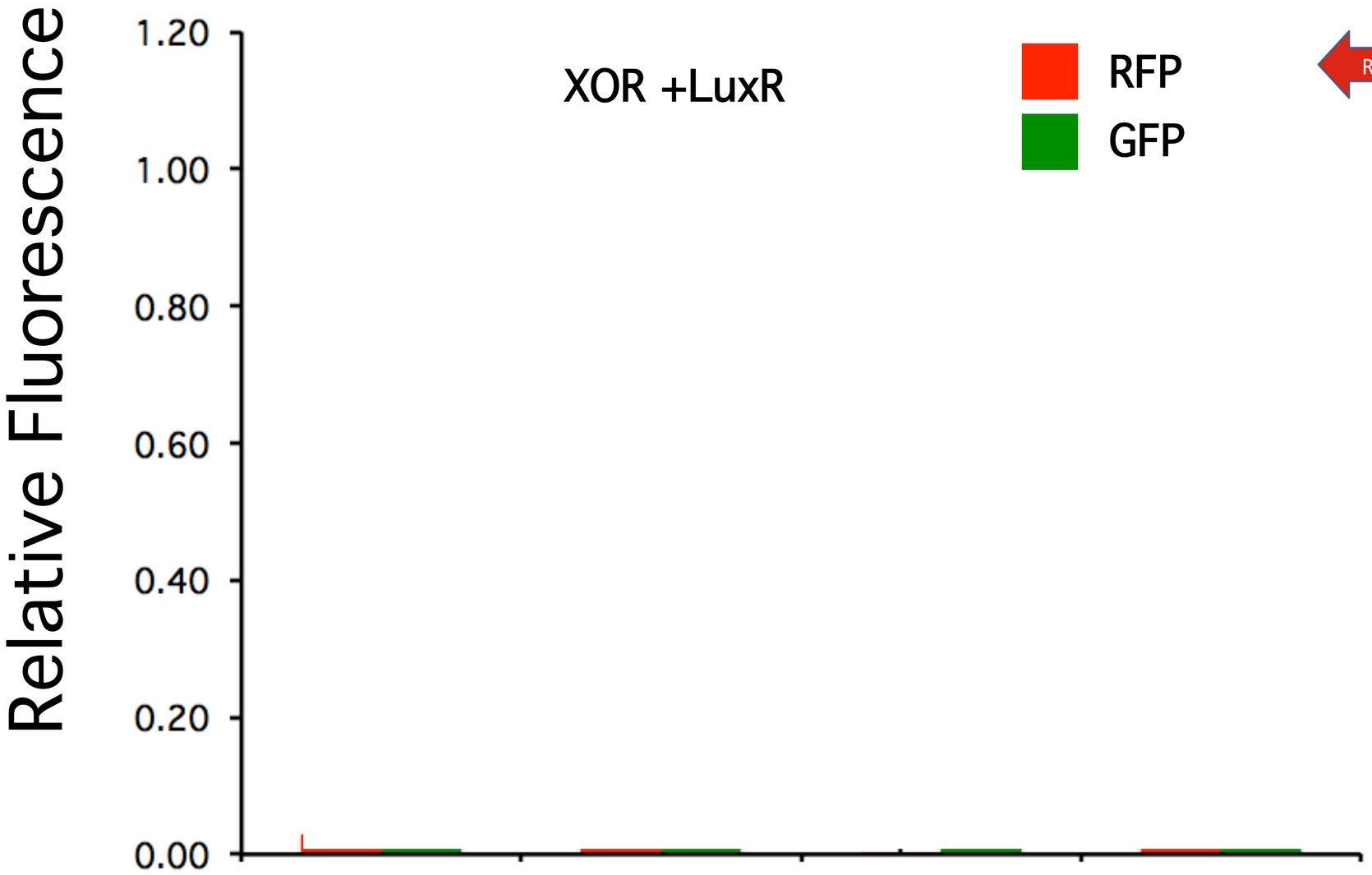
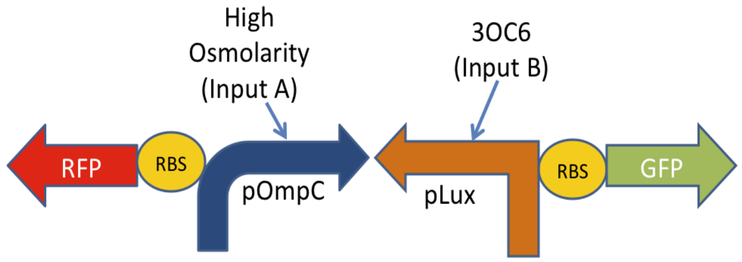
Testing Bacterial XOR Logic Gate



XOR +LuxR

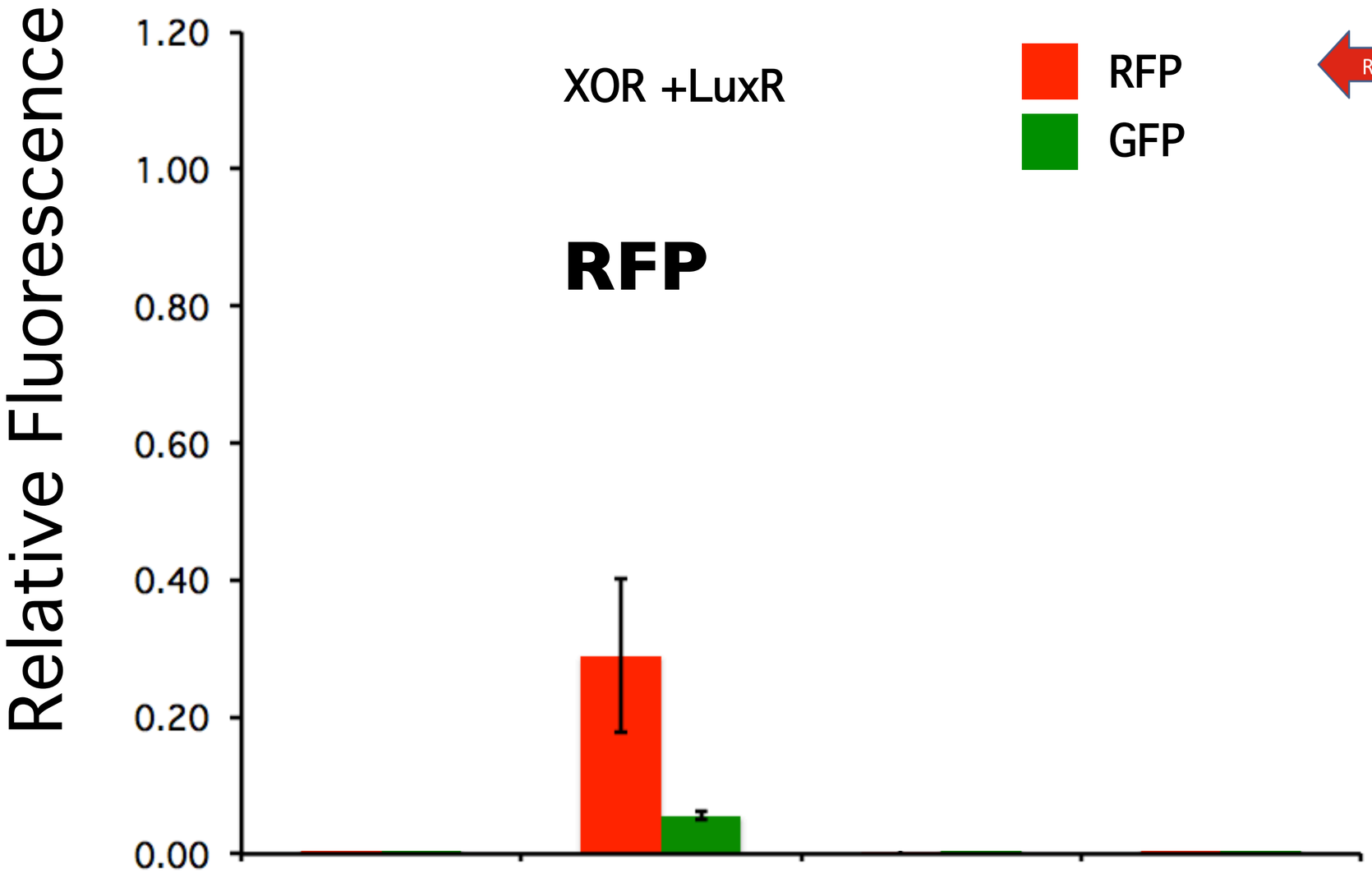
RFP

GFP



LB	-	-	+	+
3OC6	-	+	-	+

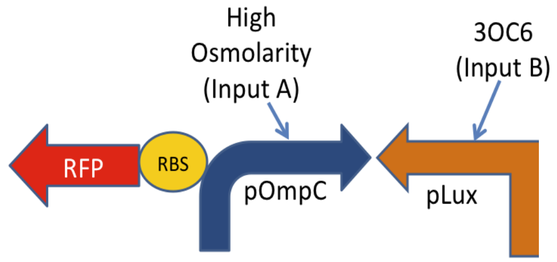
Testing Bacterial XOR Logic Gate



XOR +LuxR

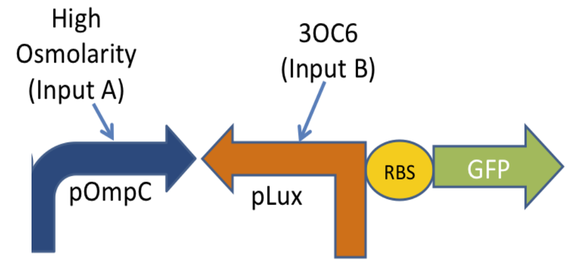
RFP

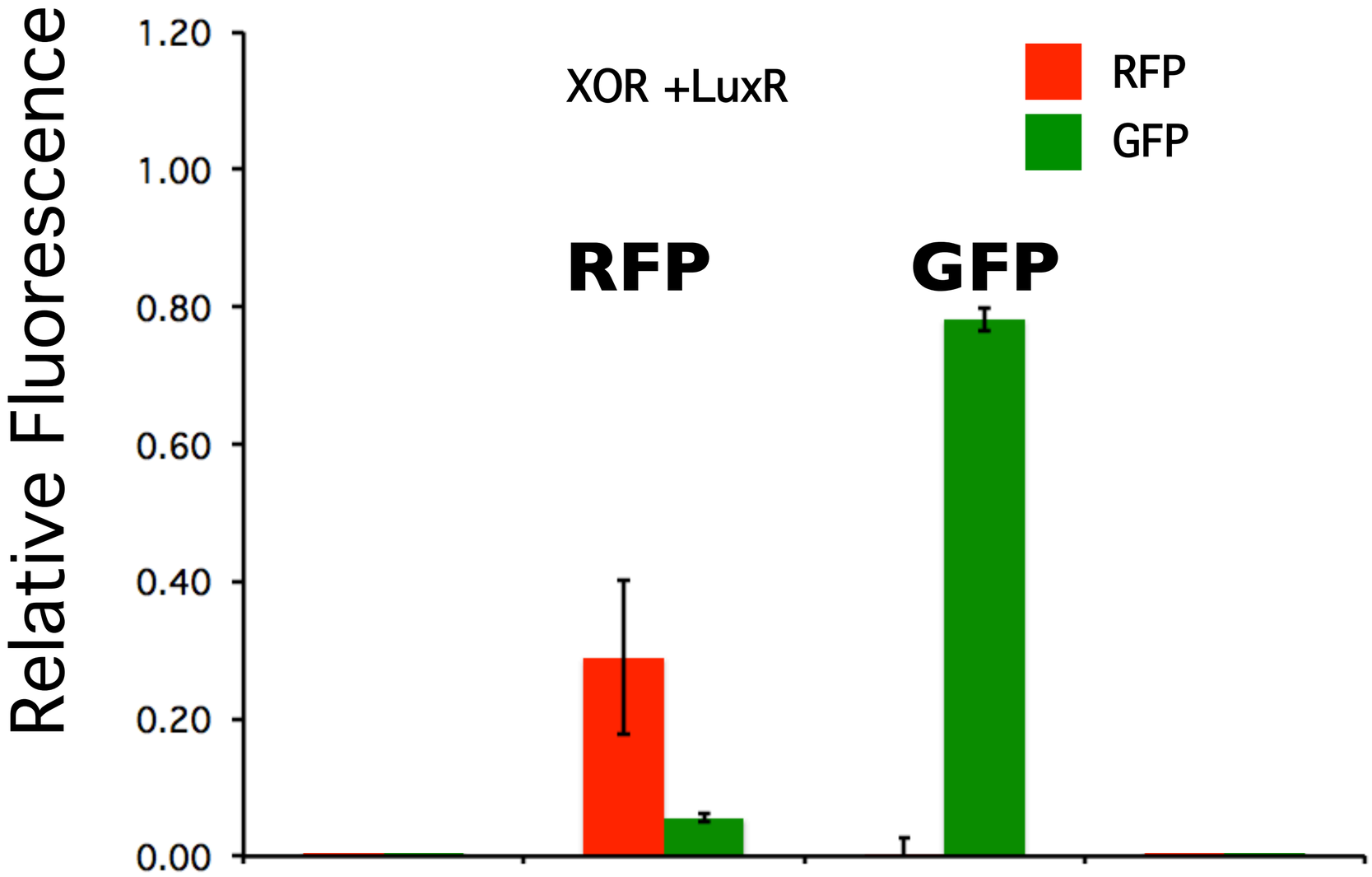
RFP
GFP



LB	-	-	+	+
3OC6	-	+	-	+

Testing Bacterial XOR Logic Gate





LB	-	-	+	+
3OC6	-	+	-	+

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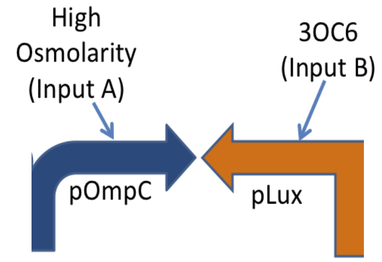

