What Should High School Students Do to Prepare for a Successful (College) Career?

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Biology Department and **GCAT**

DAVIDSON

Asheville School
September 22, 2012

Outline of Presentation

What skills do HS students need to develop for college?

How can you teach these skills to your students?

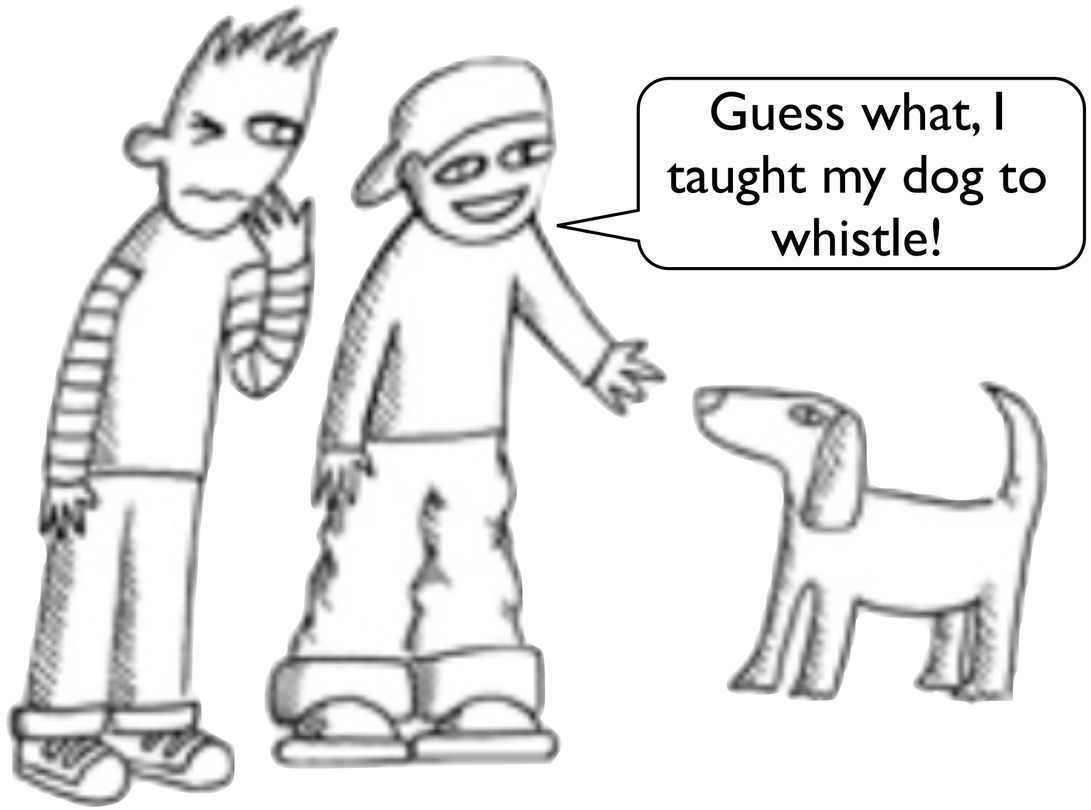
What's wrong with typical biology (science) course?

How has AP Biology addressed these challenges?

What have we developed that you can use?

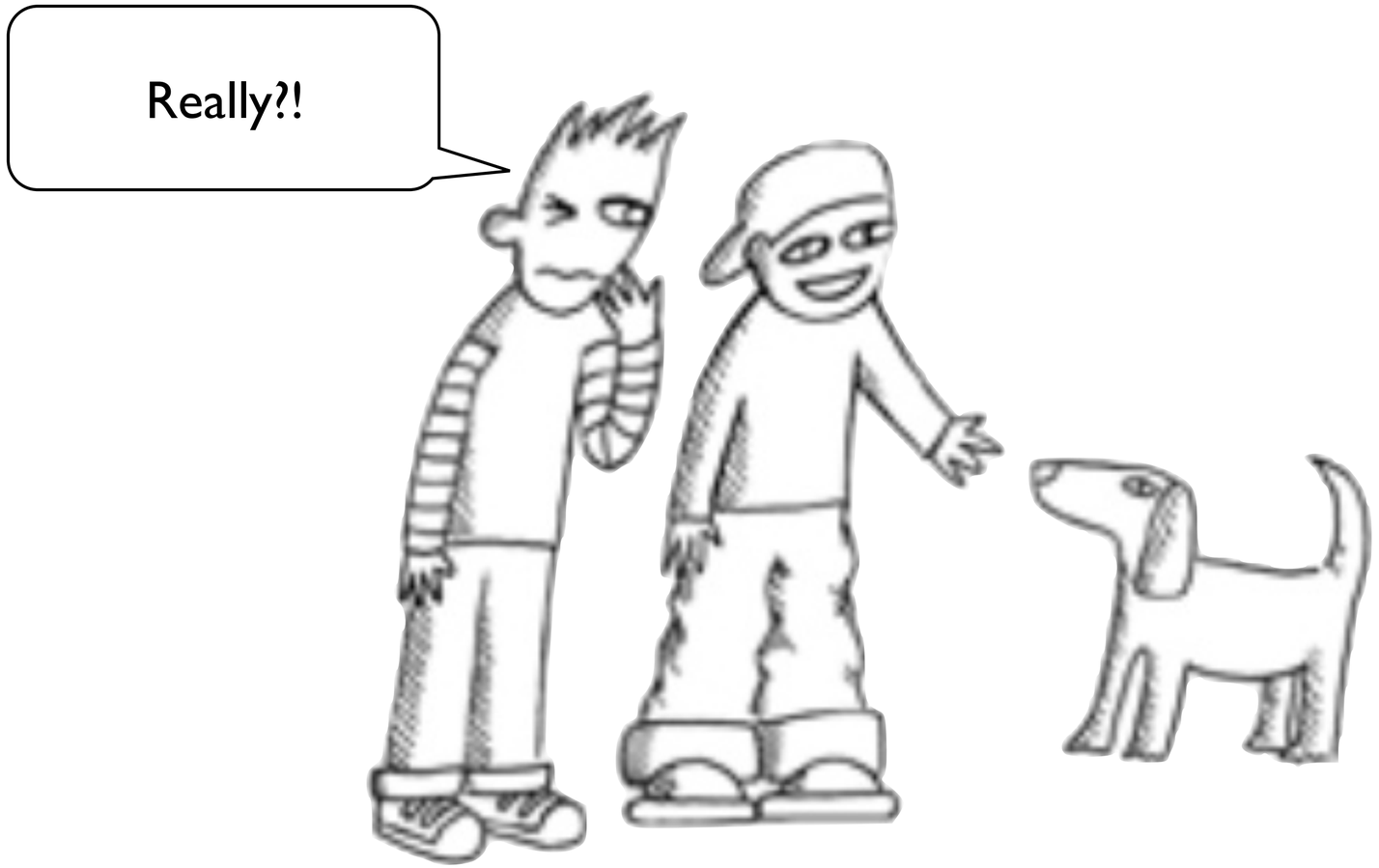
What evidence supports our approach?

Teaching *vs* Learning



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

Teaching *vs* Learning



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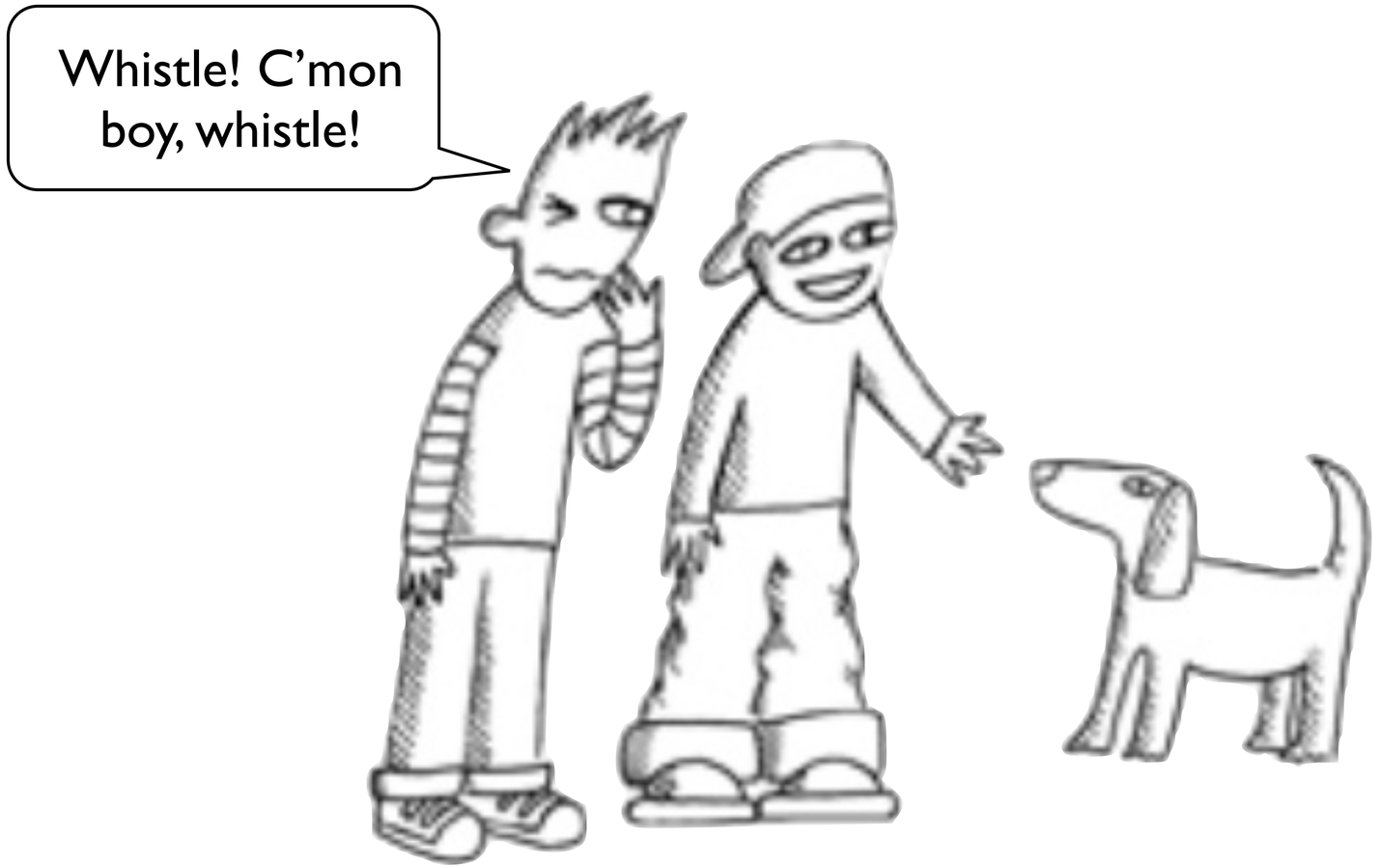