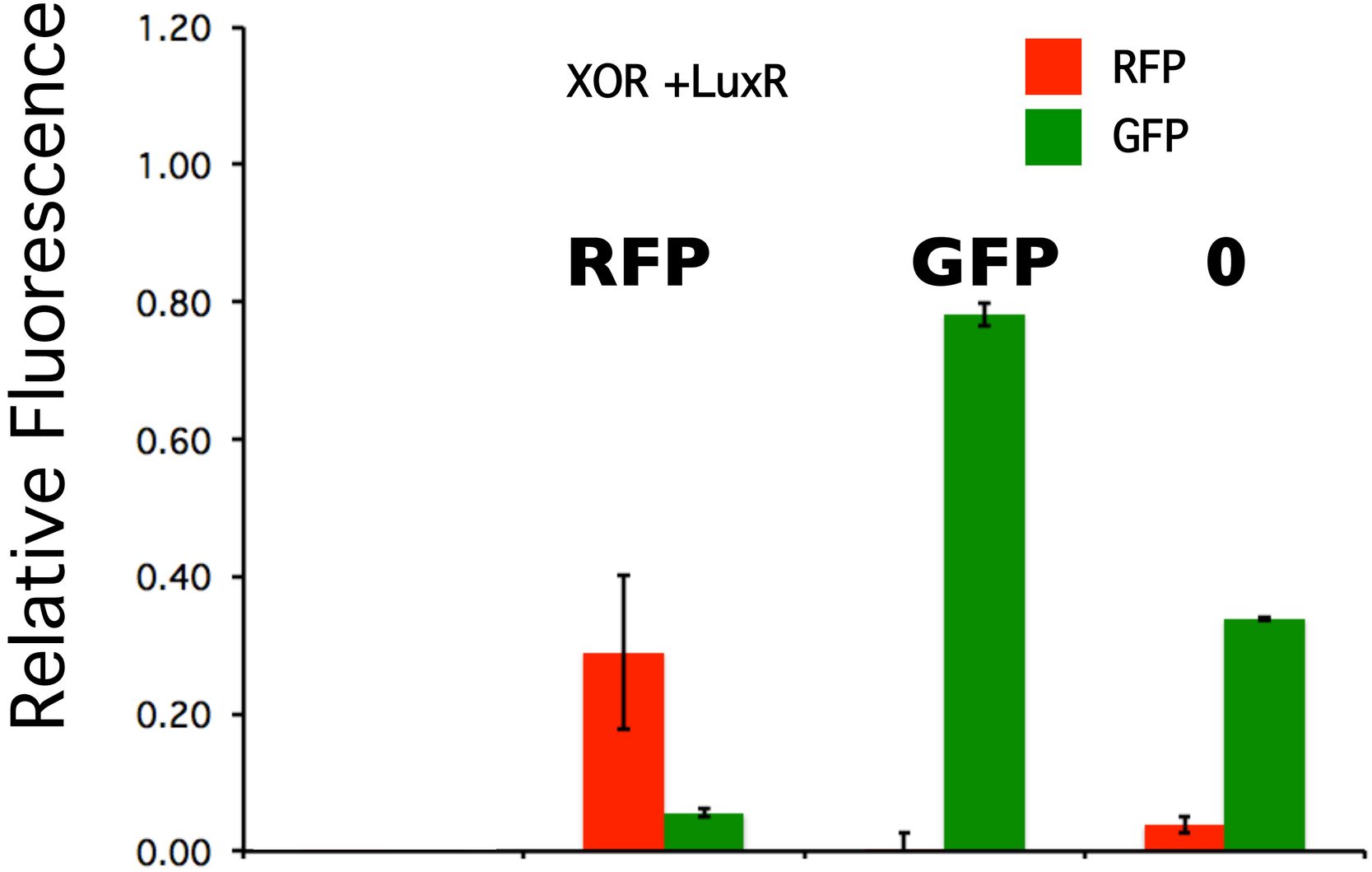

LB	-	-	+	+
3OC6	-	+	-	+

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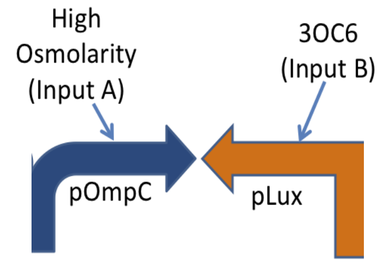
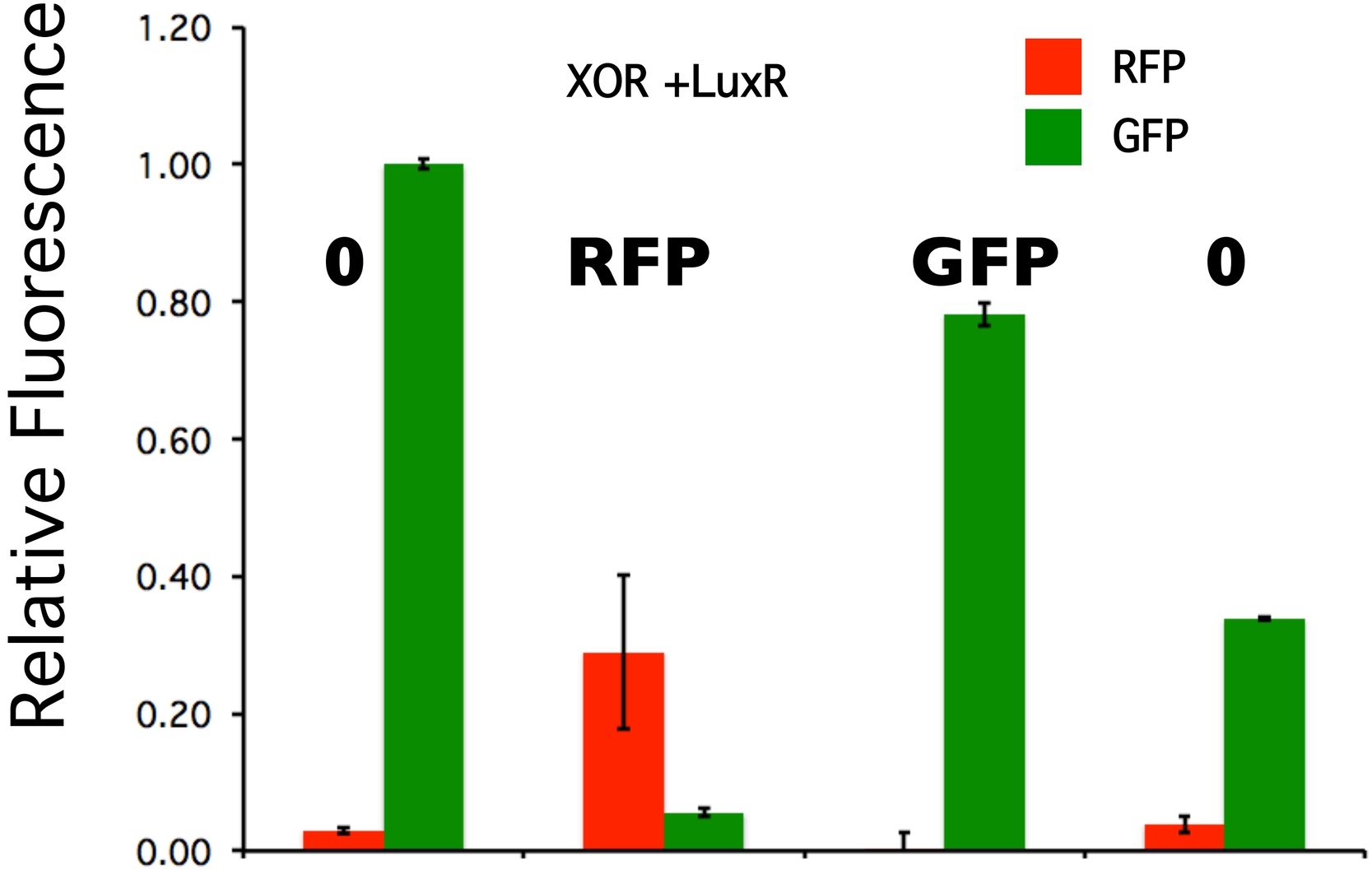
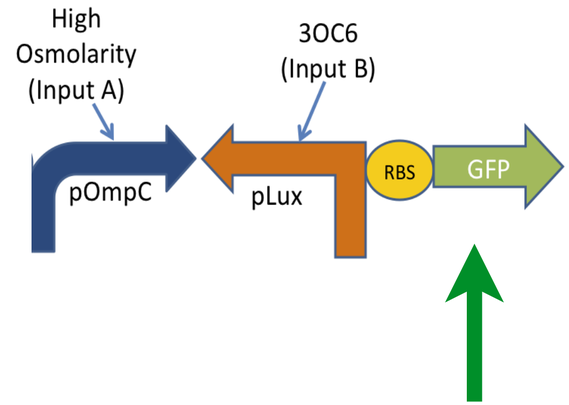
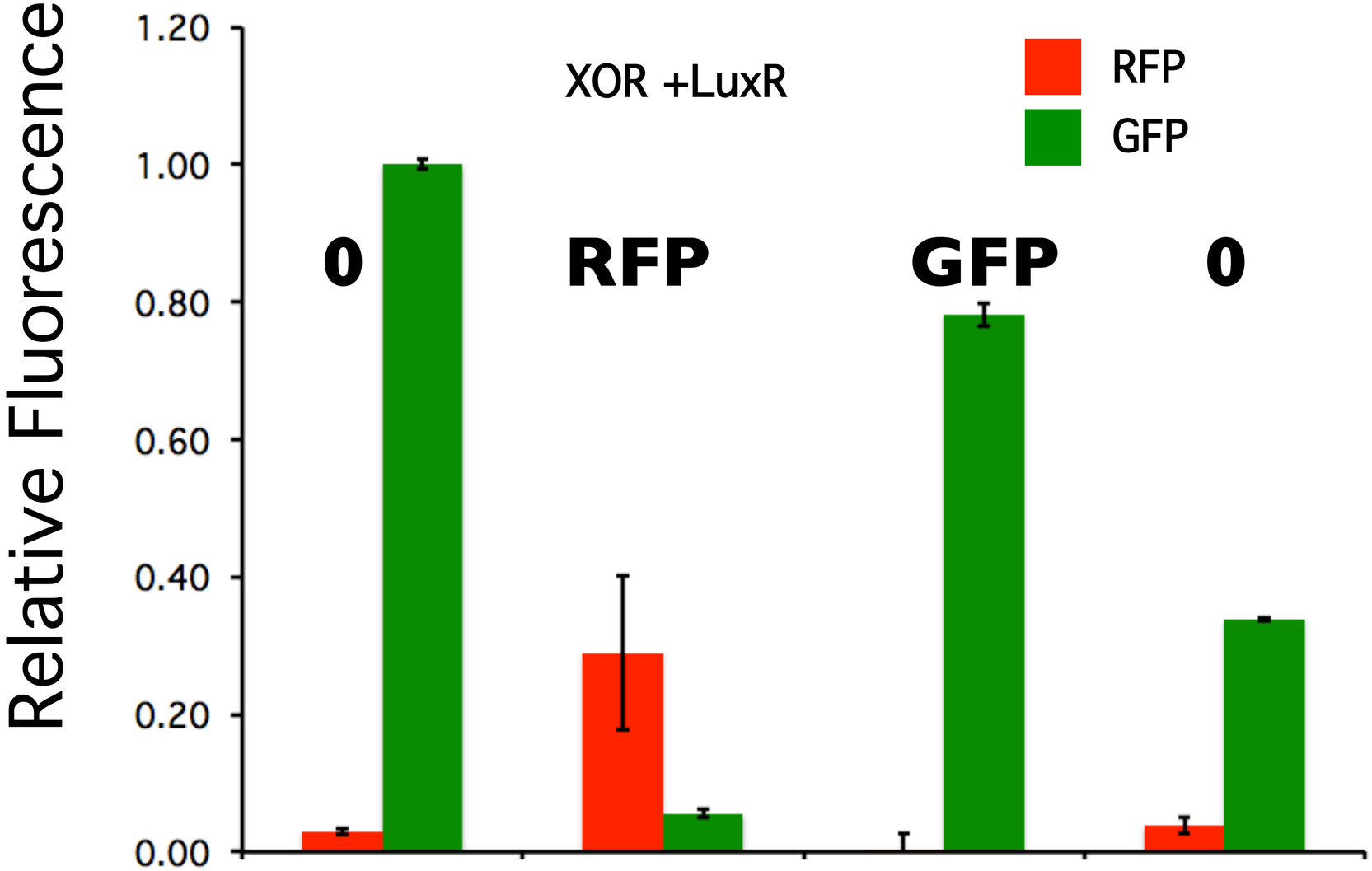