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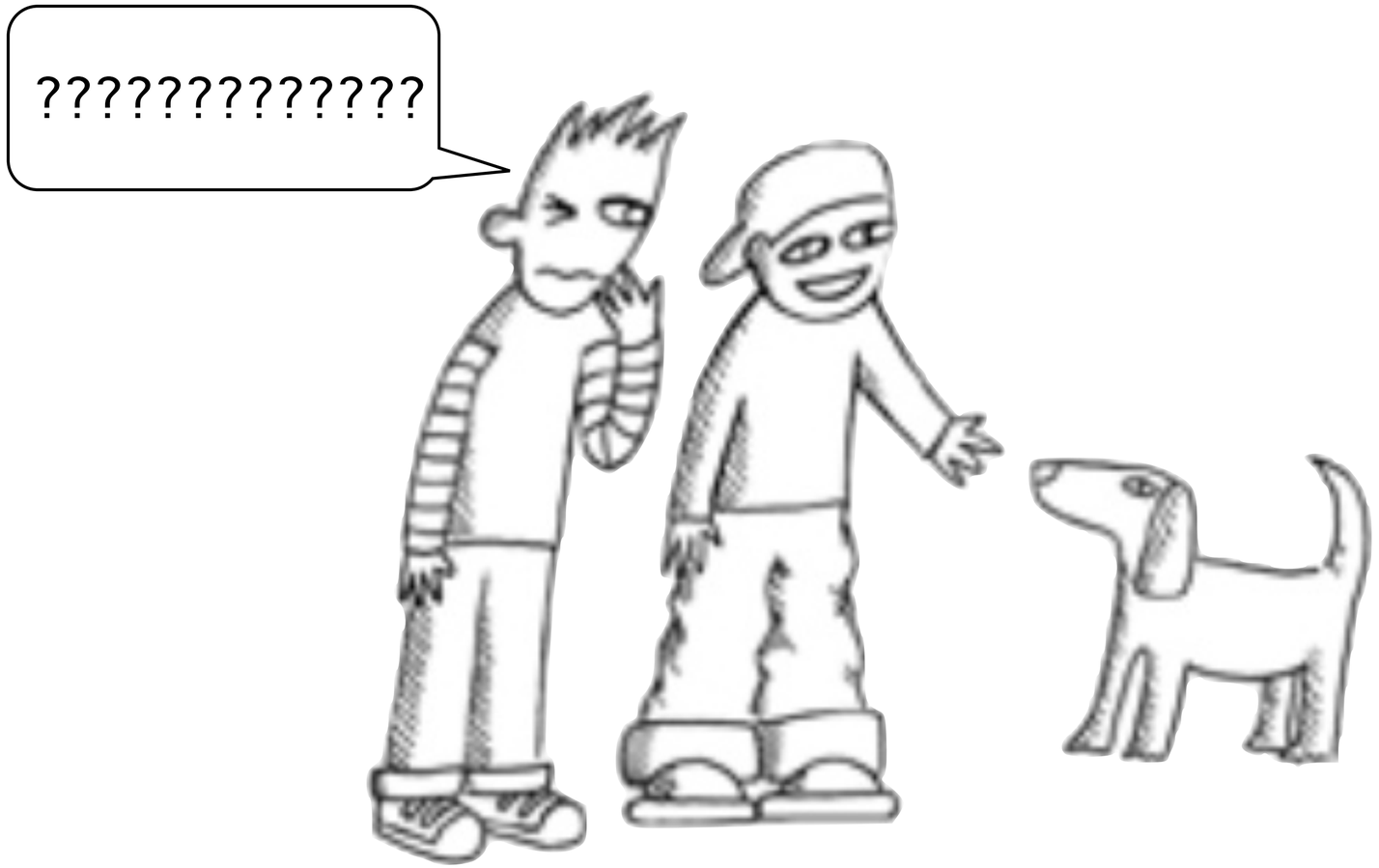

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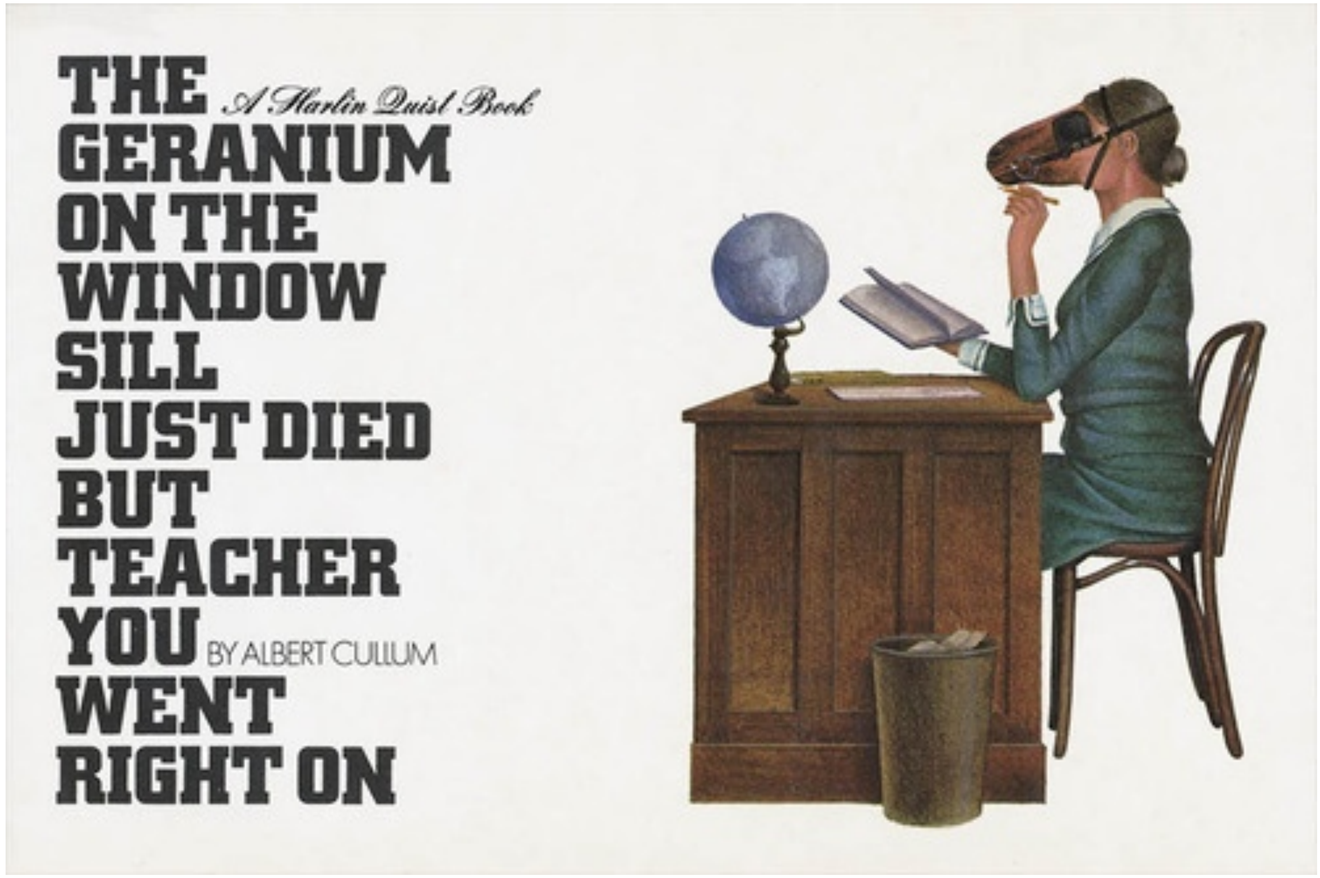


"We have to remember that education is not about how we teacah but how children learn."

Albert Cullum

Why do students go to college?

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

Are they 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 they 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

Who is John Taylor Gotto?

(prize for first correct answer)

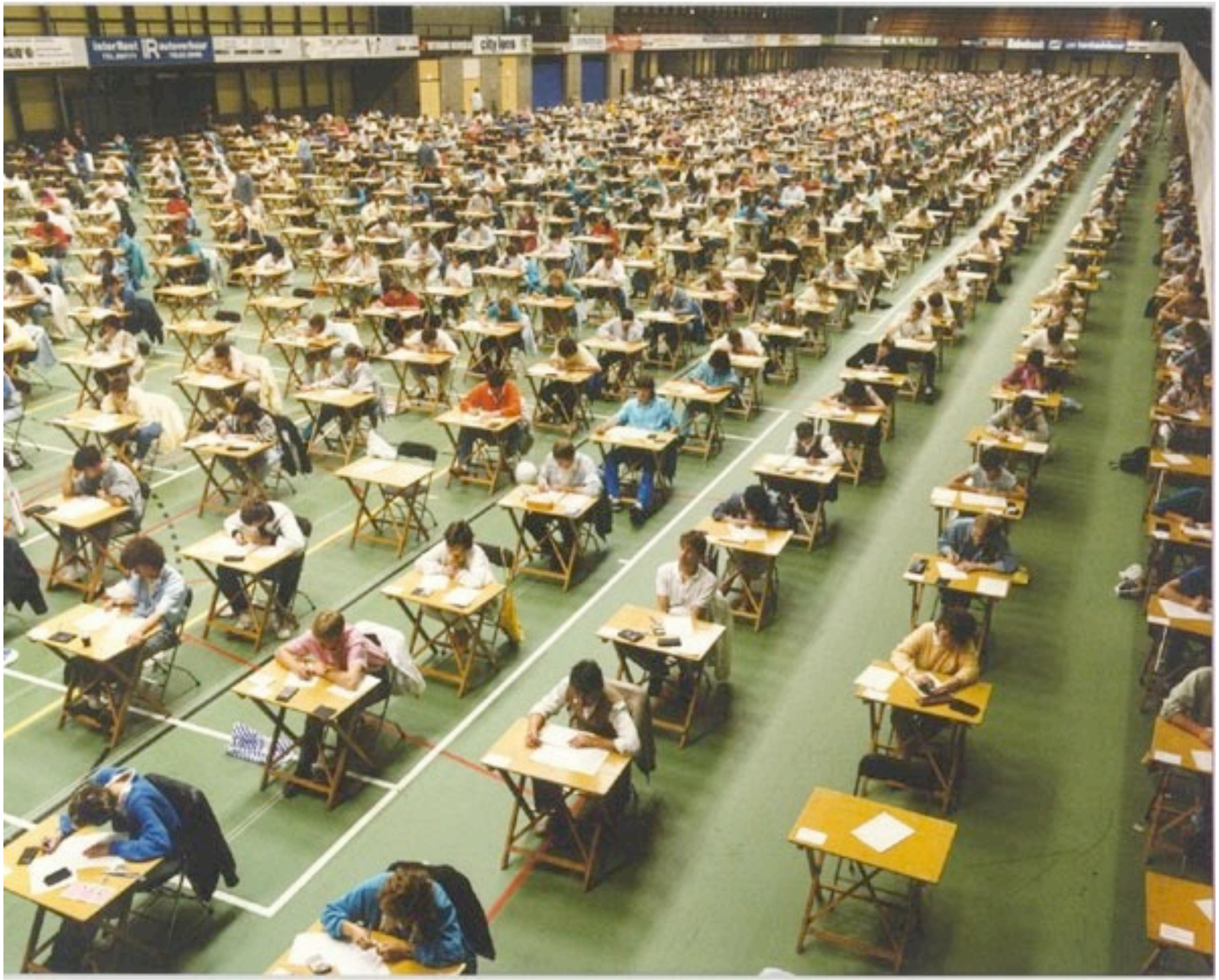
Why is it that students can look up this,
but when they hit a word in their reading,
they ask the teacher what it means?

Ask your students to describe the best learning experience they've had outside of school.

Ask your students to describe the best educational experience they've had in school.

Listen to Your Students (data)

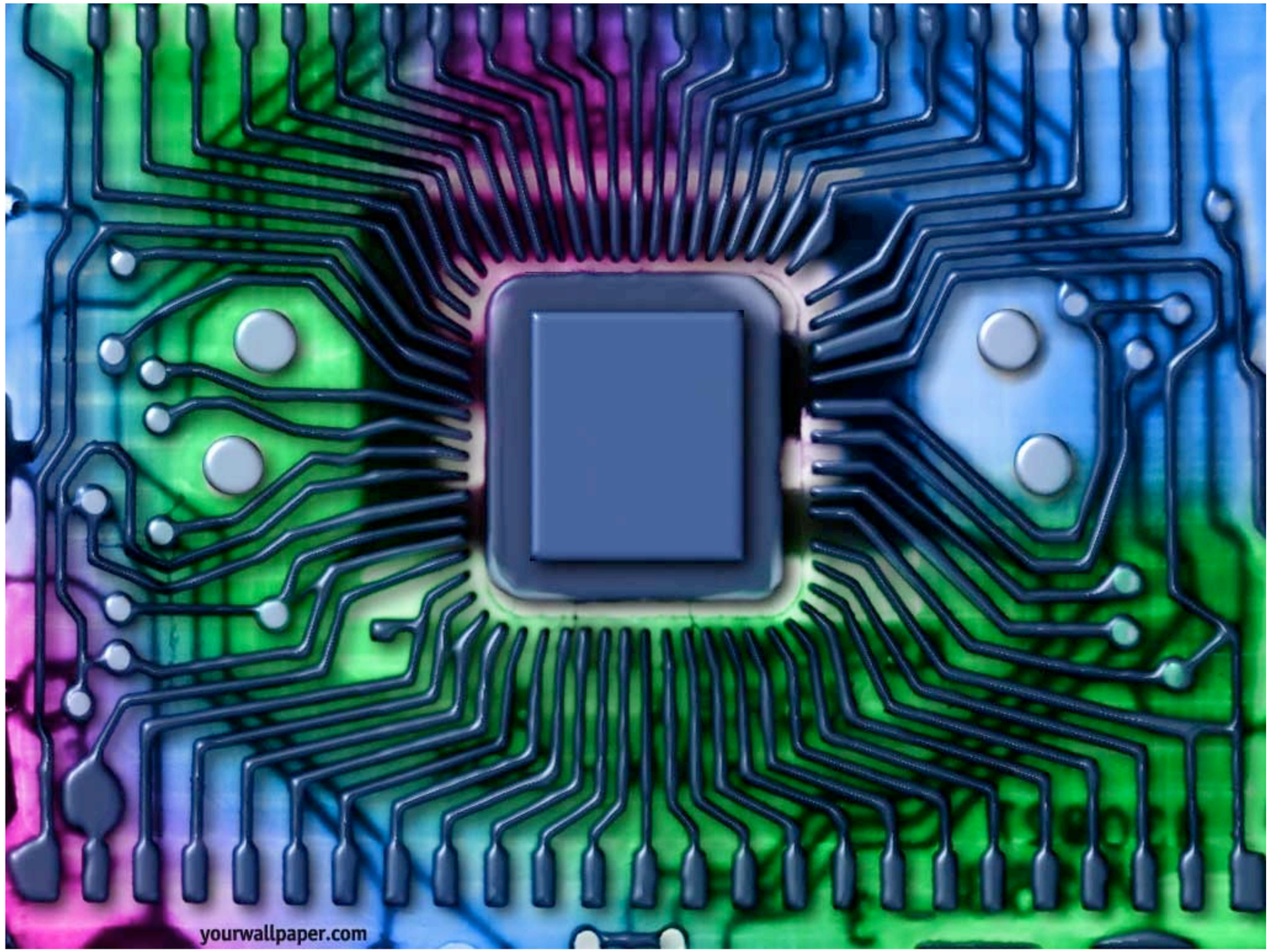
Use the best, and do not emulate the worst practices.



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?

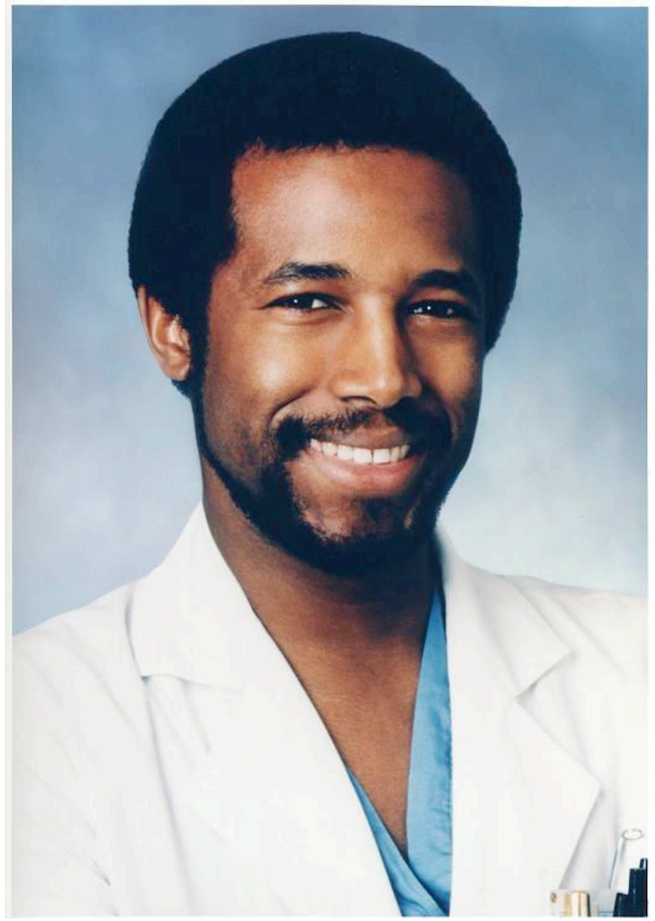


http://yourwallpaper.com/abstract/circuitboard01-1024.phtml

Why try to compete with computers by memorizing?

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

In college, students should enhance their skills that computers cannot perform.



Dr. Ben Carson

Edgar Degas

Beyonce

JK Rowling

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.

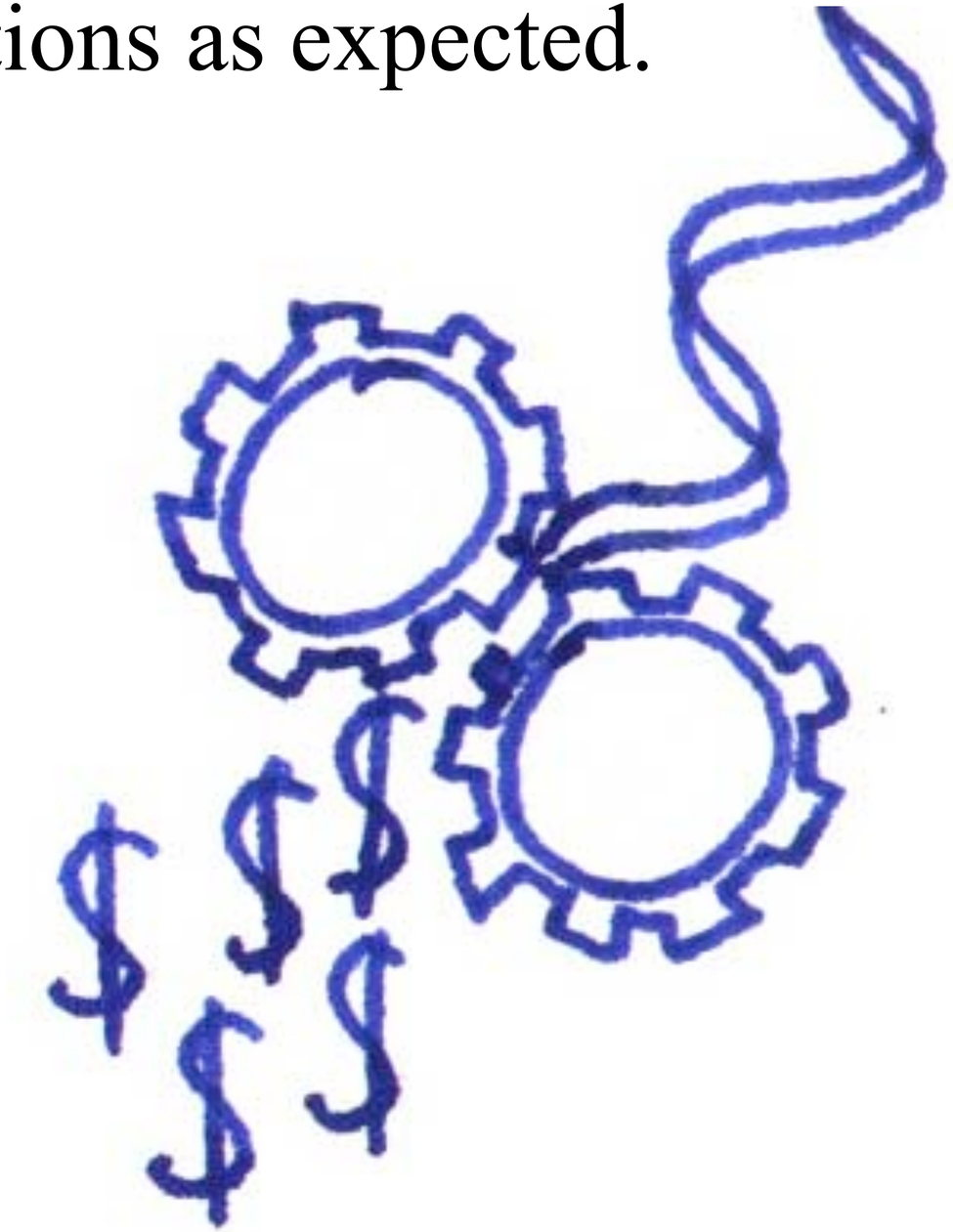
http://usgovinfo.about.com/od/censusandstatistics/a/collegepays.htm

Students must be allowed to take charge of their own education.