LB	-	-	+	+
3OC6	-	+	-	+

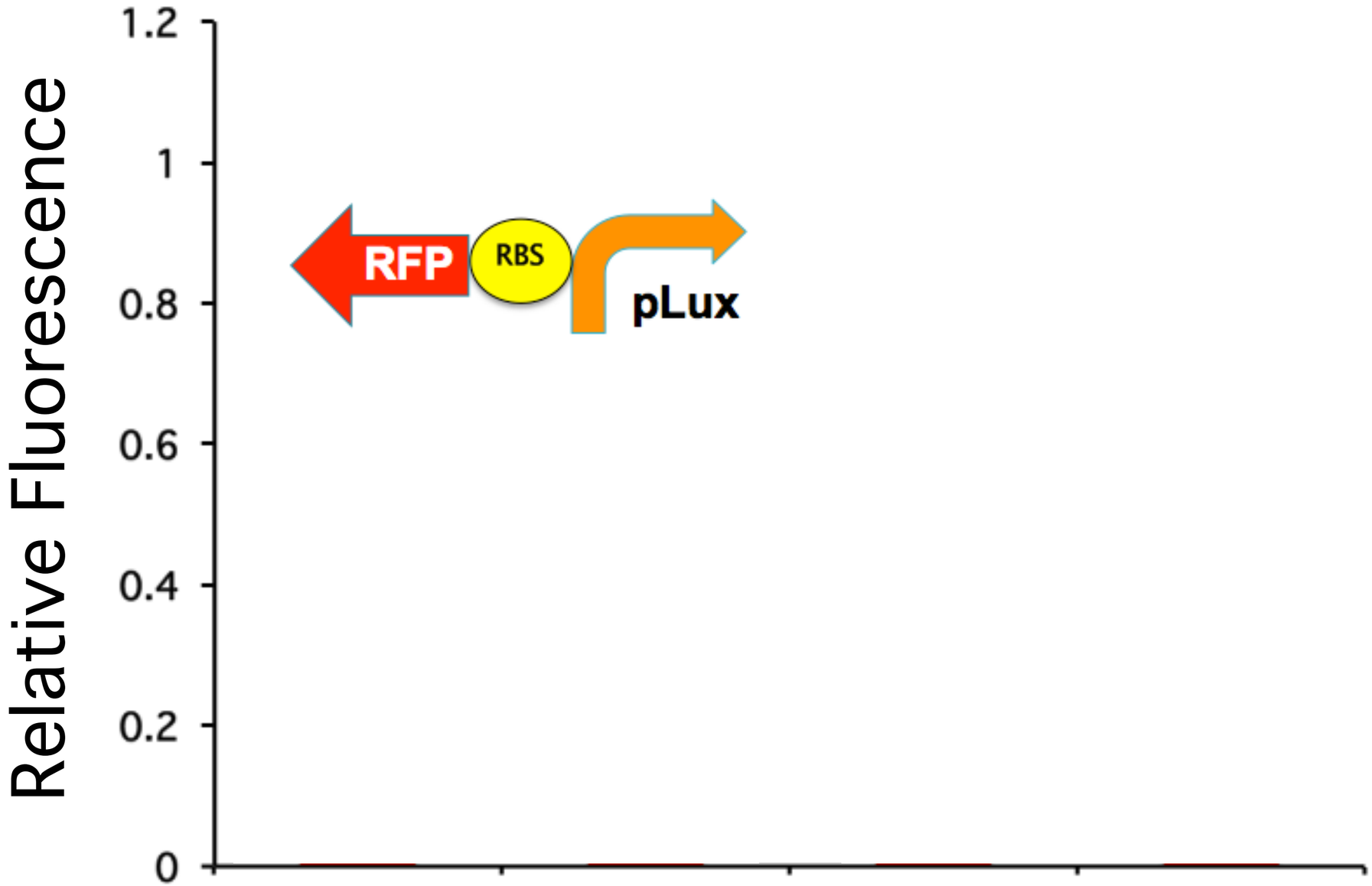
Testing Bacterial XOR Logic Gate





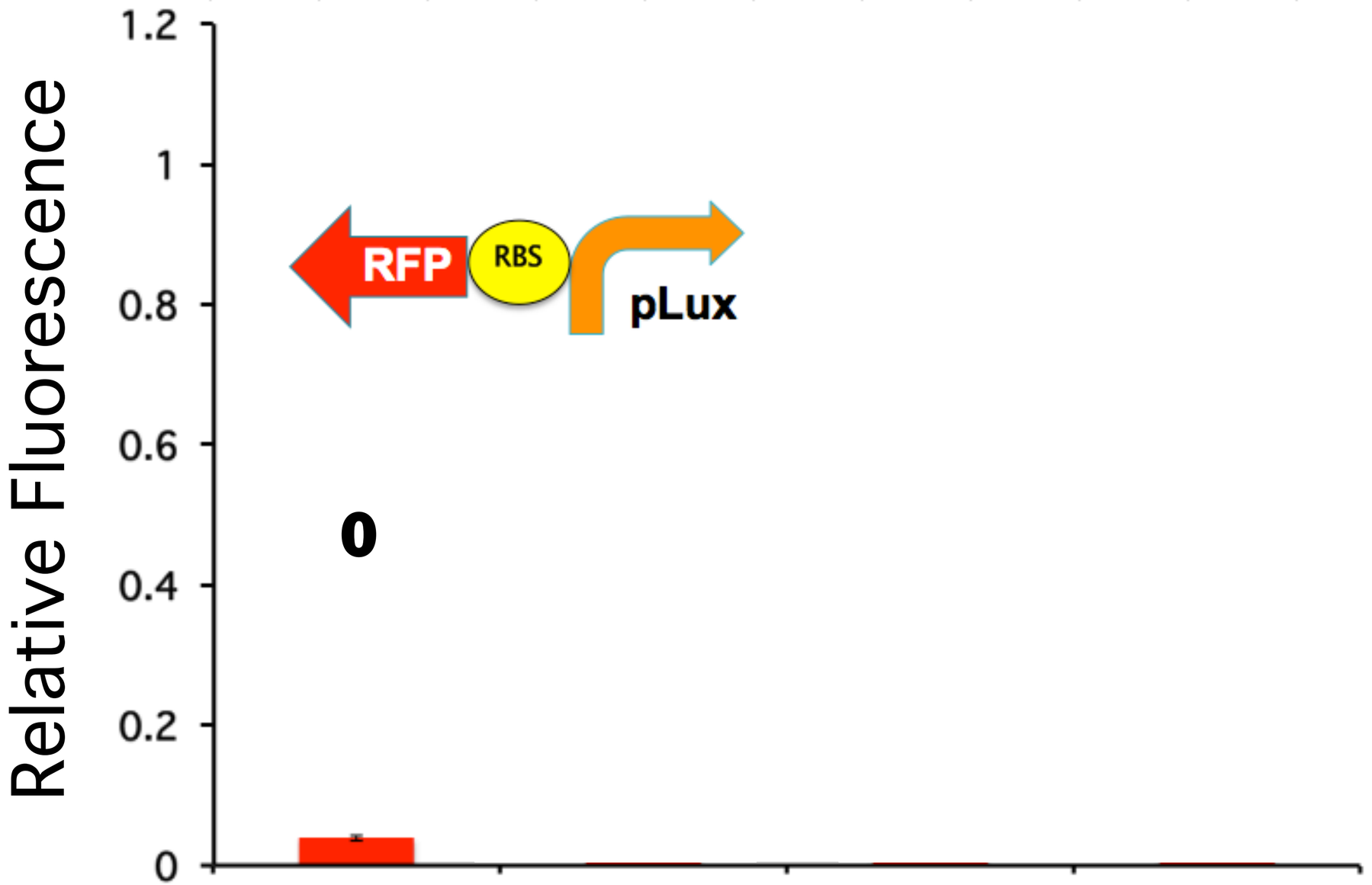
LB	-	-	+	+
3OC6	-	+	-	+

pLux + LuxR Promotes Backwards



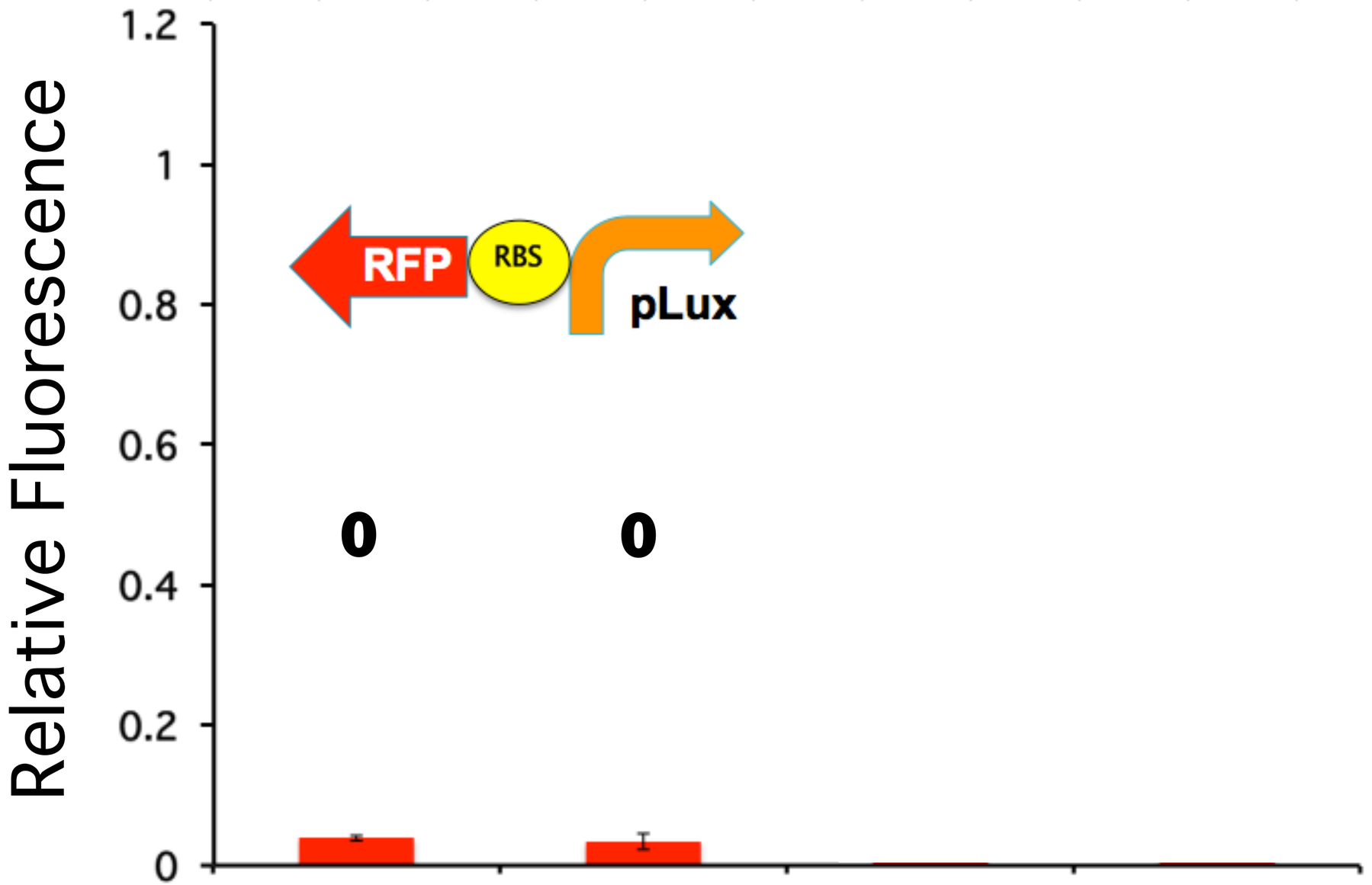
LuxR	-	-	+	+
3OC6	-	+	-	+

pLux + LuxR Promotes Backwards



LuxR	-	-	+	+
3OC6	-	+	-	+

pLux + LuxR Promotes Backwards



LuxR	-	-	+	+
3OC6	-	+	-	+

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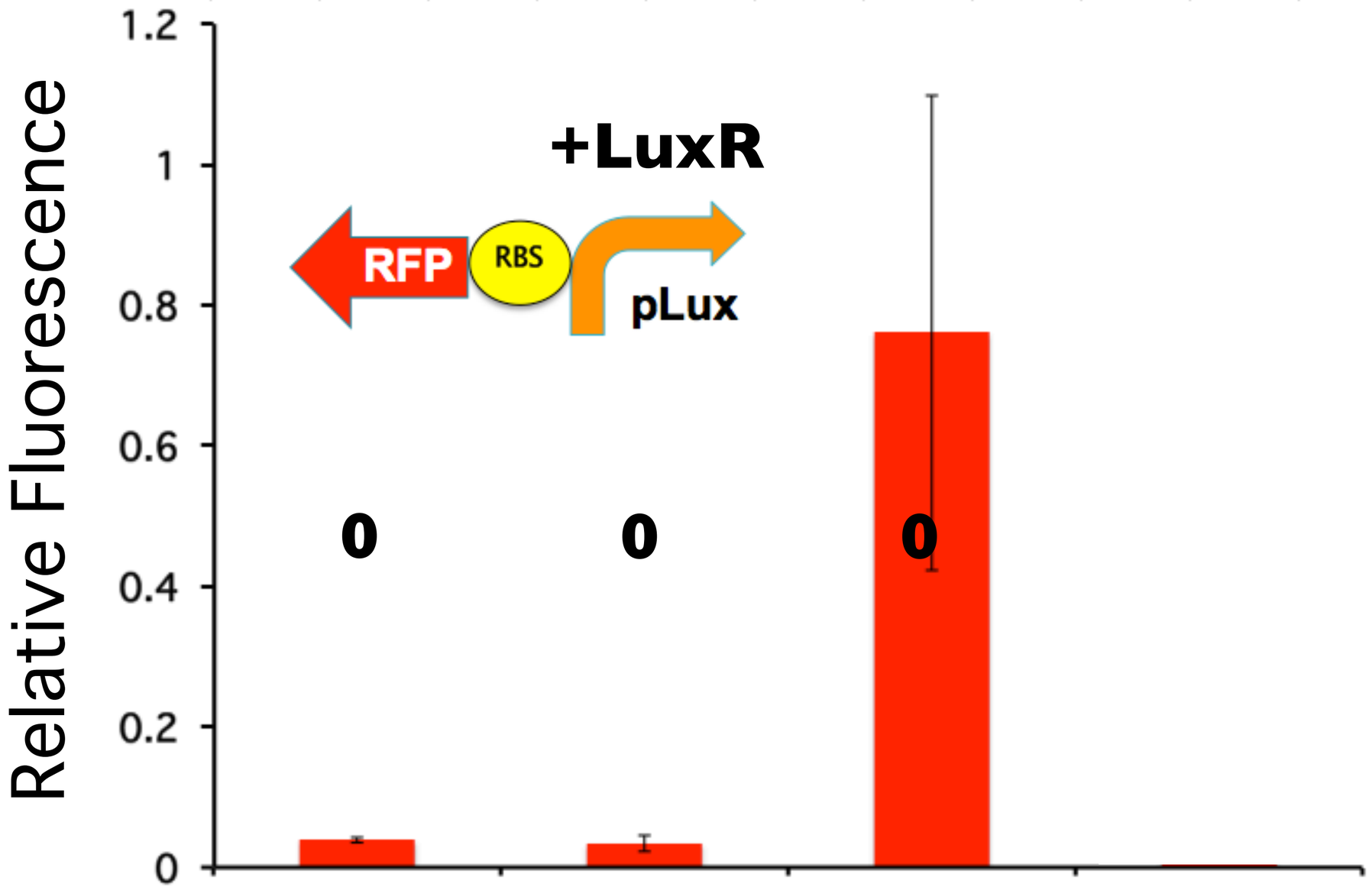

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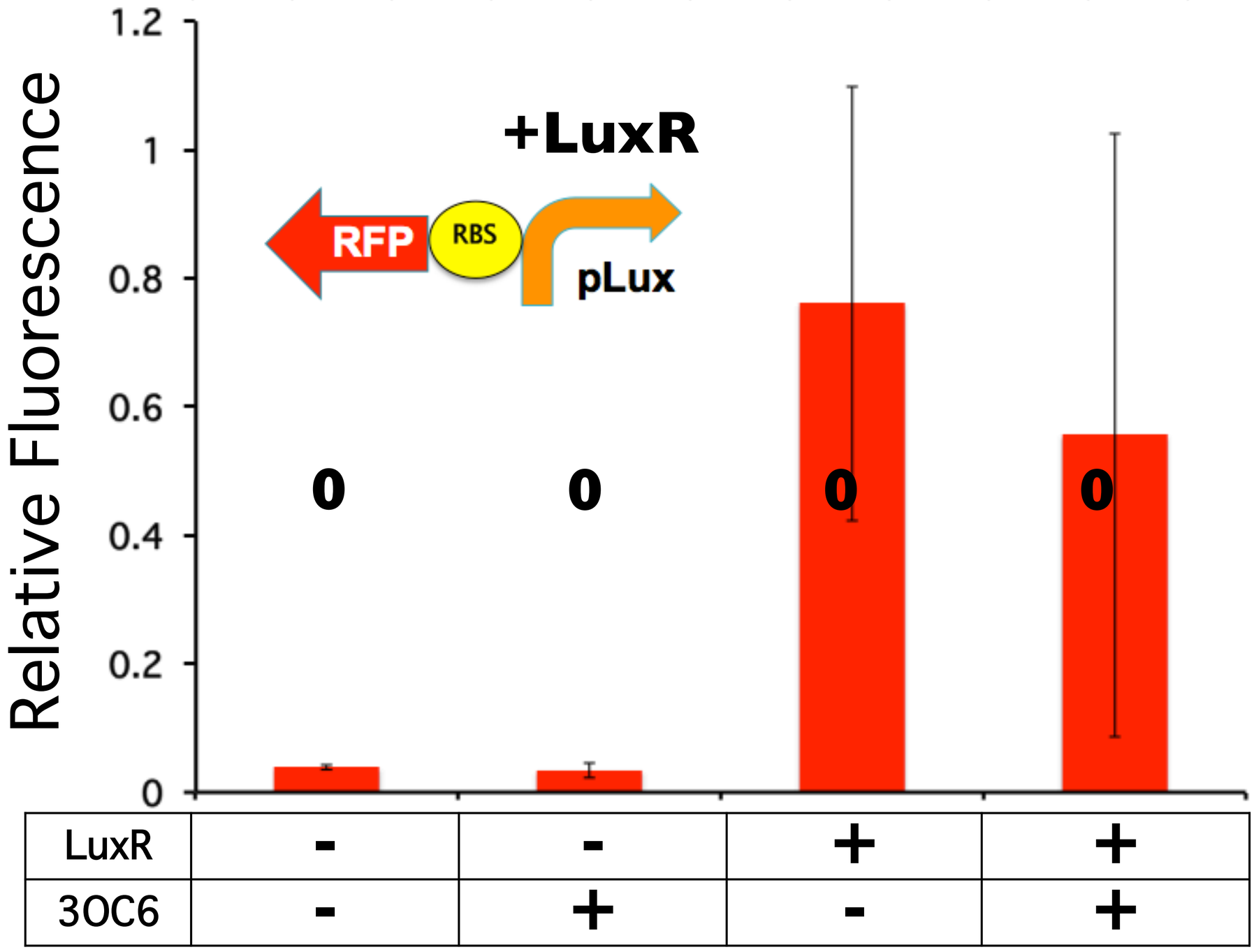
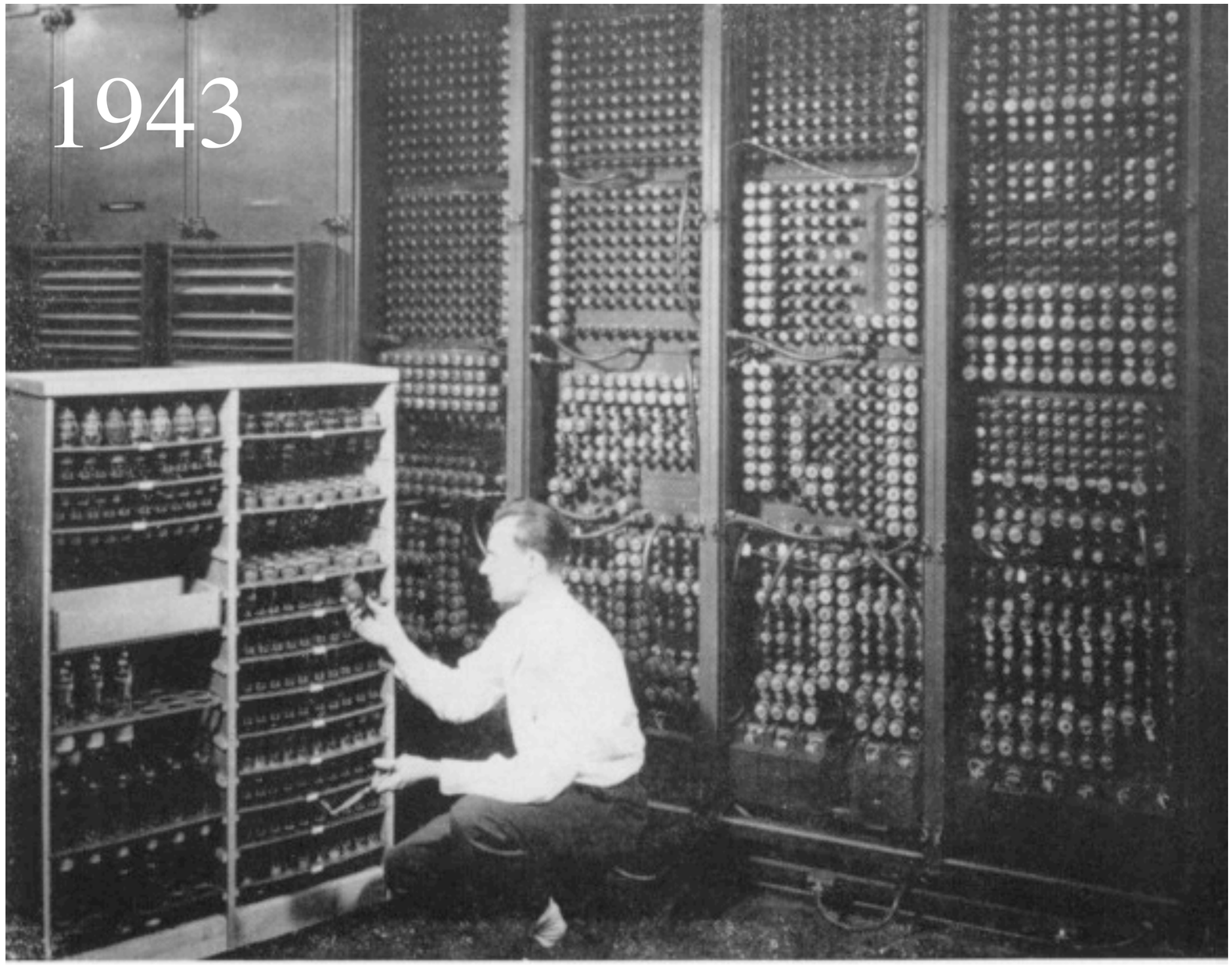