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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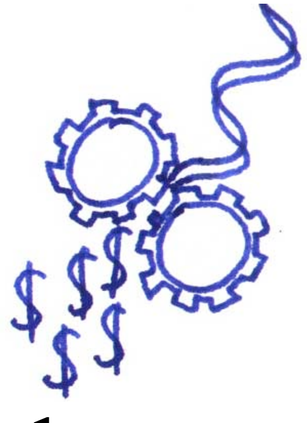
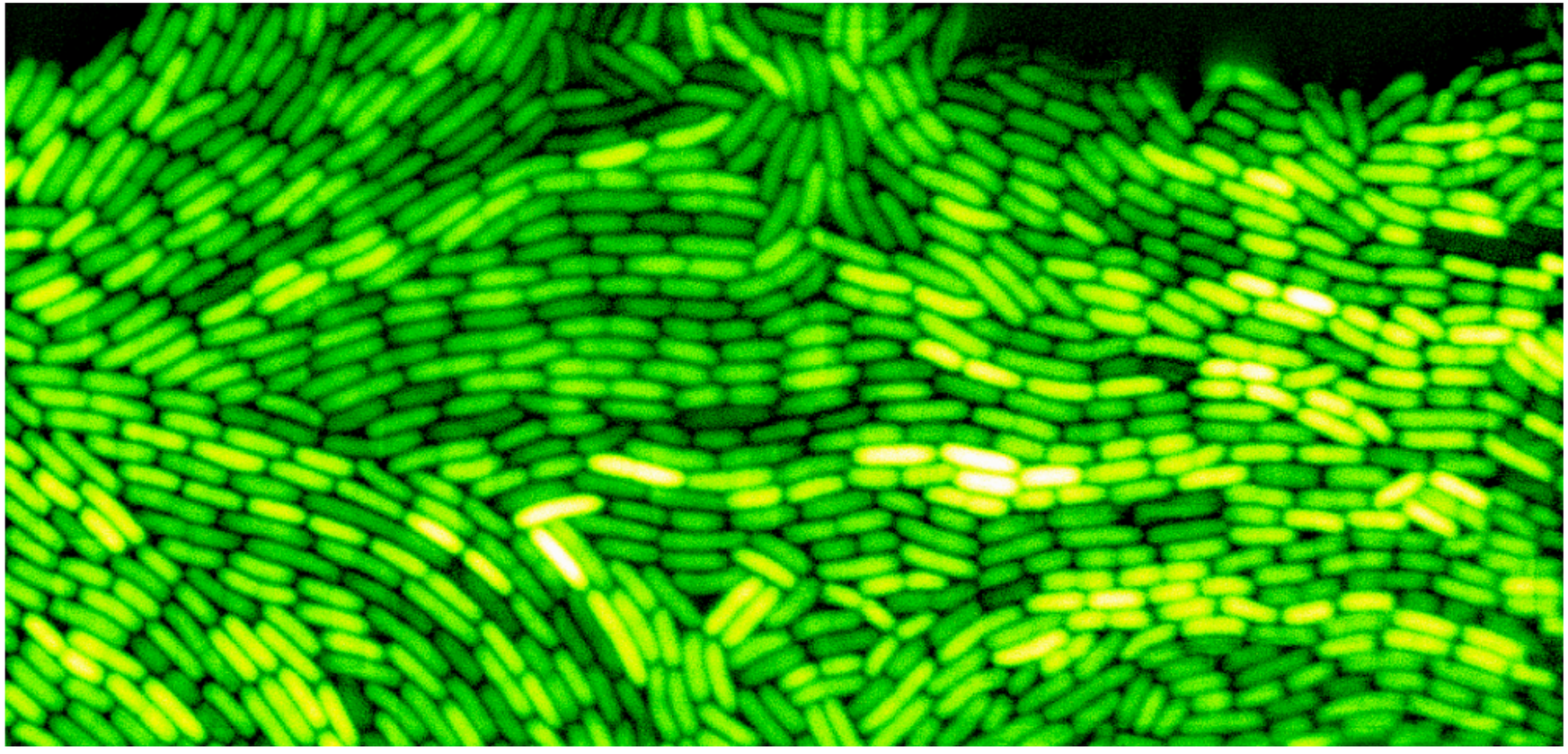
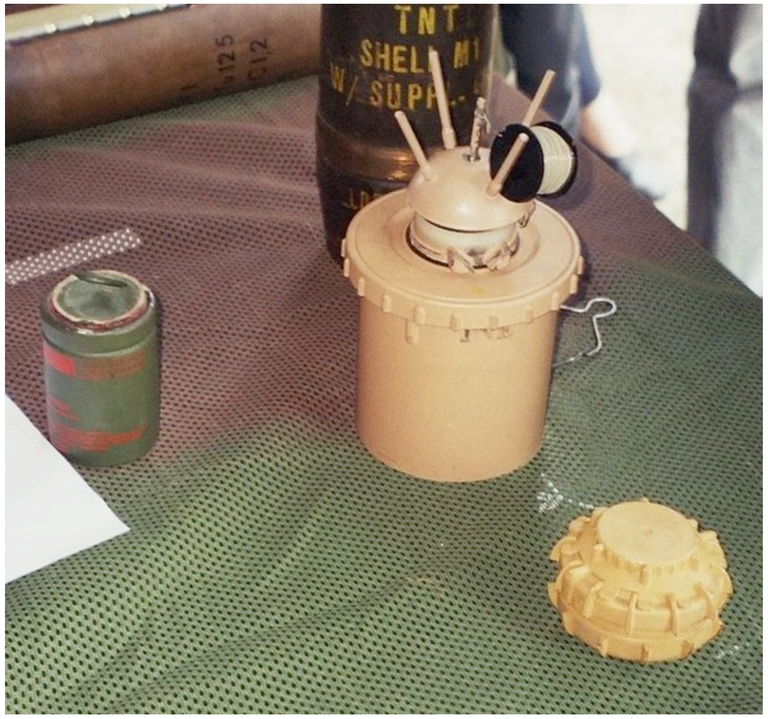


Win #2: your design fails but you uncover basic biology



Real World Applications of Synthetic Biology

Land Mine Detection



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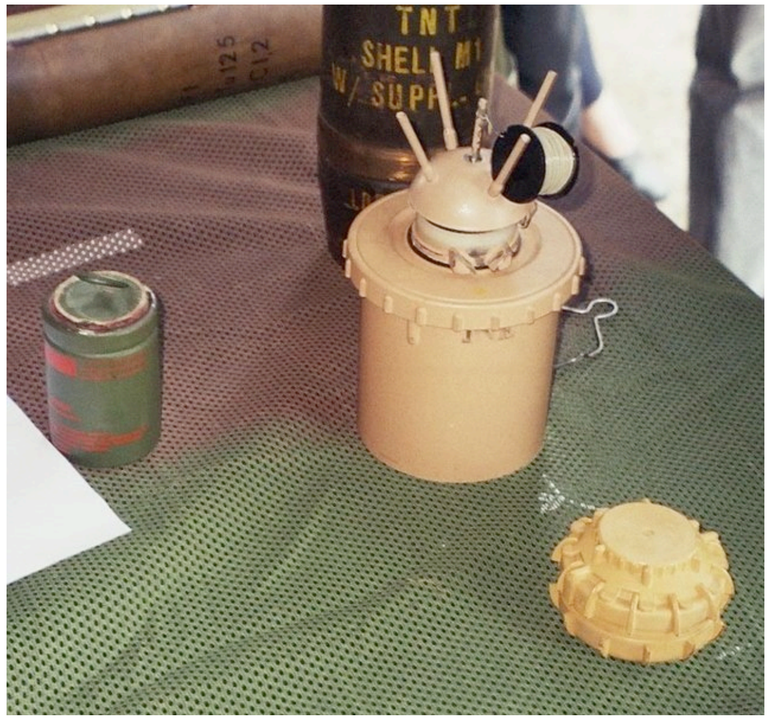

Synthetic Biology
Land Mine Detection

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*

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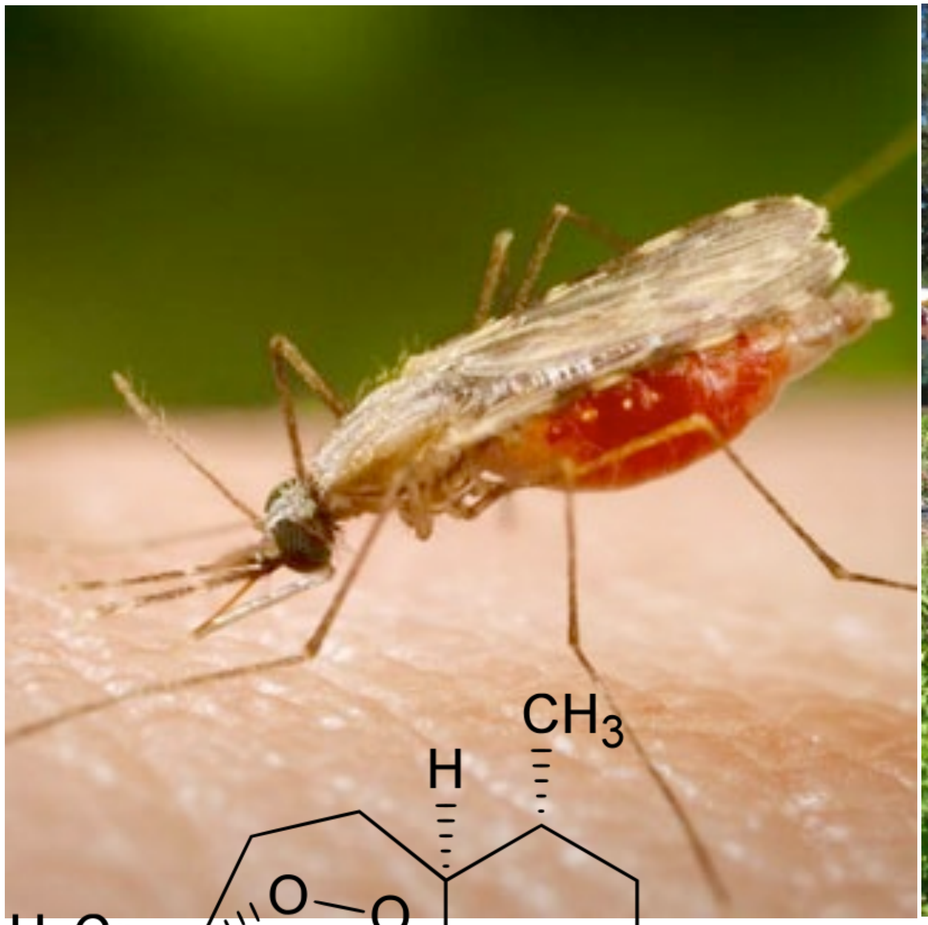
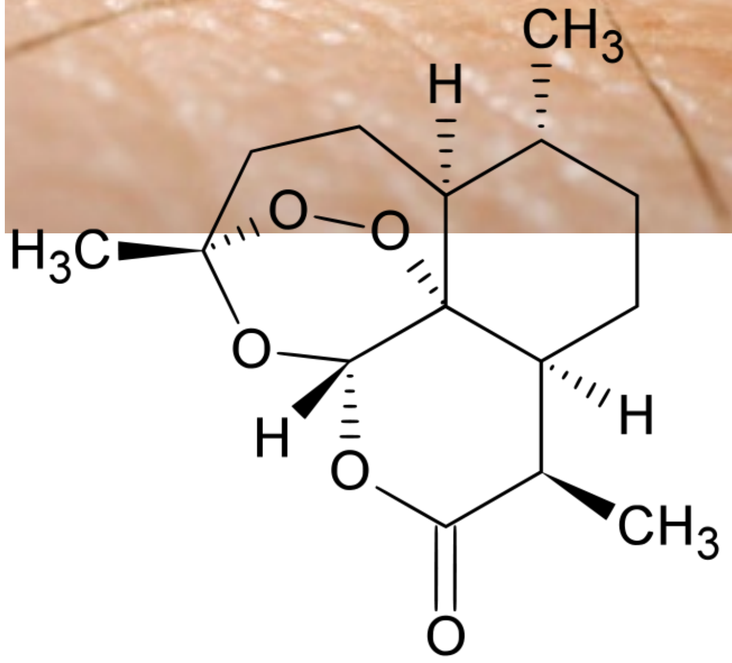
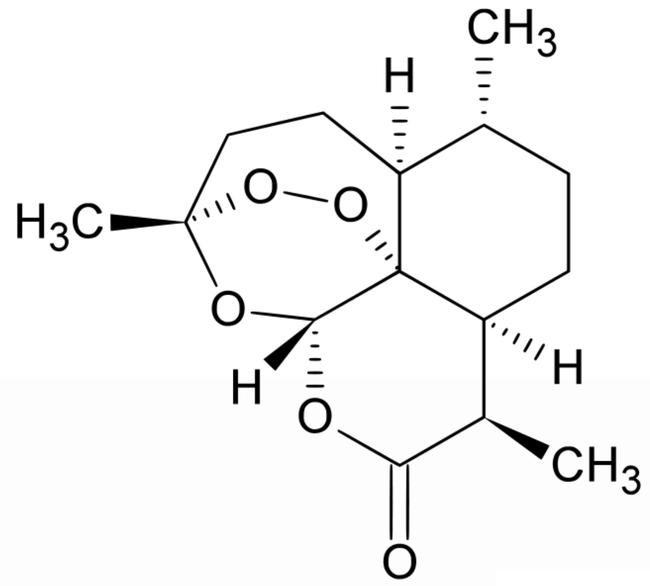
Production of Medicines



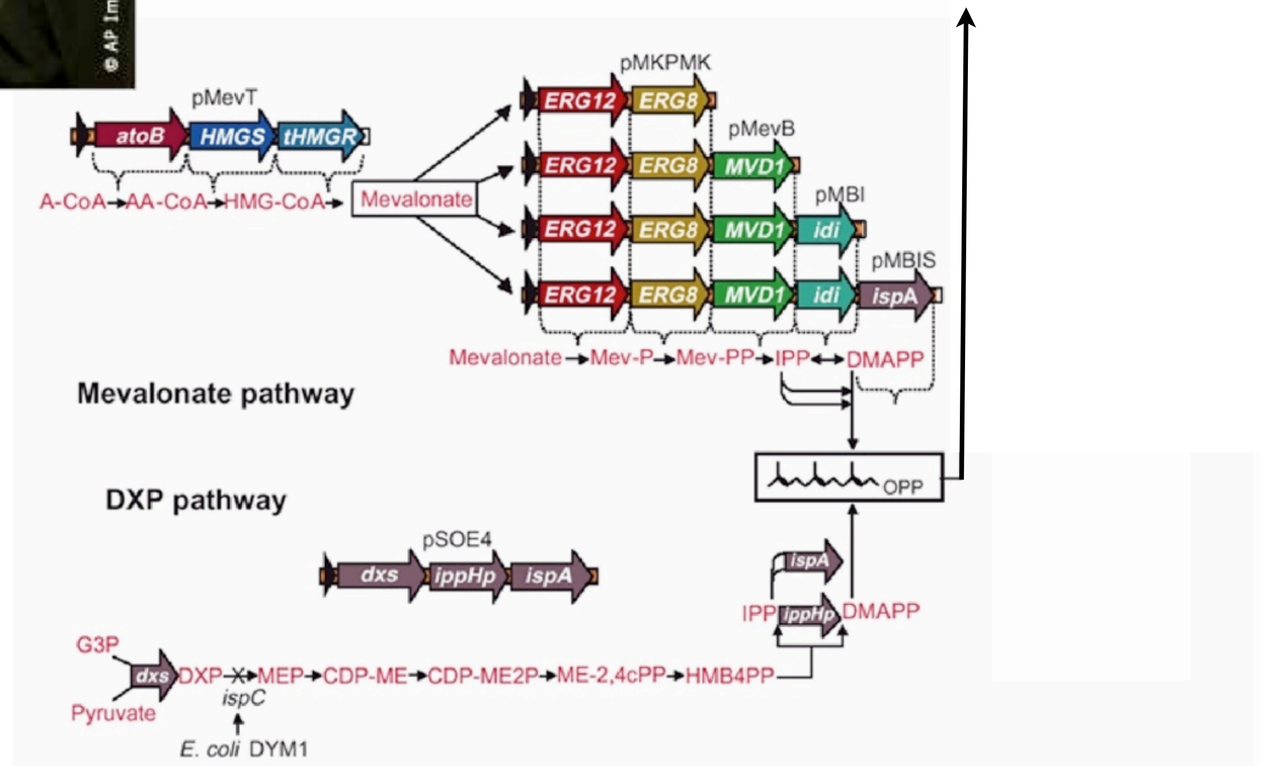


$1 per pill

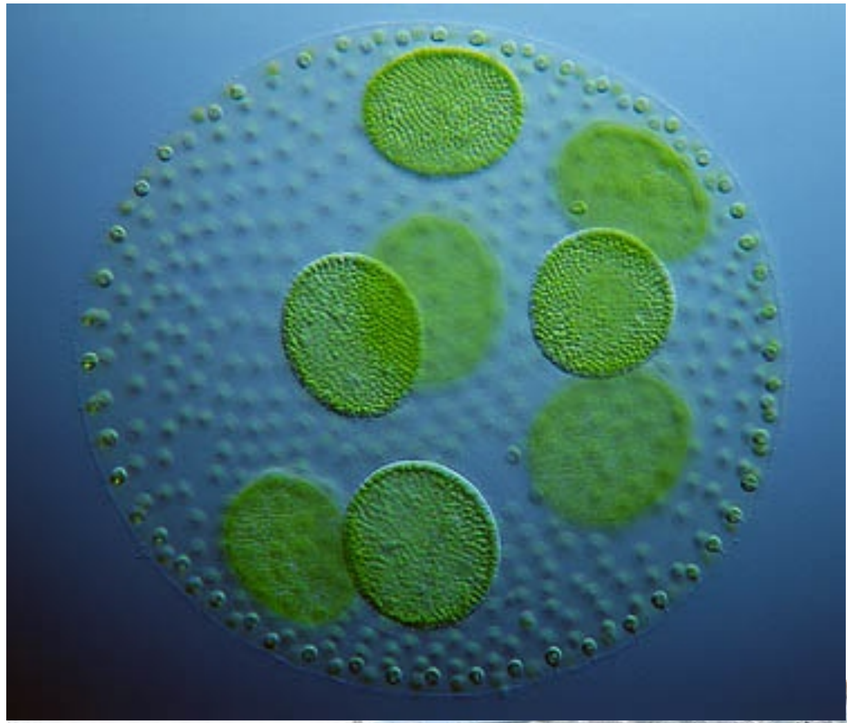
Production of Medicines



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

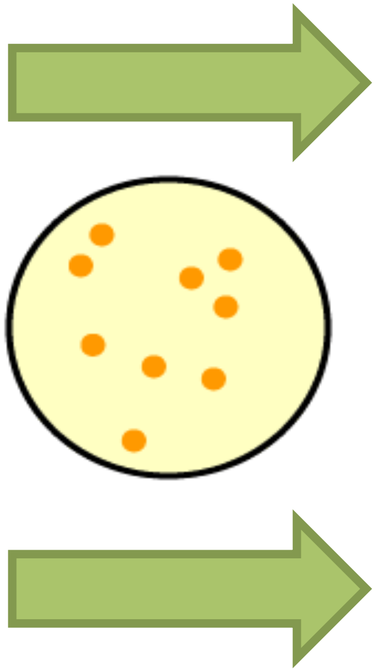
Building Bacterial Computers

Can we build a bacterial cryptographic hash function?

What is a hash function?

HGTf34$2

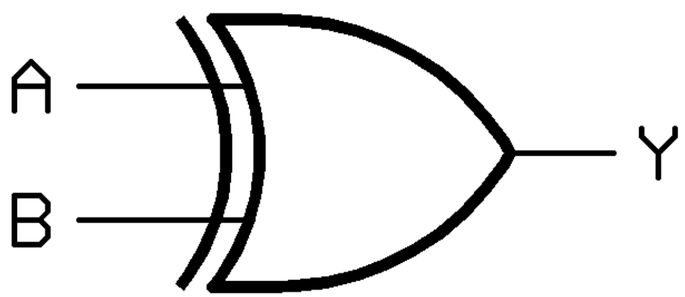
Can Bacteria Perform a Hash Function?



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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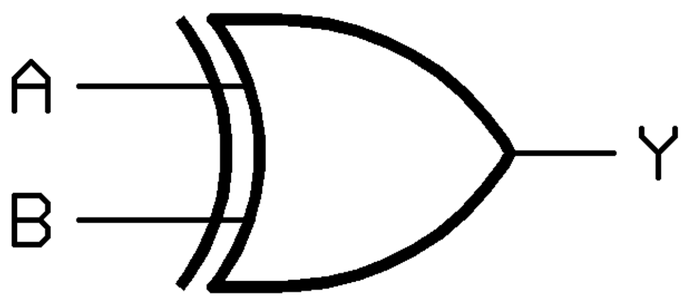

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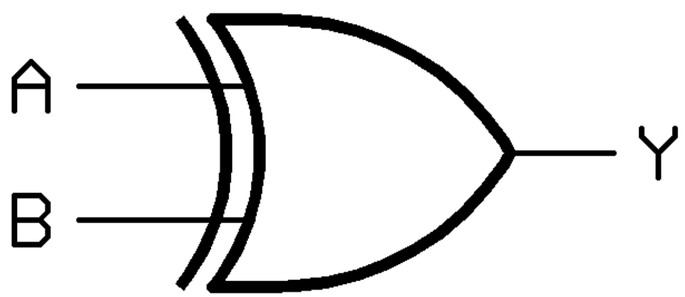
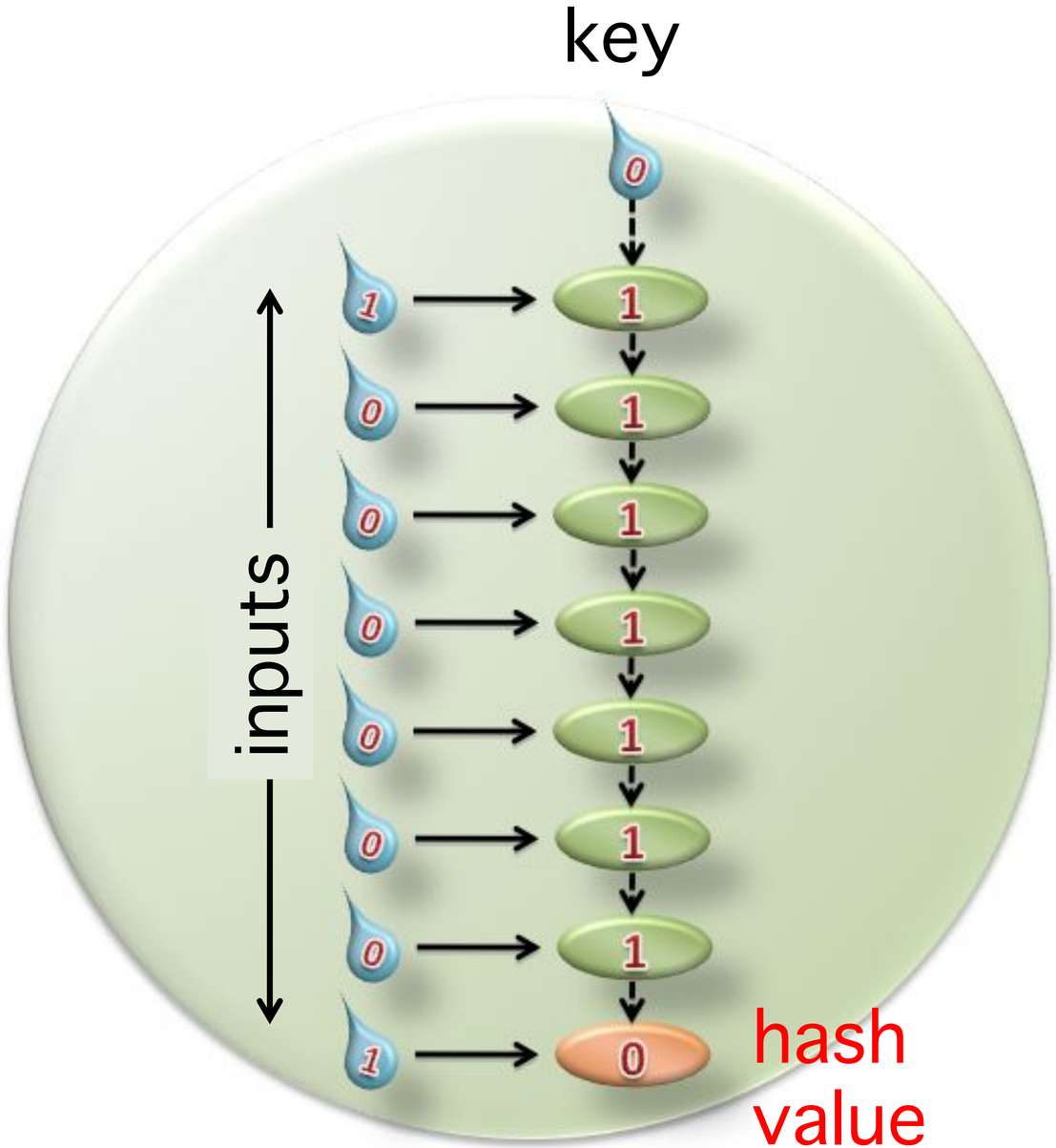