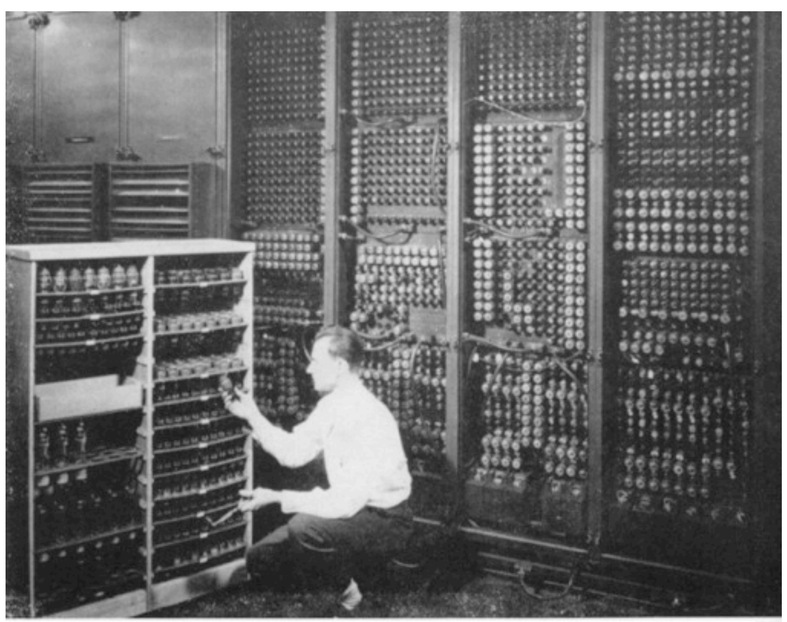
Why build bacterial computers?

Evolution of Computers



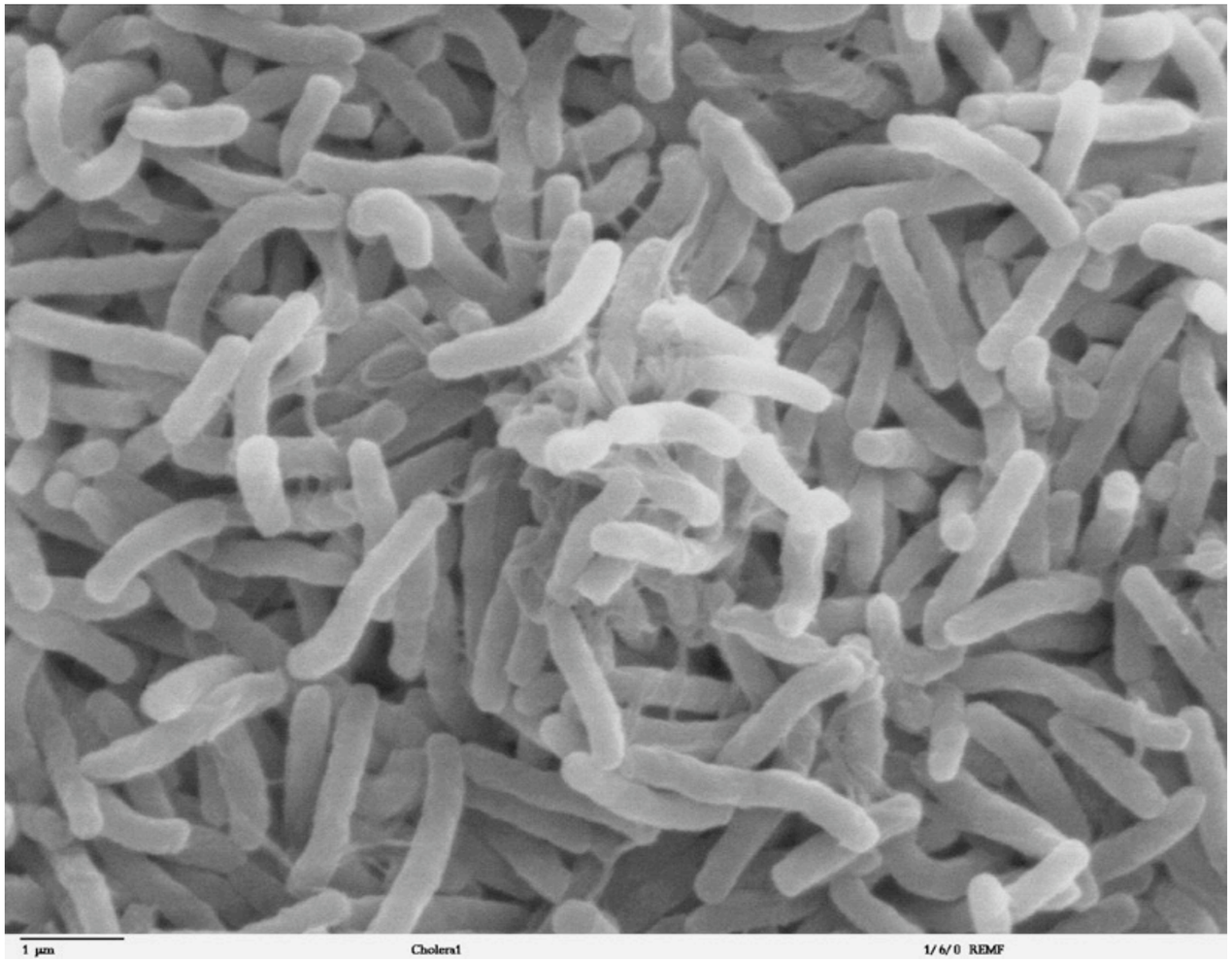
Evolution of Computers

iPhone in 2012



Evolution of Bacterial Computers

E. coli in 2012



?

Living Hardware in 2022

Without basic research, there can be no applications....

After all, electricity and the lightbulb were not invented by incremental improvements to the candle.

French President Nicholas Sarkozy

Skills Most Sought After by Employers

1) Communications Skills
2) Analytical/Research Skills
3) Computer Literacy
4) Flexibility
5) Interpersonal Abilities
6) Leadership Skills
7) Multicultural Sensitivity
8) Organizational Skills
9) Problem-Solving/Creativity
10) Teamwork

http://www.quintcareers.com/job_skills_values.html

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Personal Values Employers Seek in Employees

1) Honesty/Integrity
2) Adaptability
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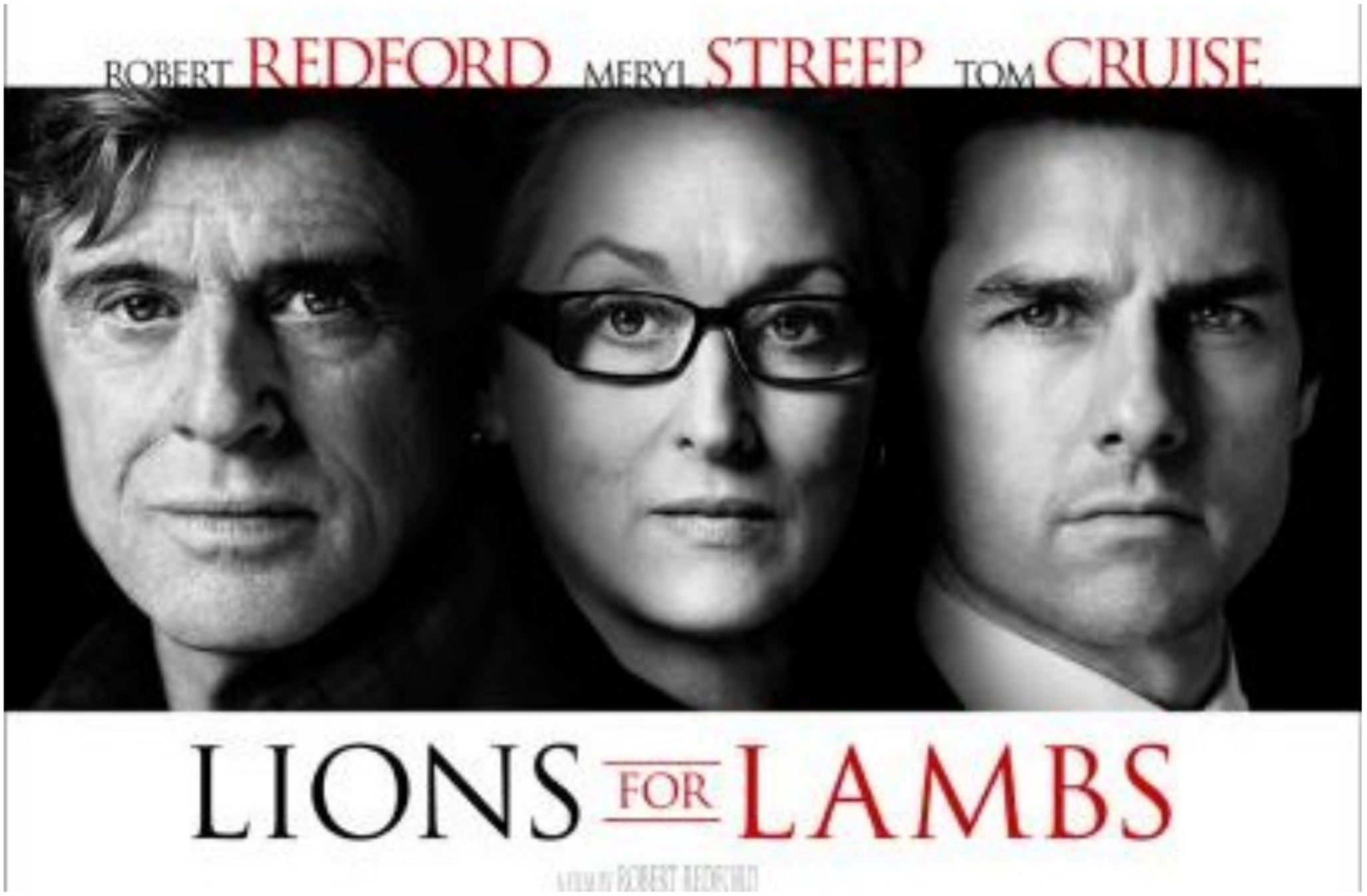
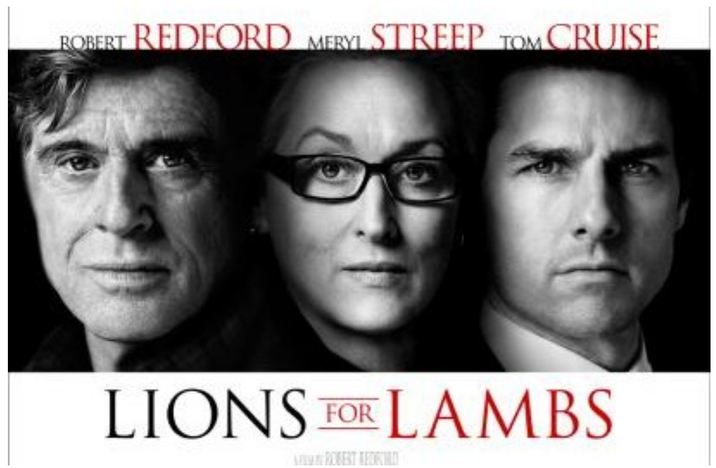
Your College Education Put Into Focus



Your College Education Put Into Focus

Would you rather settle for a blue collar B

or try for an A and risk failure?



Thomas J. Watson, founder of IBM

“Would you like me to give you a formula for success? It's quite simple, really. **Double your rate of failure.** You are thinking of failure as the enemy of success. But it isn’t at all. You can be discouraged by failure or you can learn from it, so go ahead and make mistakes. Make all you can. Because remember that’s where you will find success.”

Thomas J. Watson

The scenery only changes for the lead dog.

The scenery only changes for the lead dog.