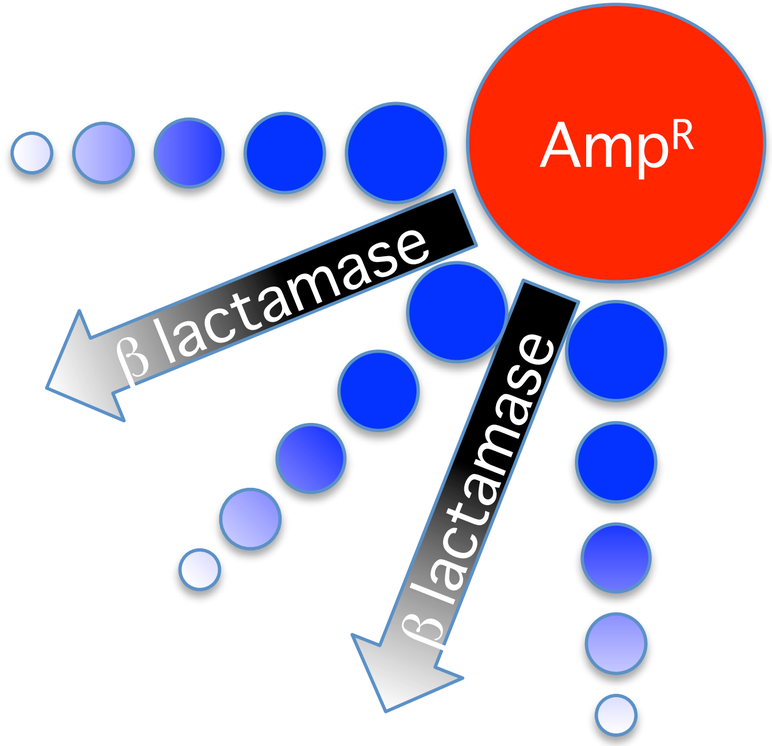
Design Linear Bacterial Hash Function

CAB = 010000001

HASH VALUE = 0



Time-Delayed Bacterial Growth



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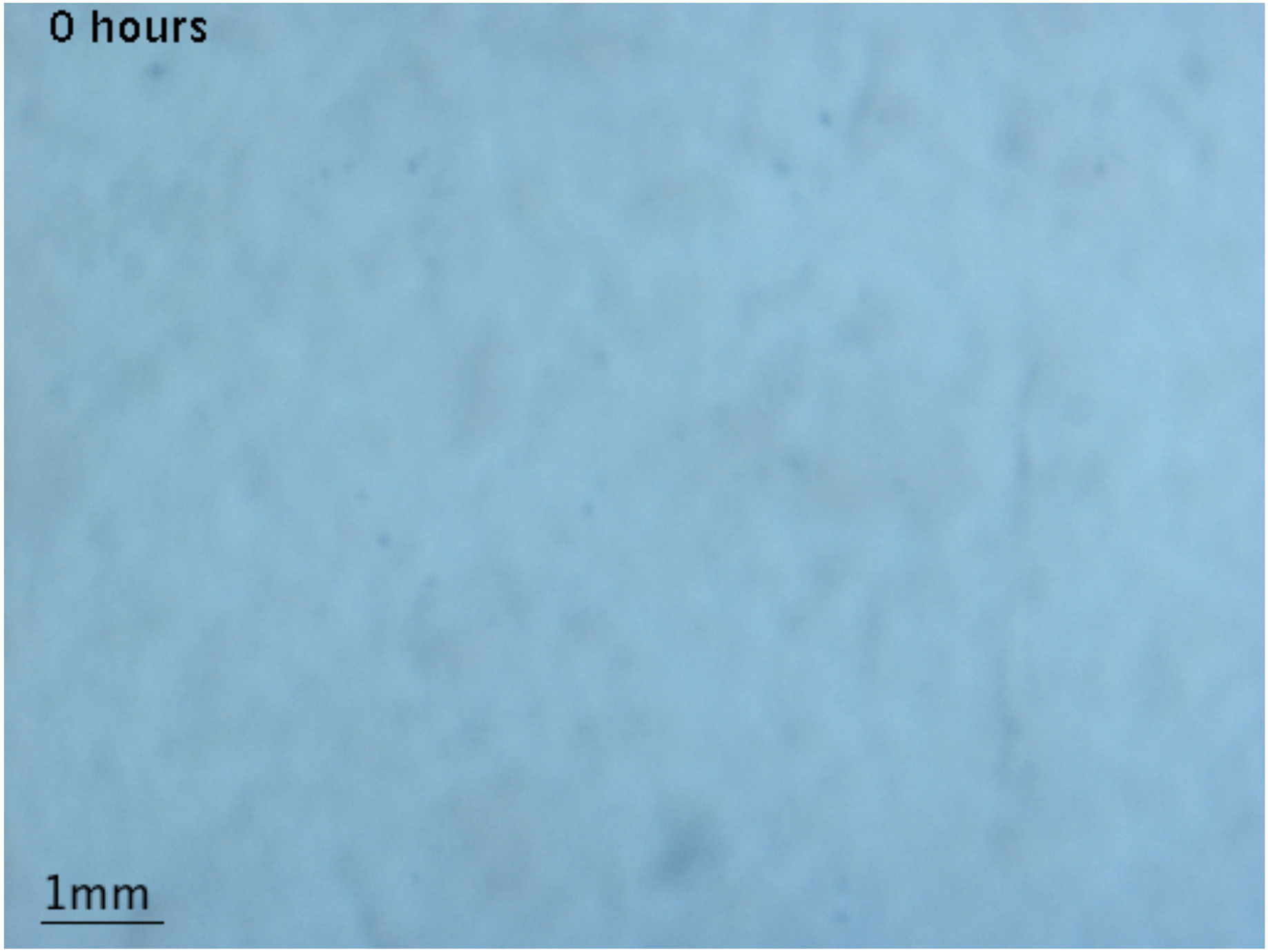
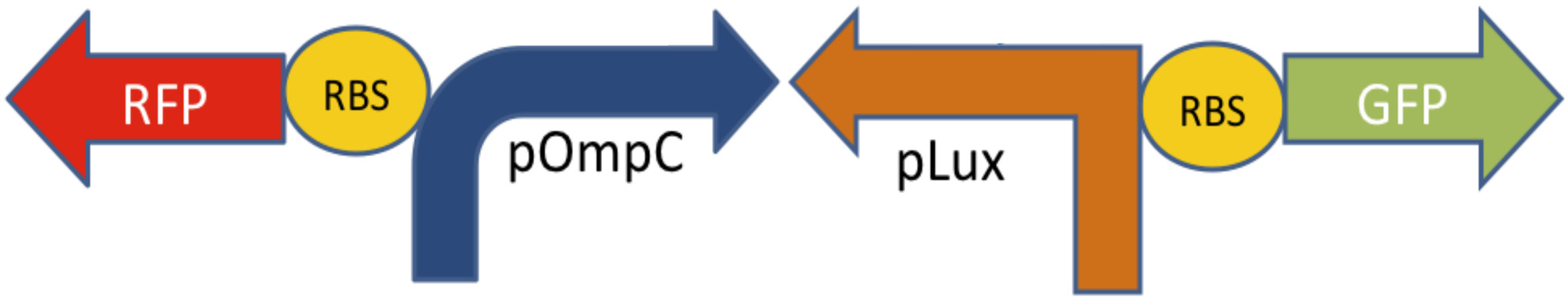


DNA-based XOR Logic Gate



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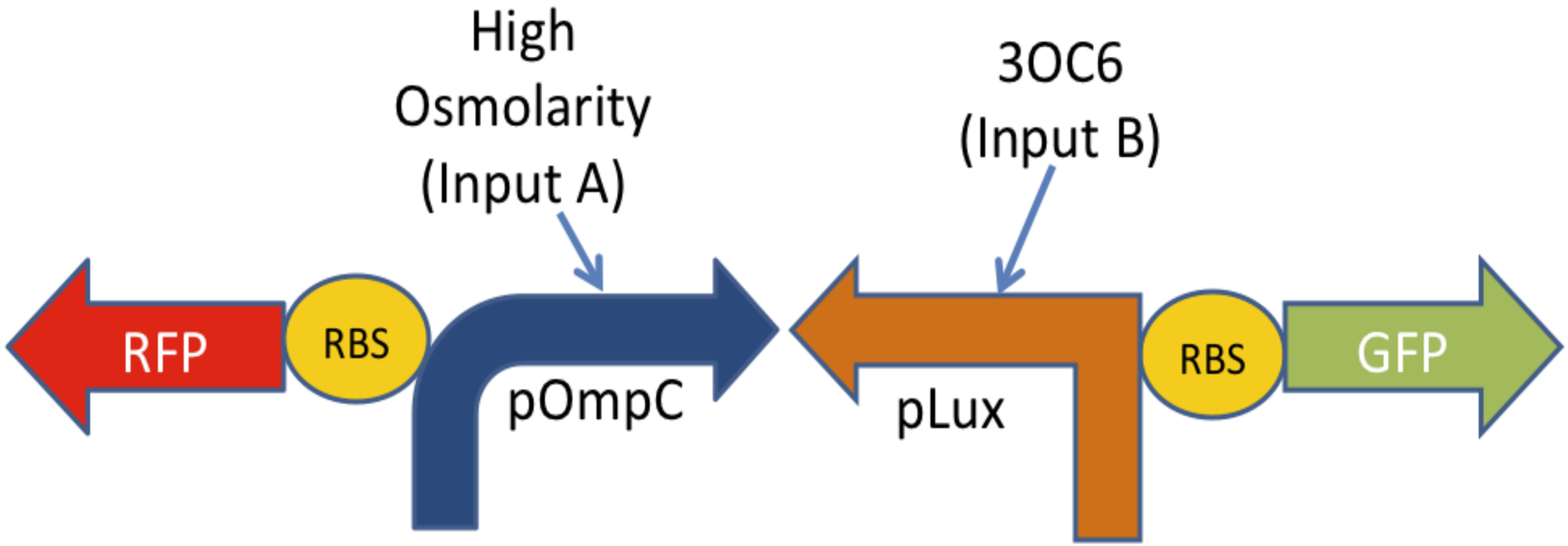

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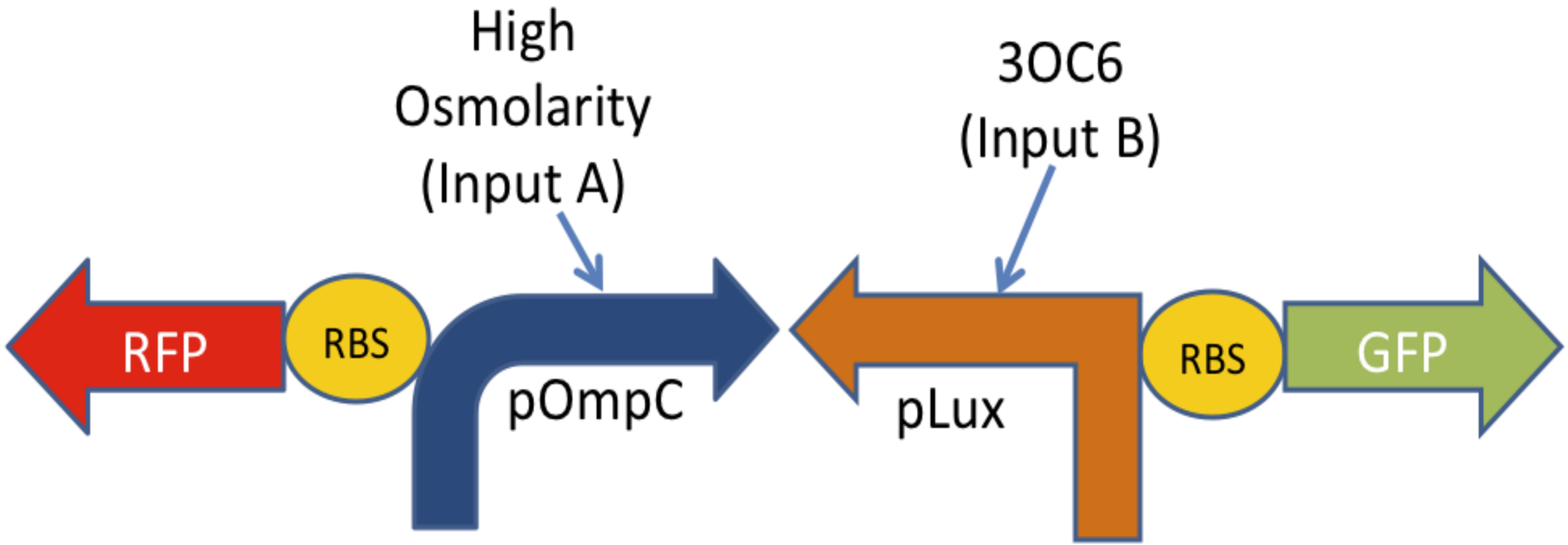
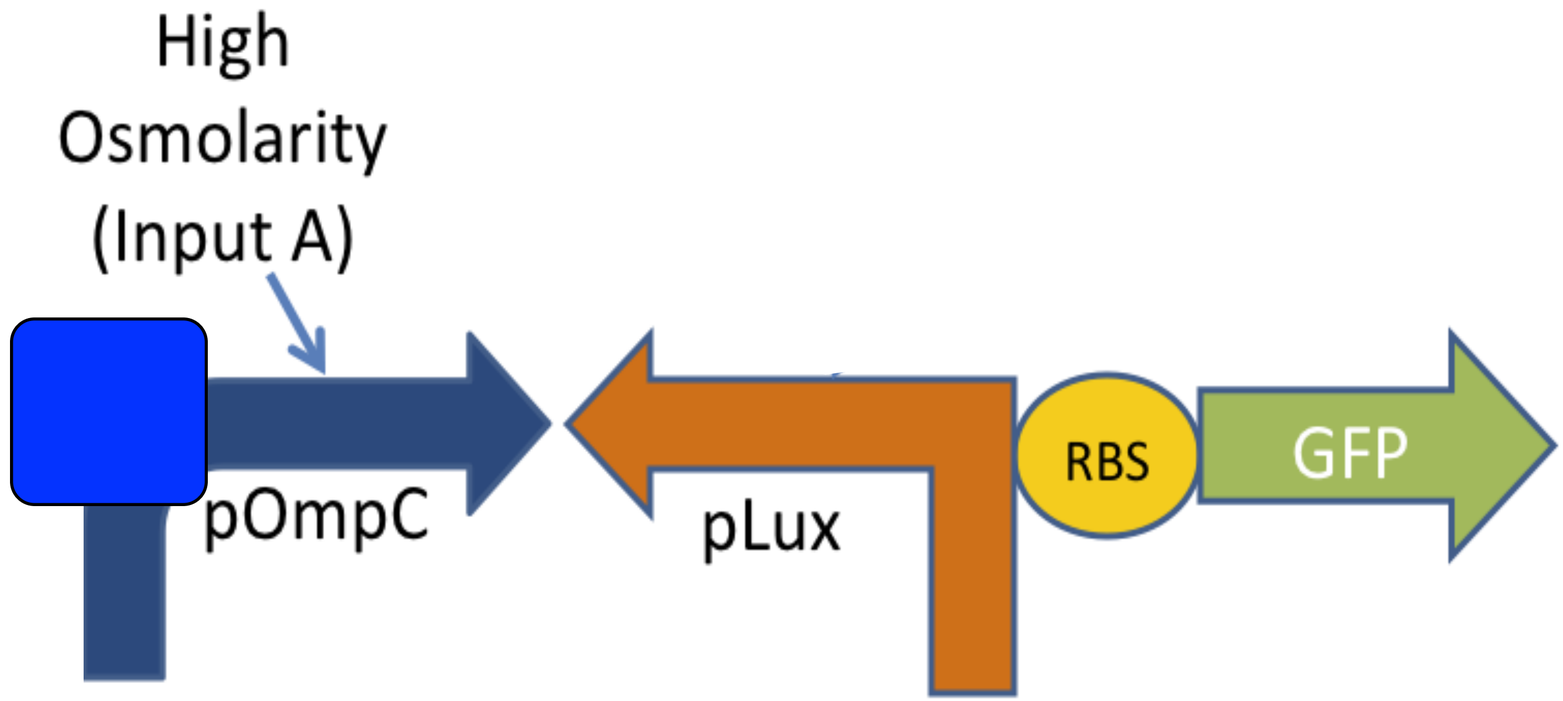


High Osmolarity (Input A)	3OC6 (Input B)	Fluorescence (Output)
0	0	0
1	0	1 (GFP)
0	1	1 (RFP)
1	1	0

DNA-based XOR Logic Gate



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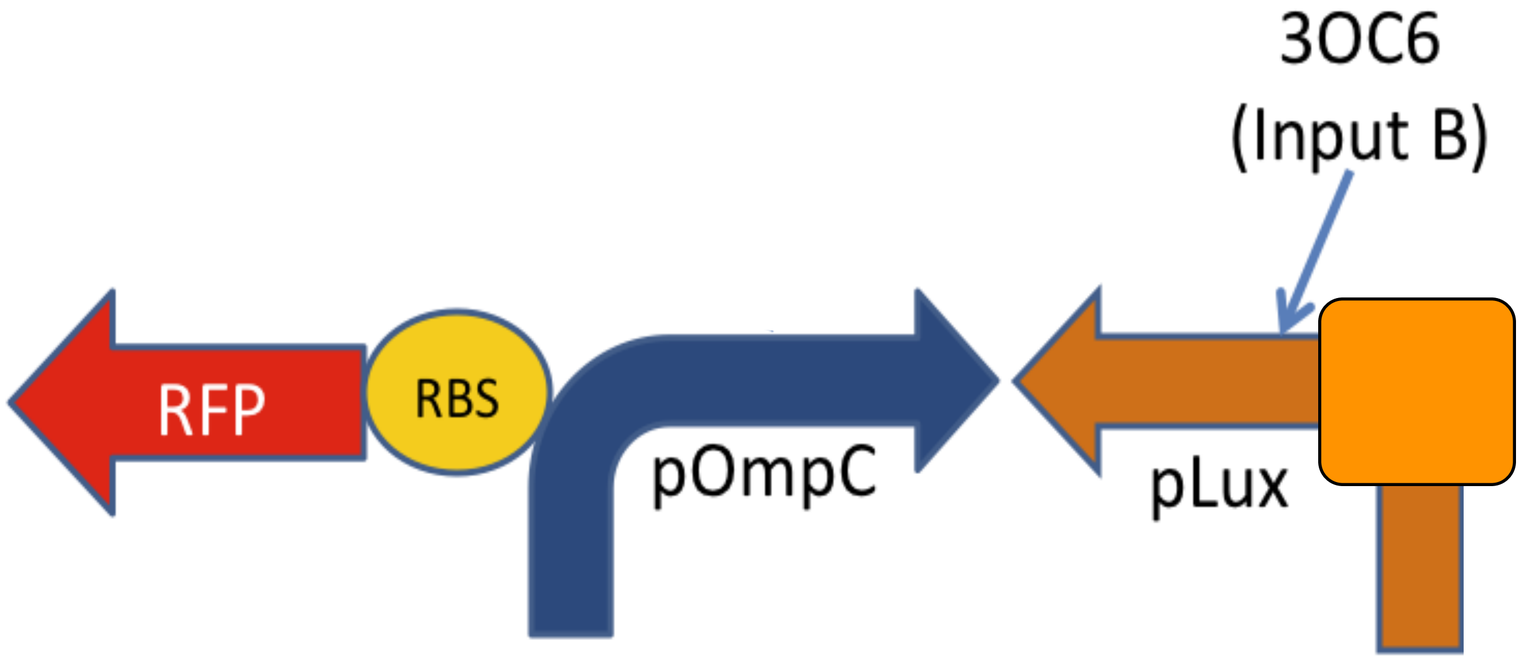

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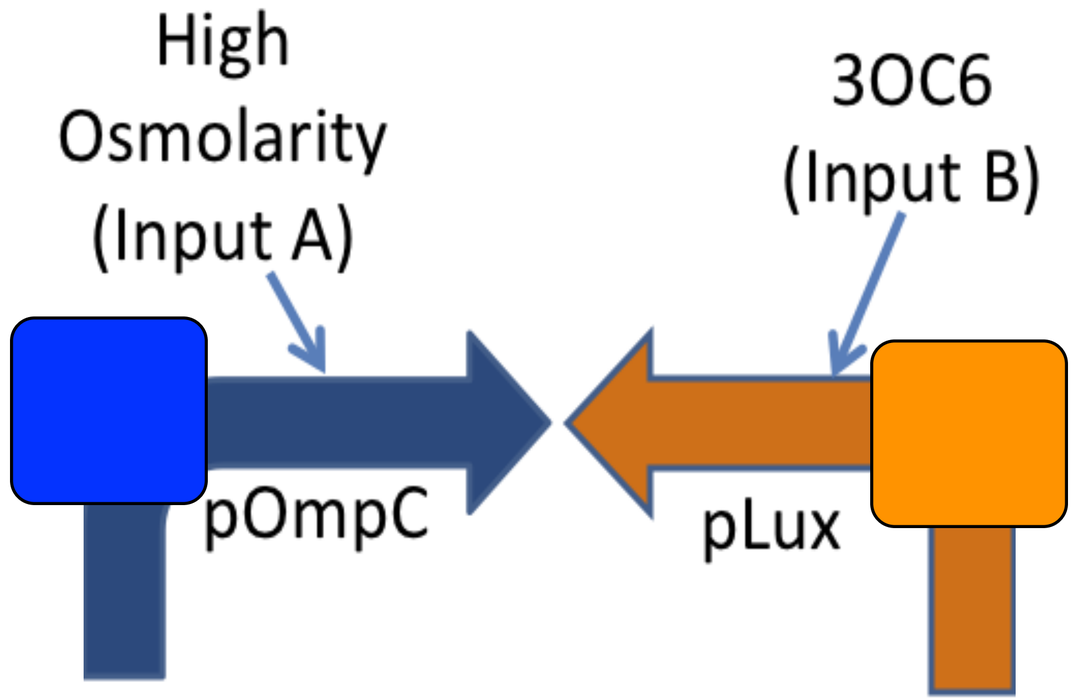