Our Current Challenge: Introductory Biology

Integrating Concepts in Biology

by

A. Malcolm Campbell, Laurie J. Heyer
and Christopher J. Paradise

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**

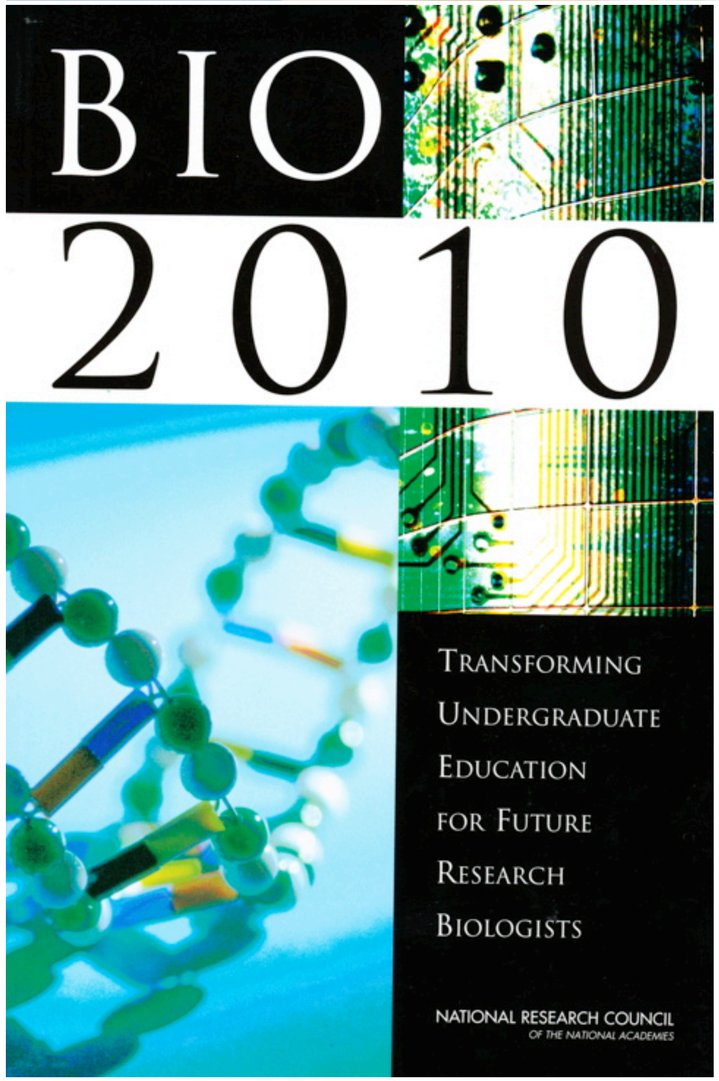
If we currently cover all the important stuff….

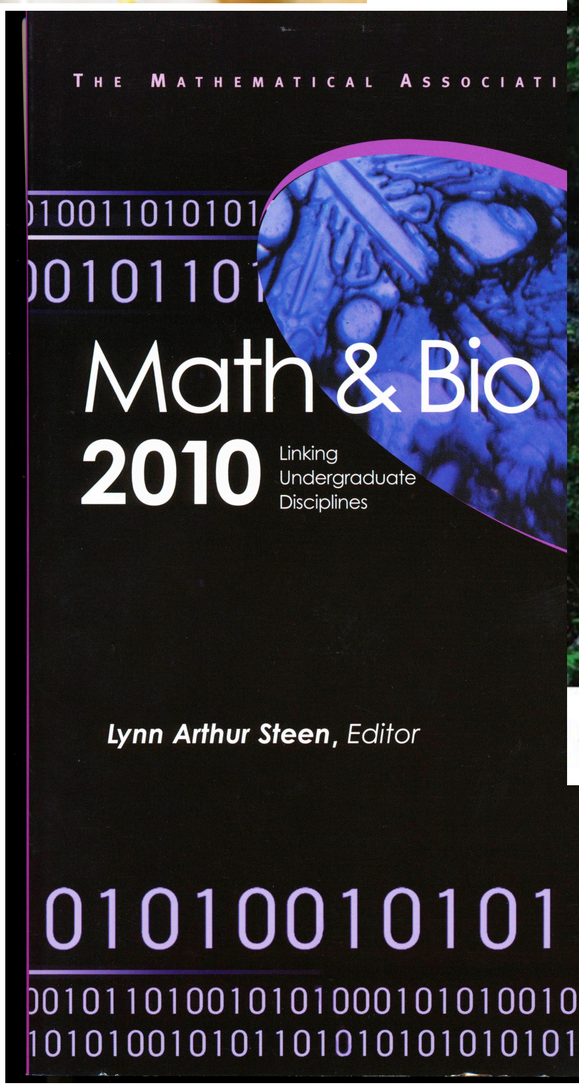
…how can we add more content?

Too much content for the containers

Too much content for the containers

Start with the literature…





Present information and data…

… in the context of the big picture.

Artificial Divide within Biology

Small Biology

Big Biology

YoungCubs.com

Five Levels of Organization

Molecular

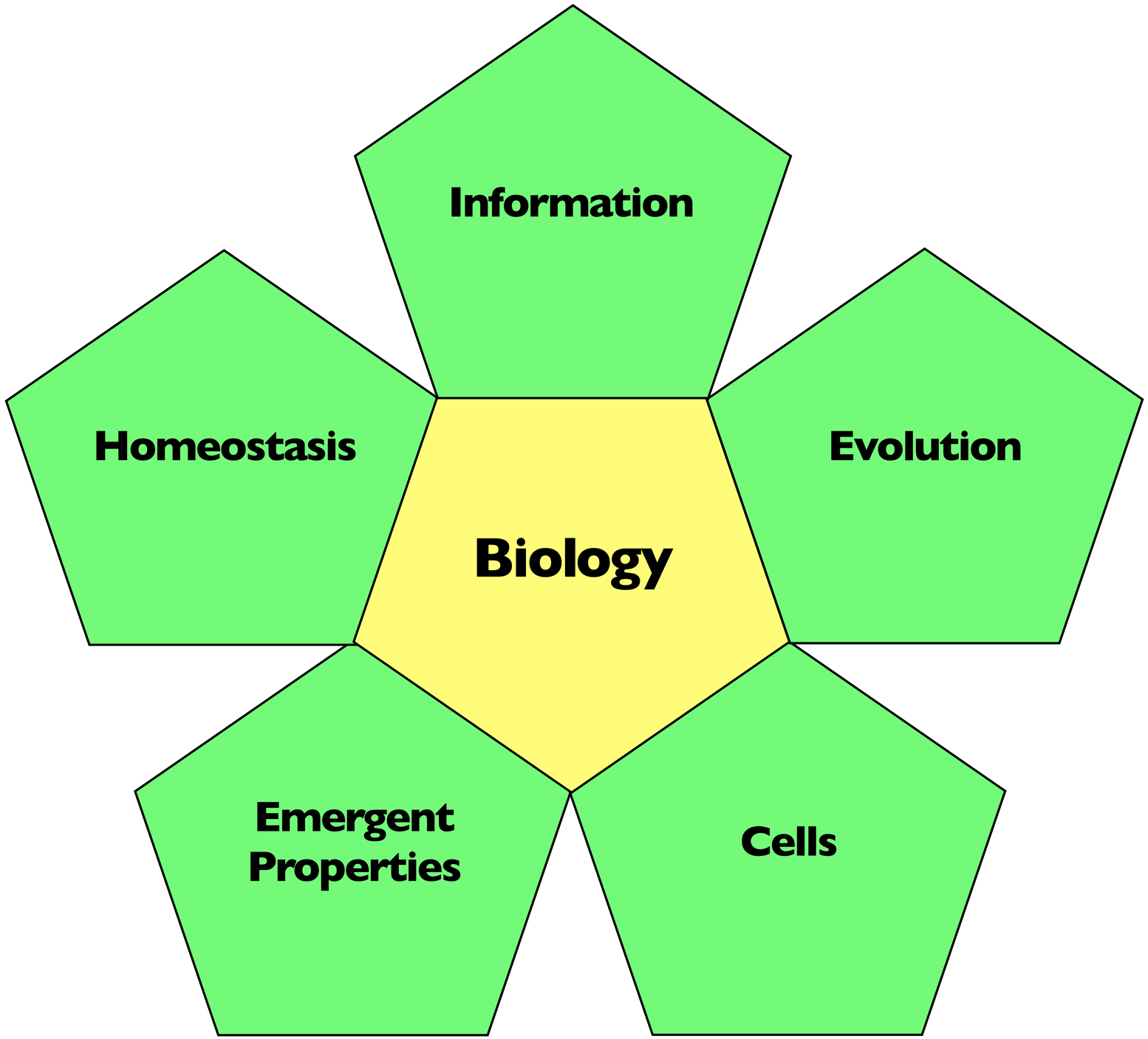
Cellular

Organismal

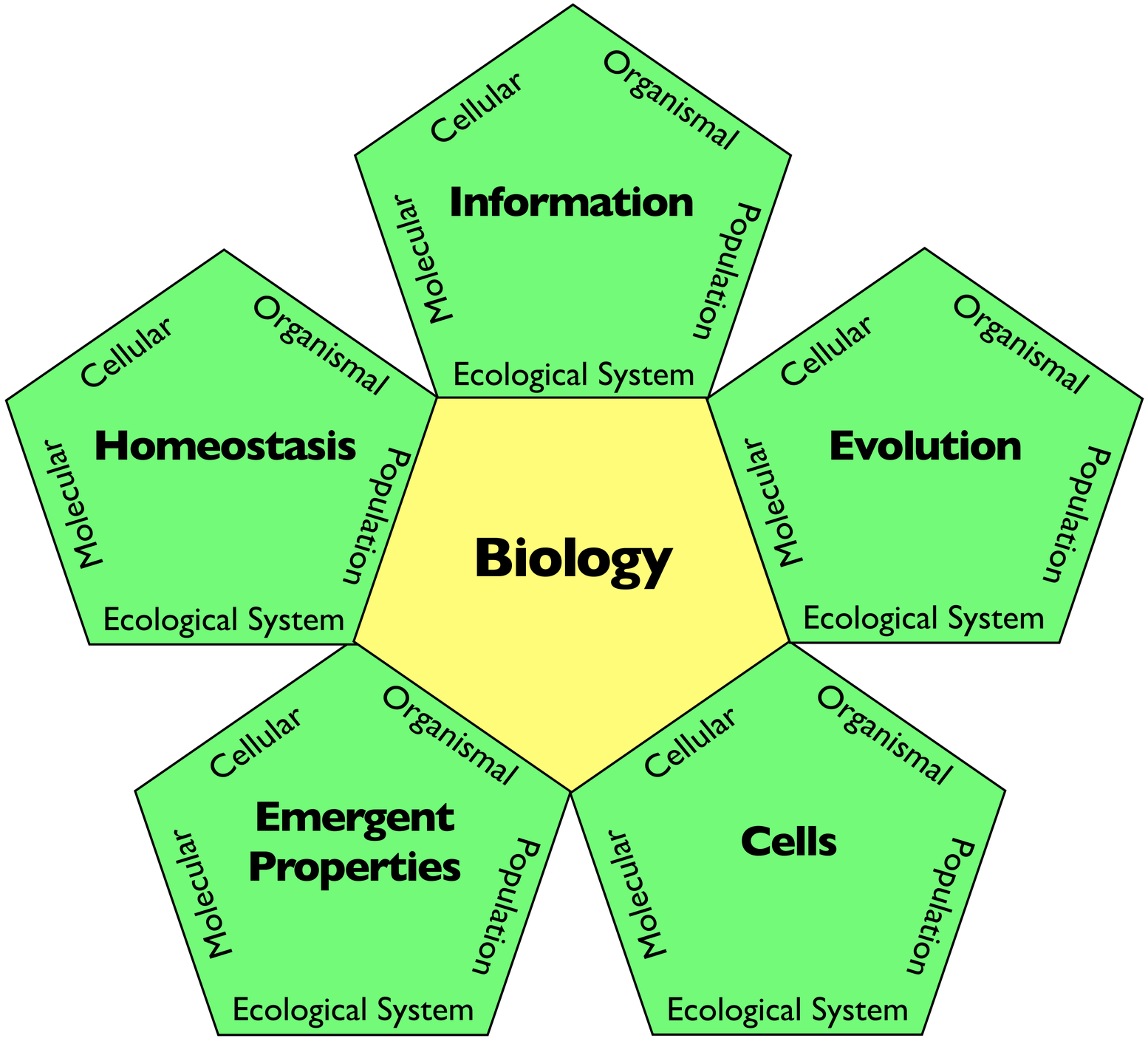
Population

Ecological System

Five Big Ideas of Biology



Five by Five Matrix of Biology



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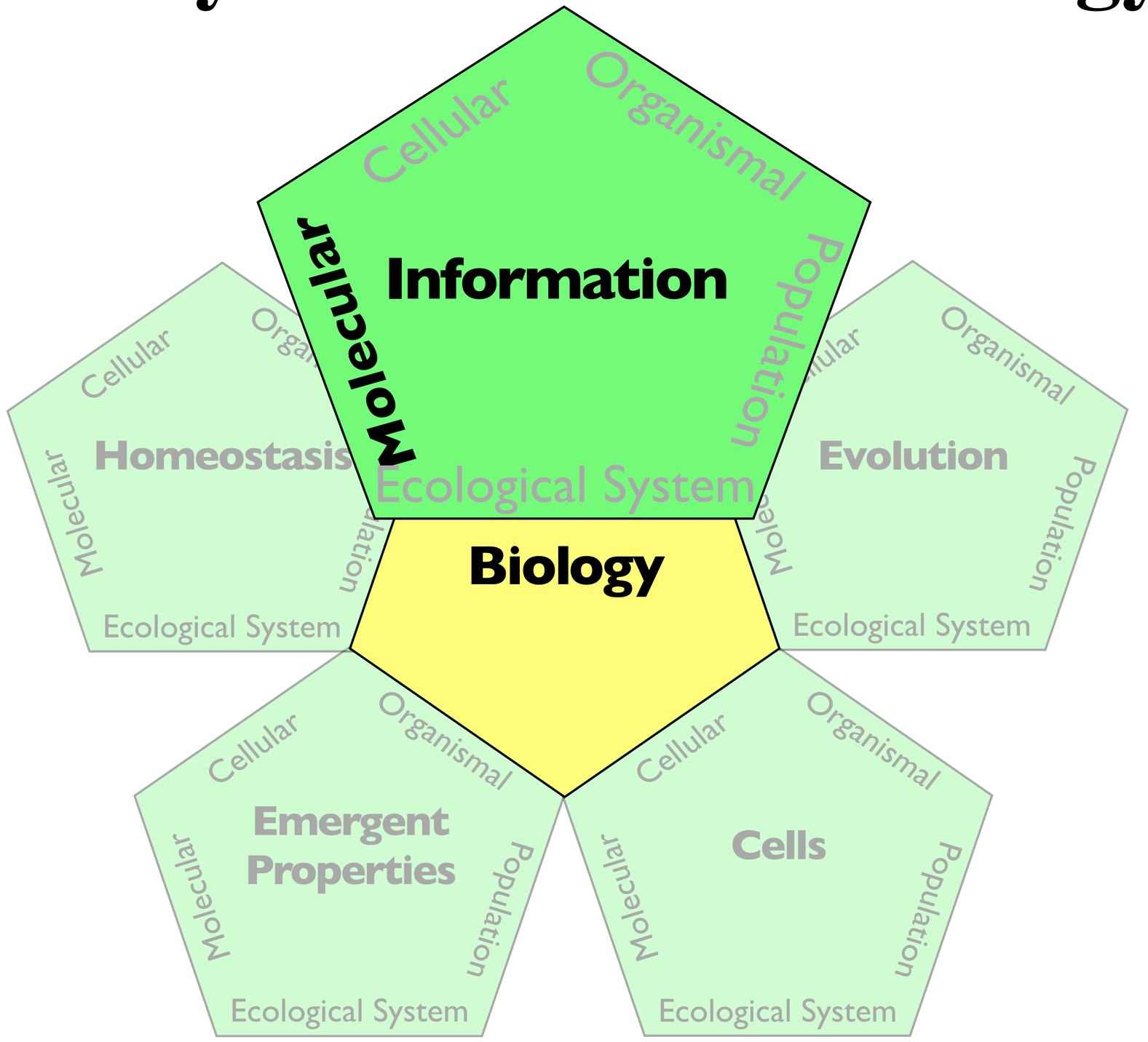

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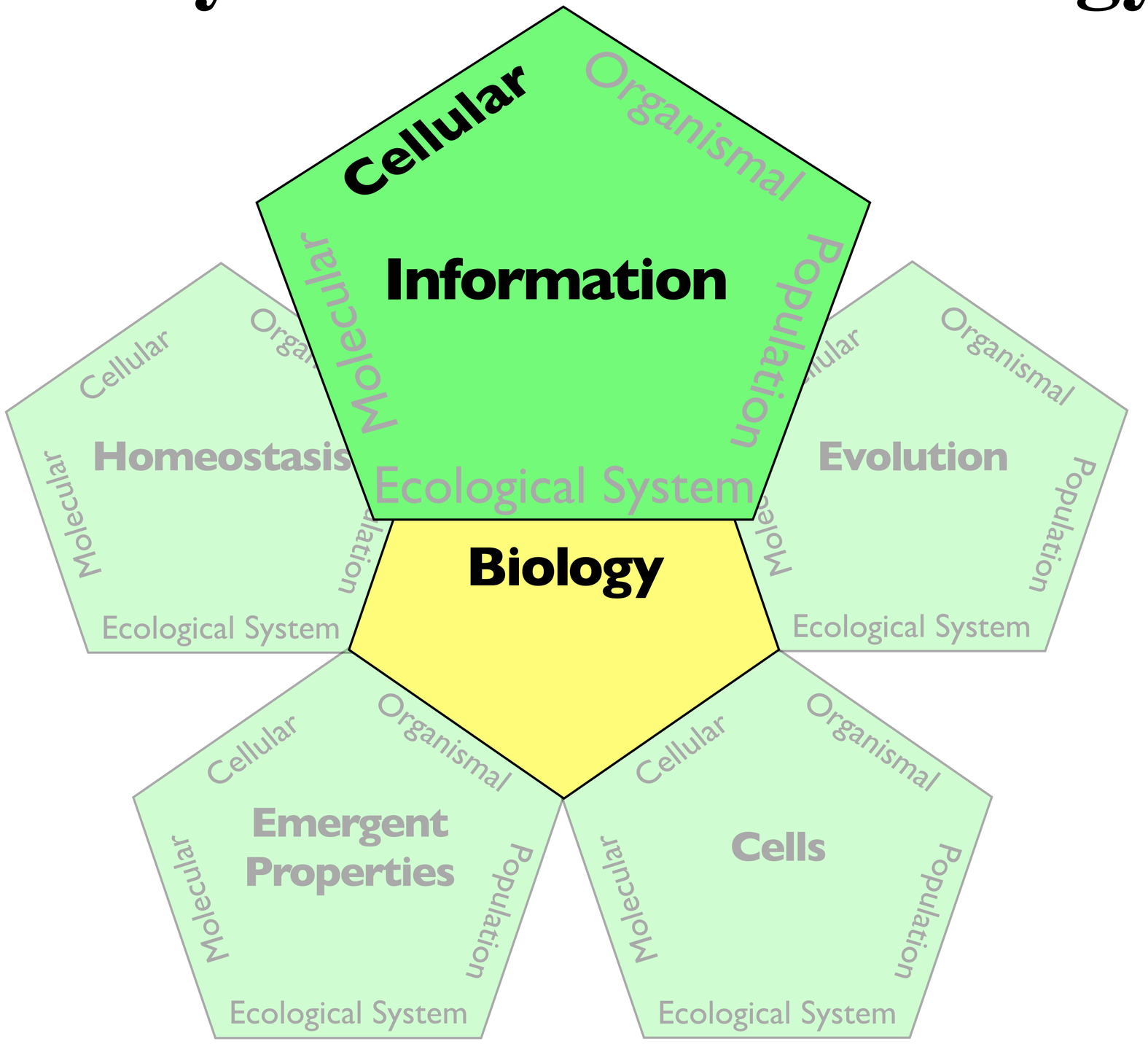

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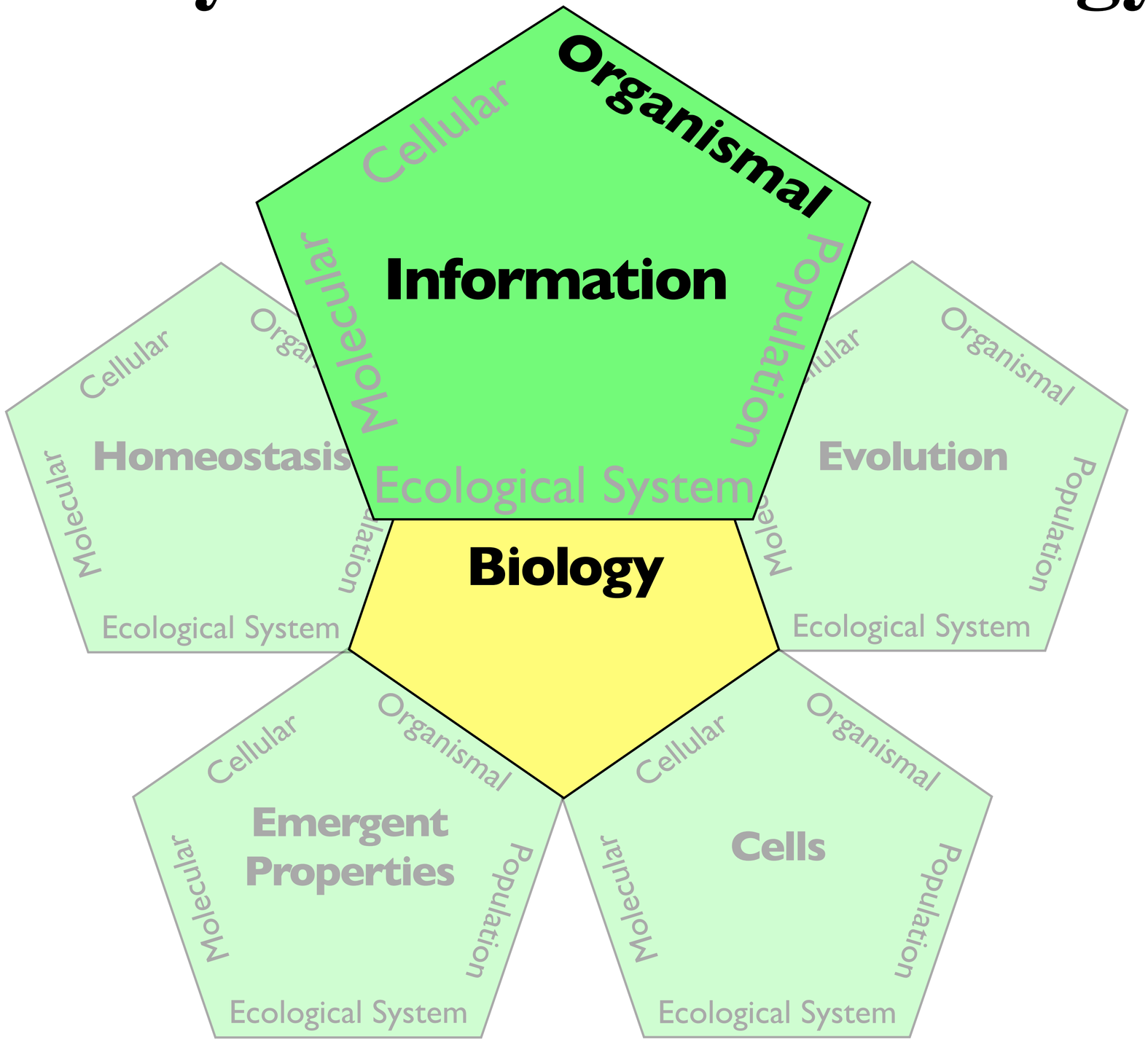

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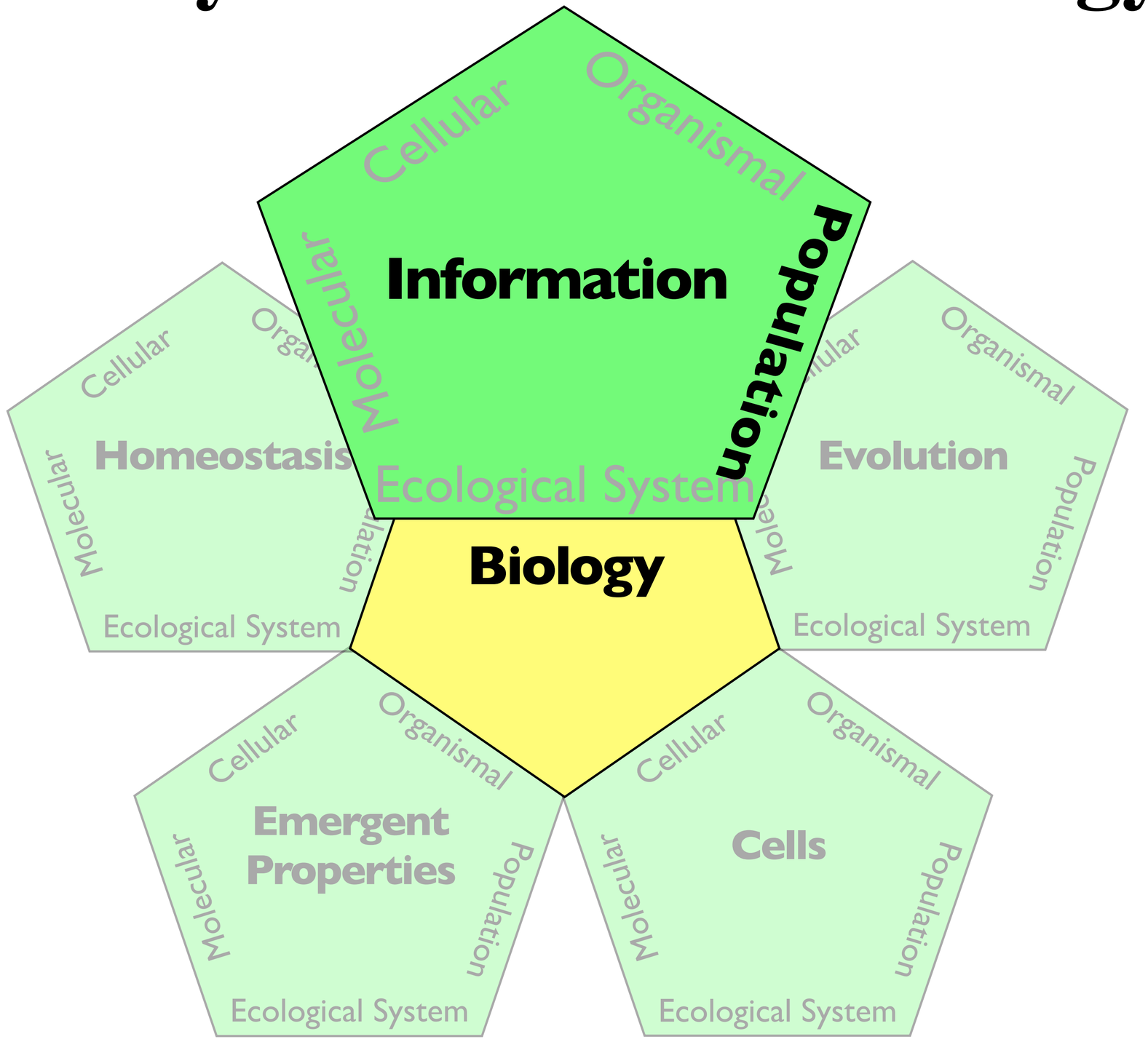

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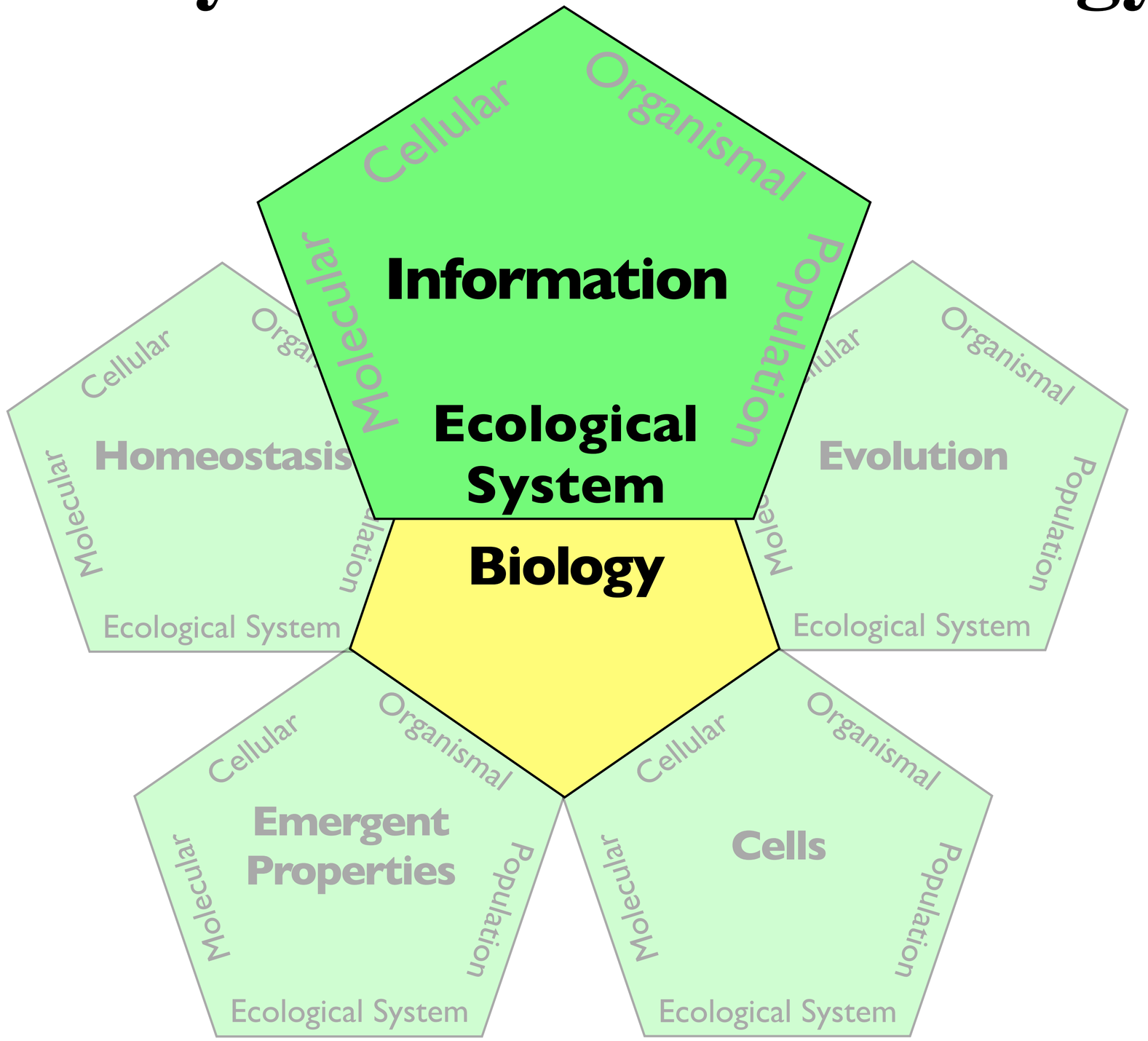

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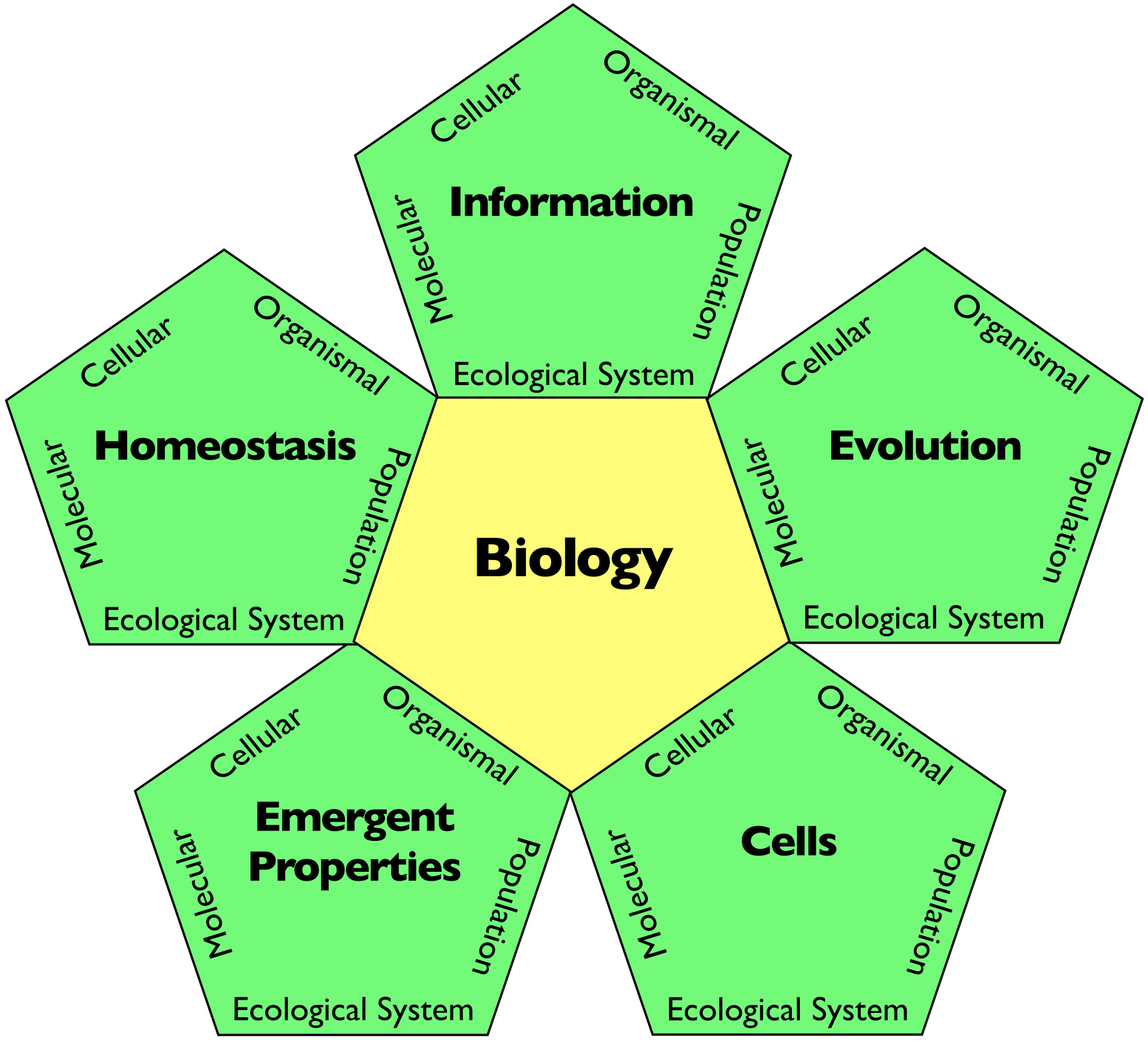
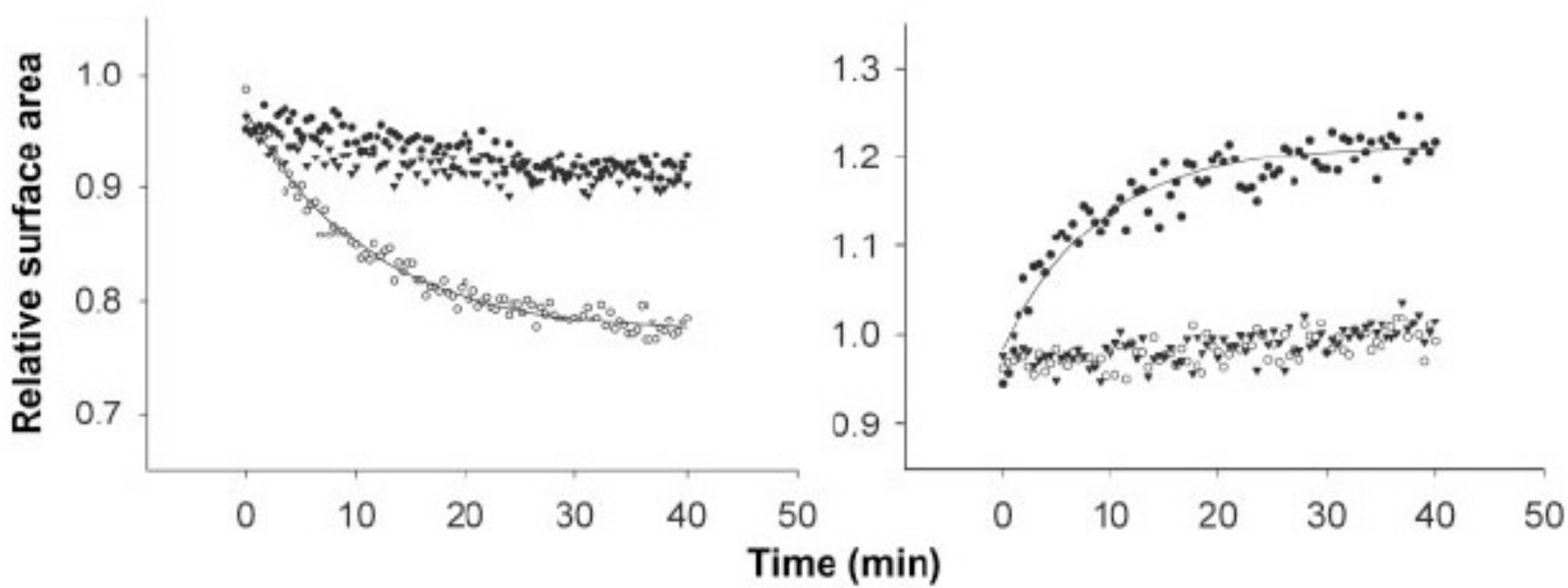


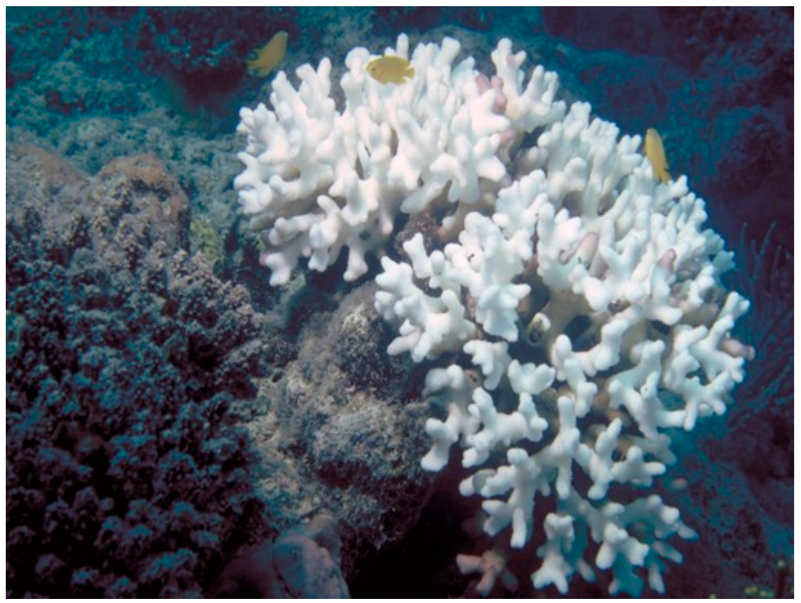
BioMath Explorations

BioMath Exploration 6.3

How can you fit exponential curves to data?



Ethical, Legal and Social Implications

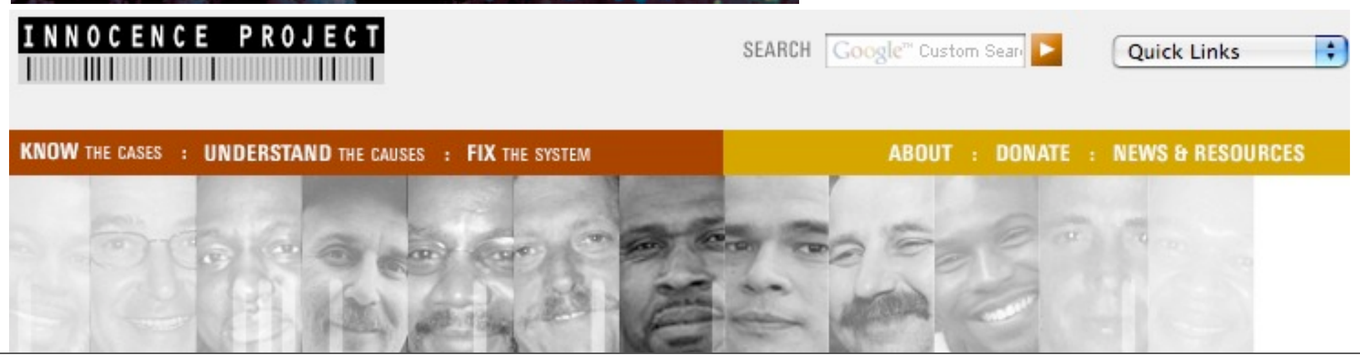


Are religion and evolution compatible?

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

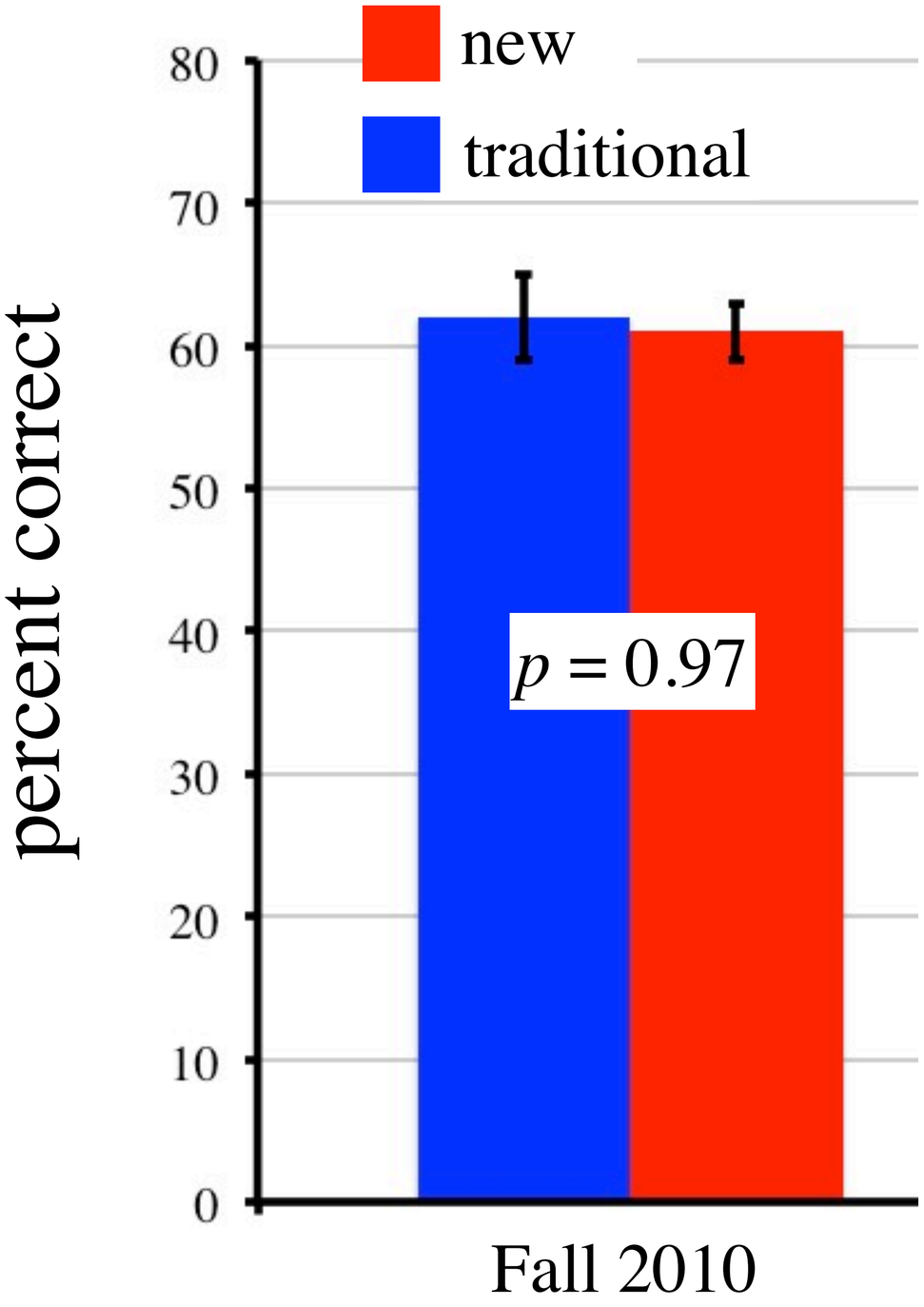
Does basic biology have any impact on the real world?

Who owns your DNA?



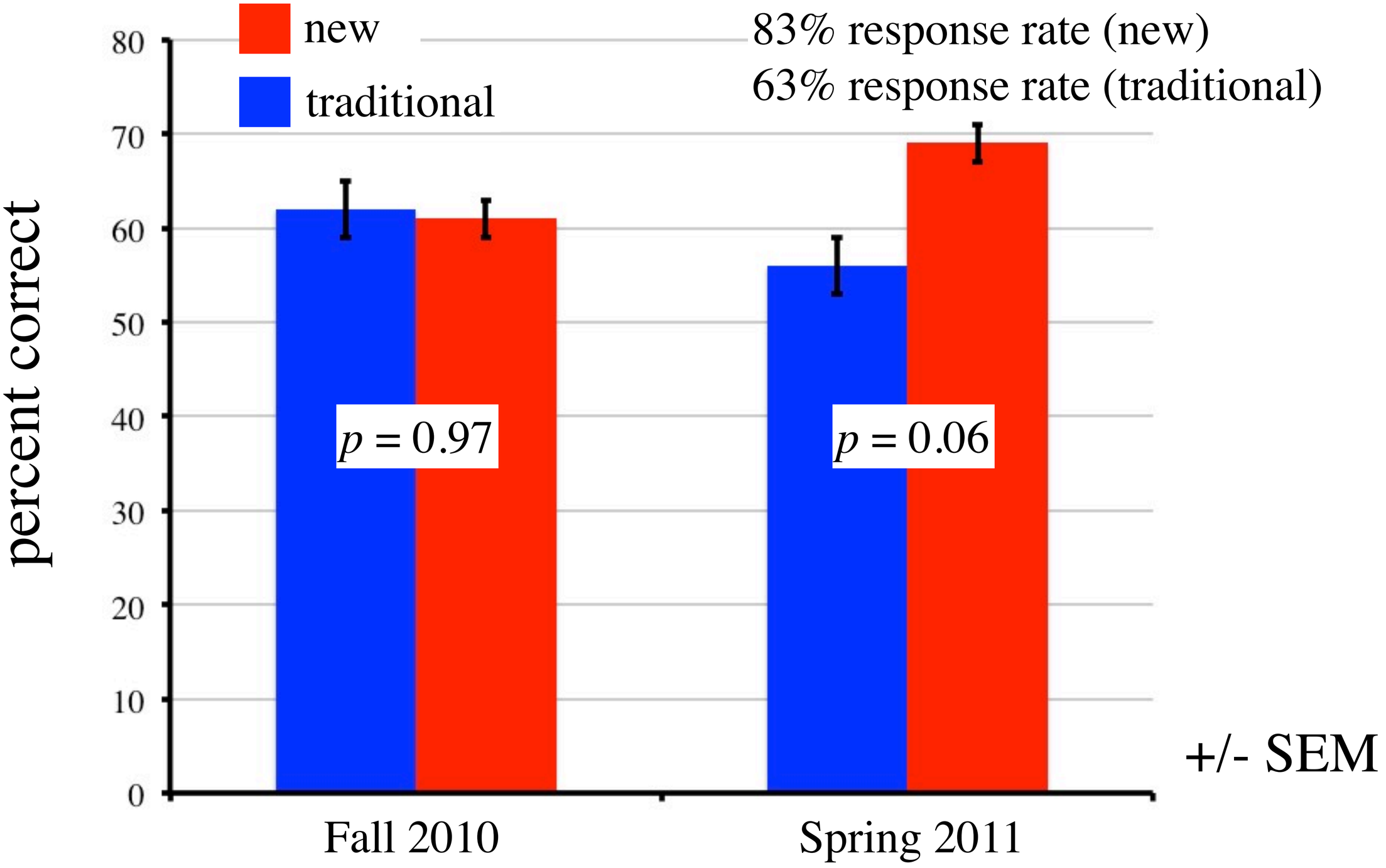
Did my students learn less content?

Student Content Assessment



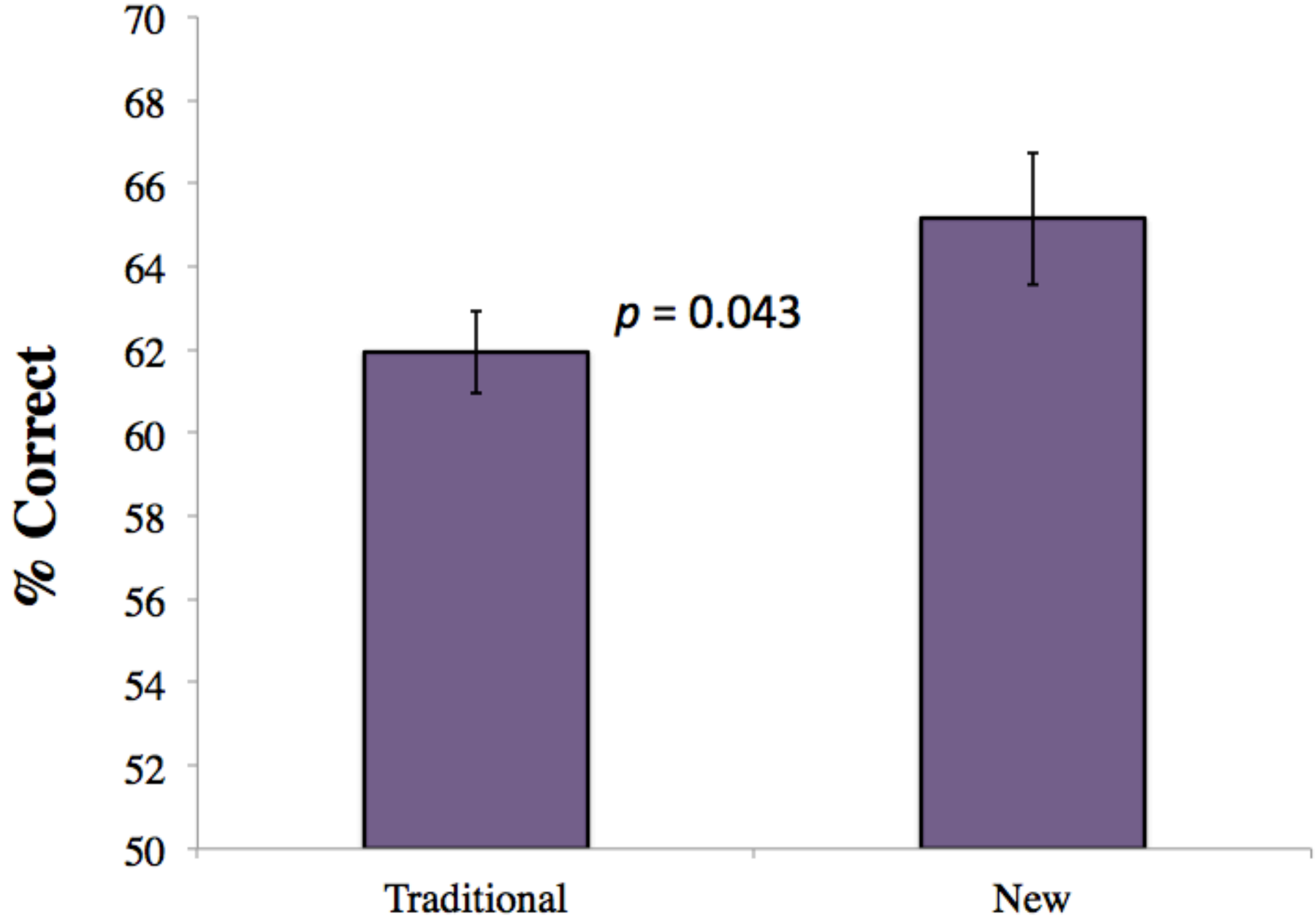
+/- SEM

Student Content Assessment

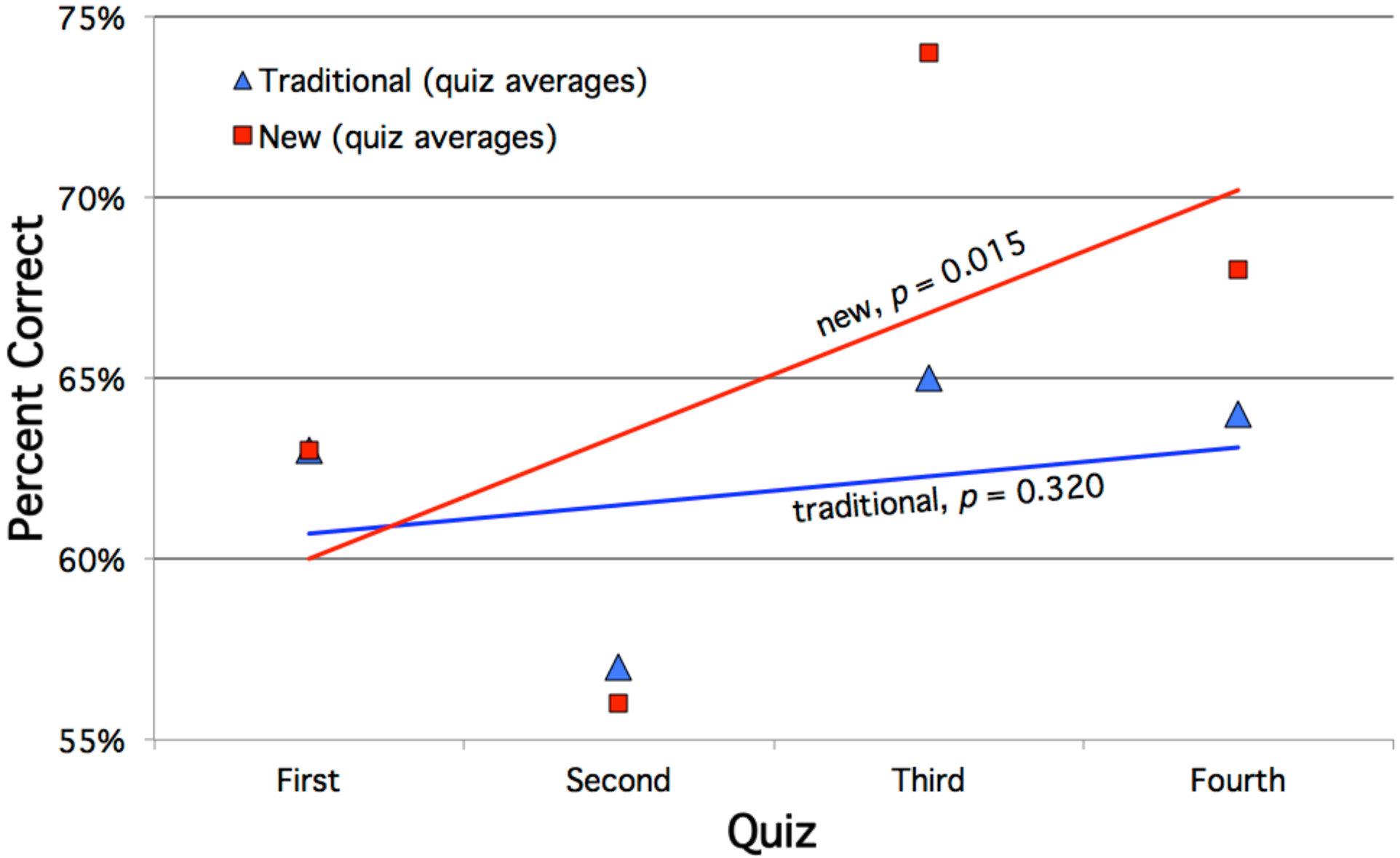


Can my students analyze data better?

Student Skills Assessment

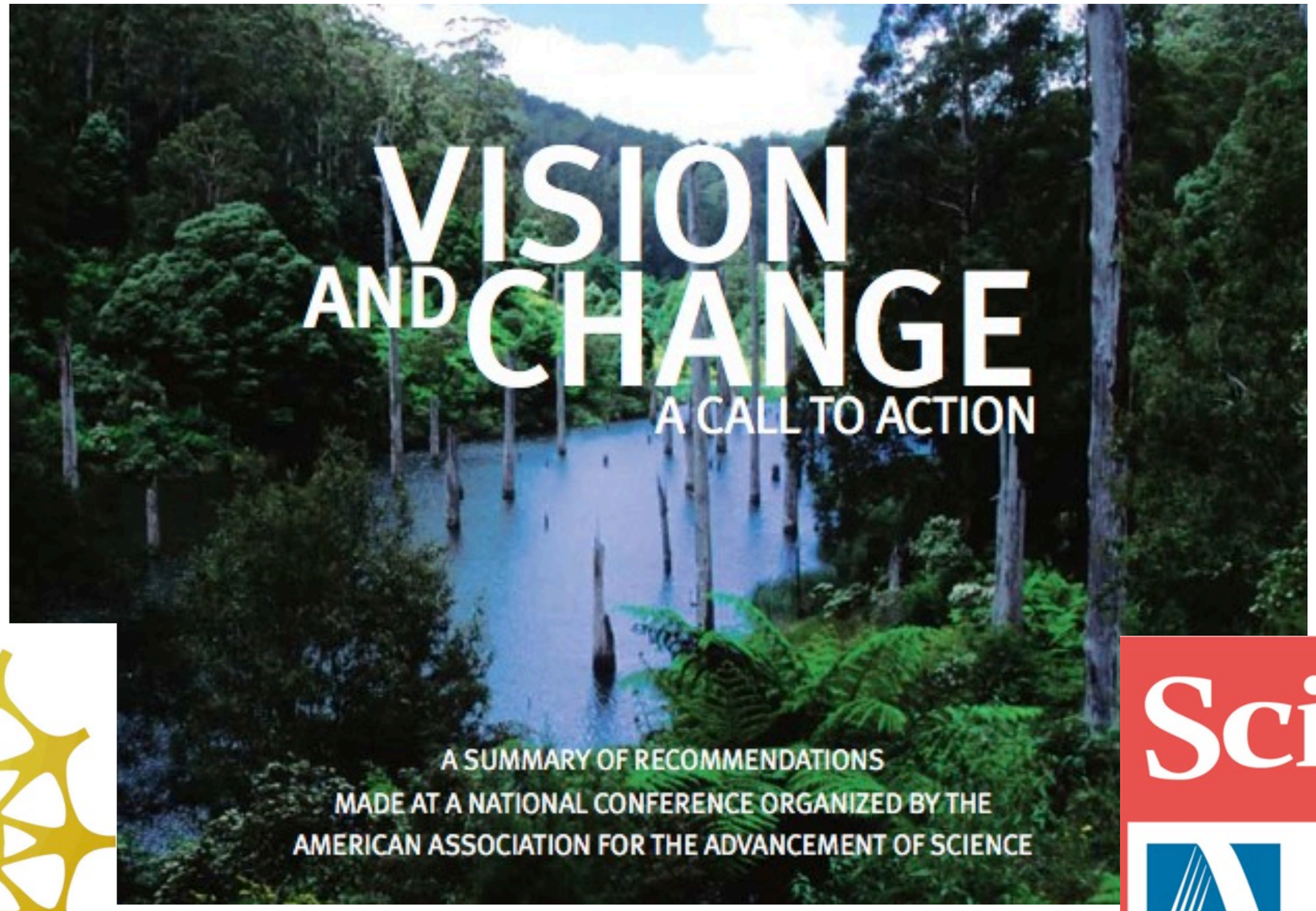


Student Skills Assessment



Why bother changing?

National Recognition of Need to Change



NSF

Science

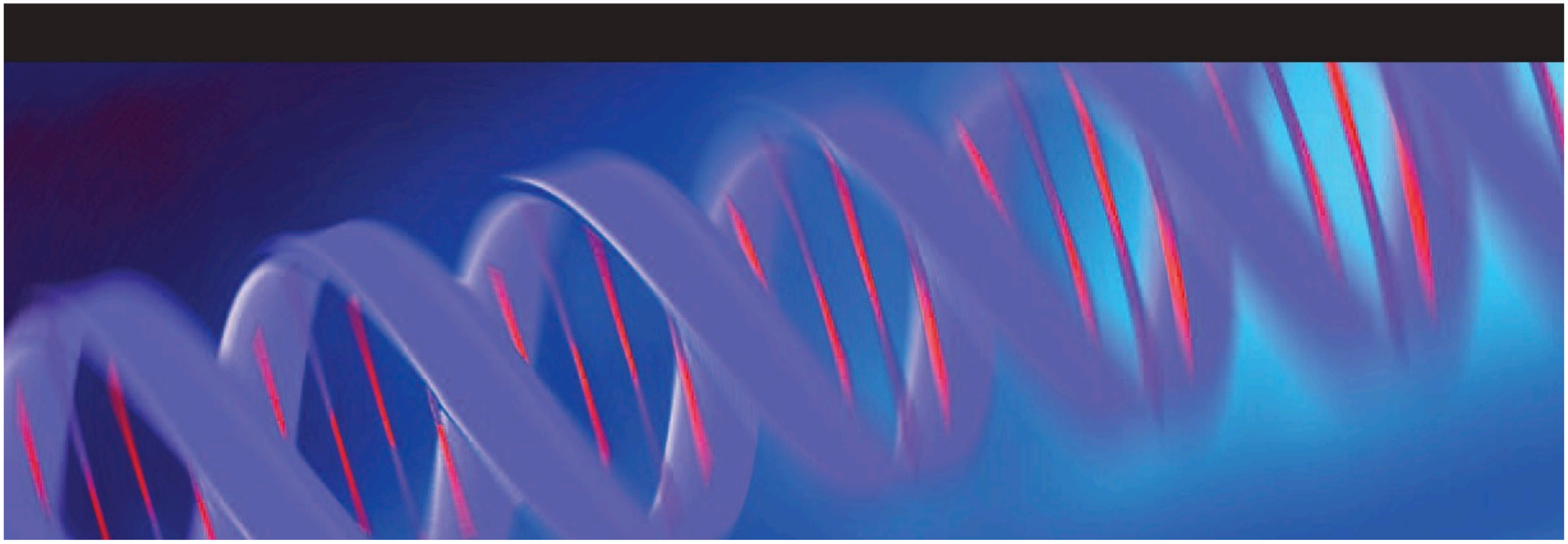
AAAS

AP Biology is Changing to Match Our Design

AP® BIOLOGY

Curriculum Framework

2012–2013



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