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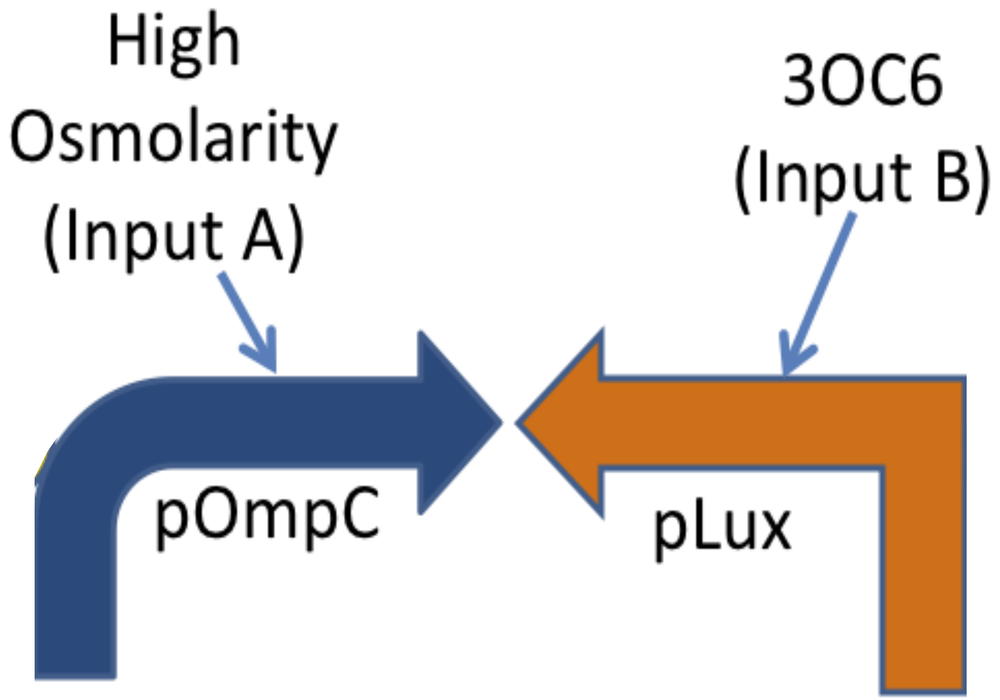

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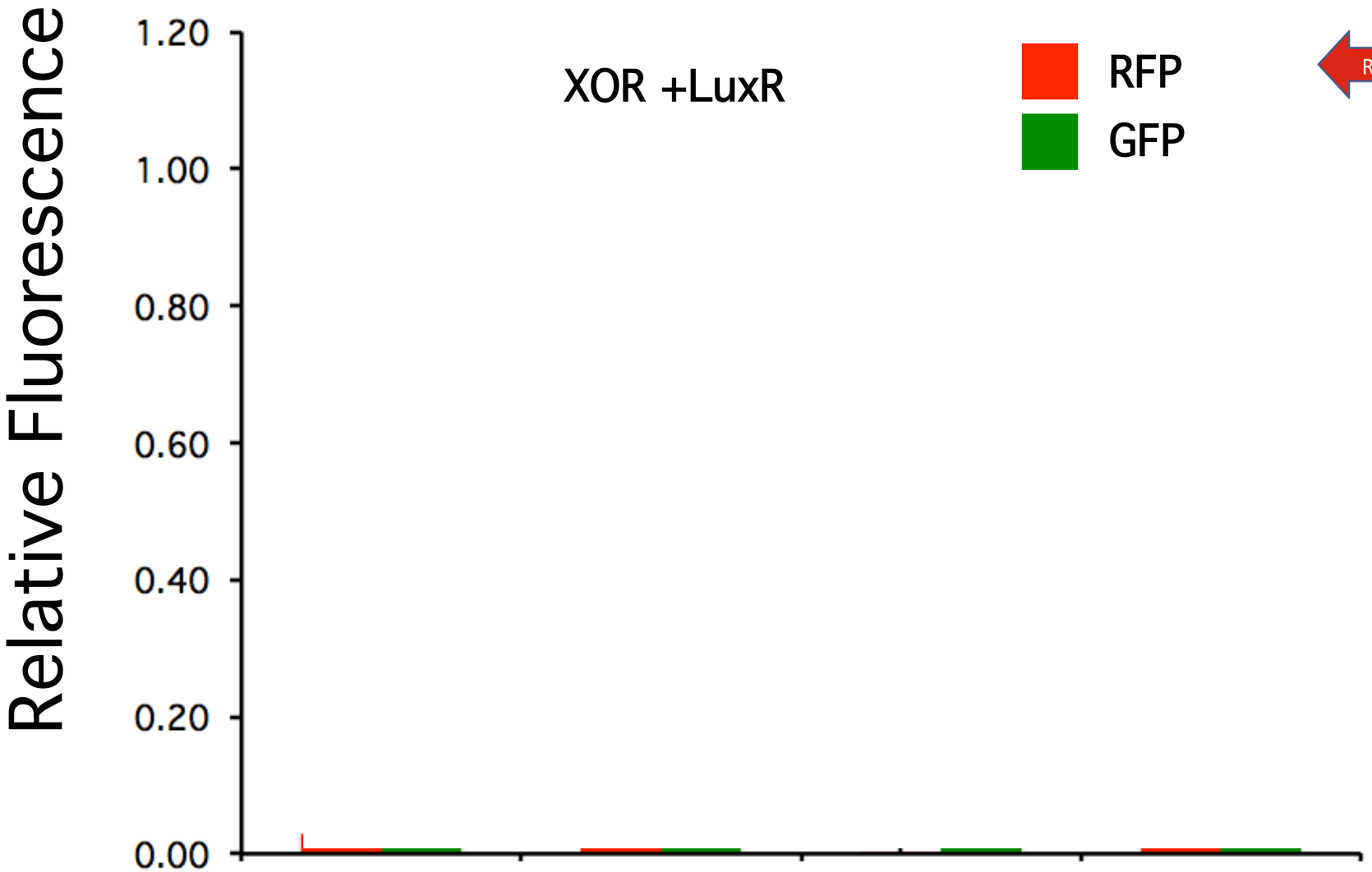
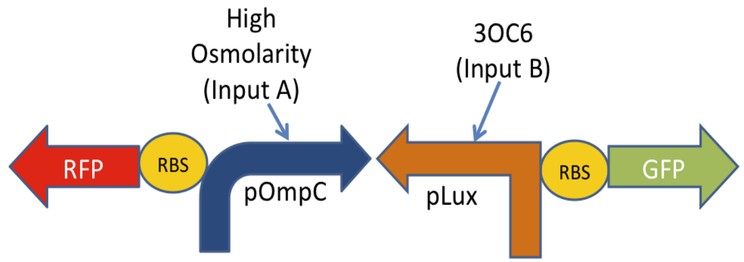
Testing Bacterial XOR Logic Gate



XOR +LuxR

RFP

GFP



LB	-	-	+	+
3OC6	-	+	-	+

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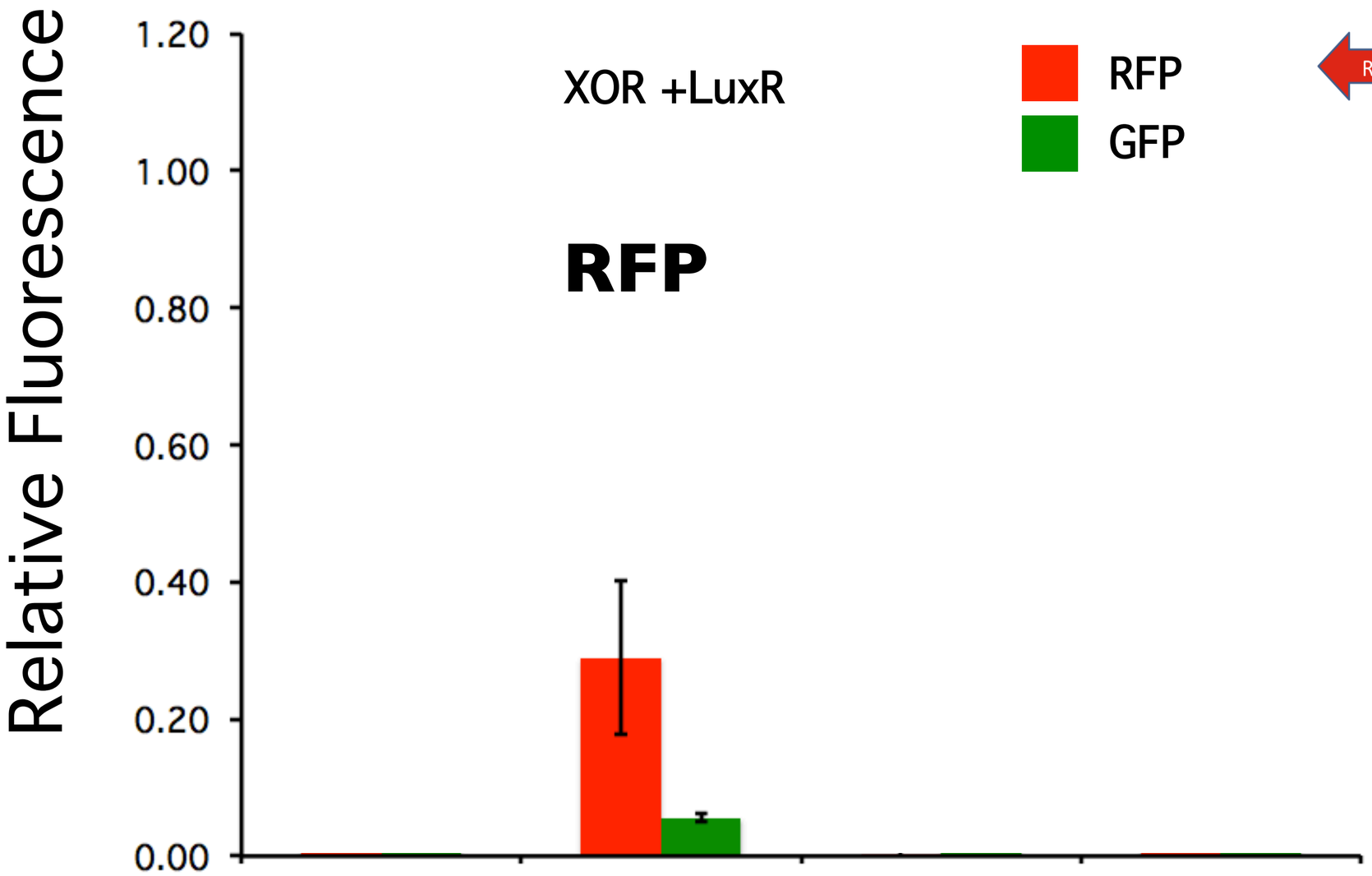
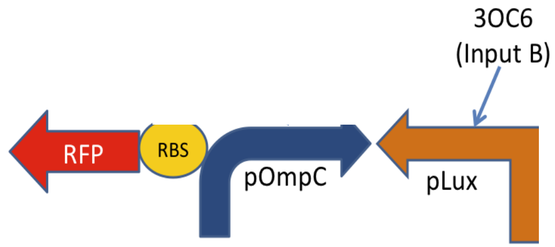


XOR +LuxR

RFP

RFP
GFP



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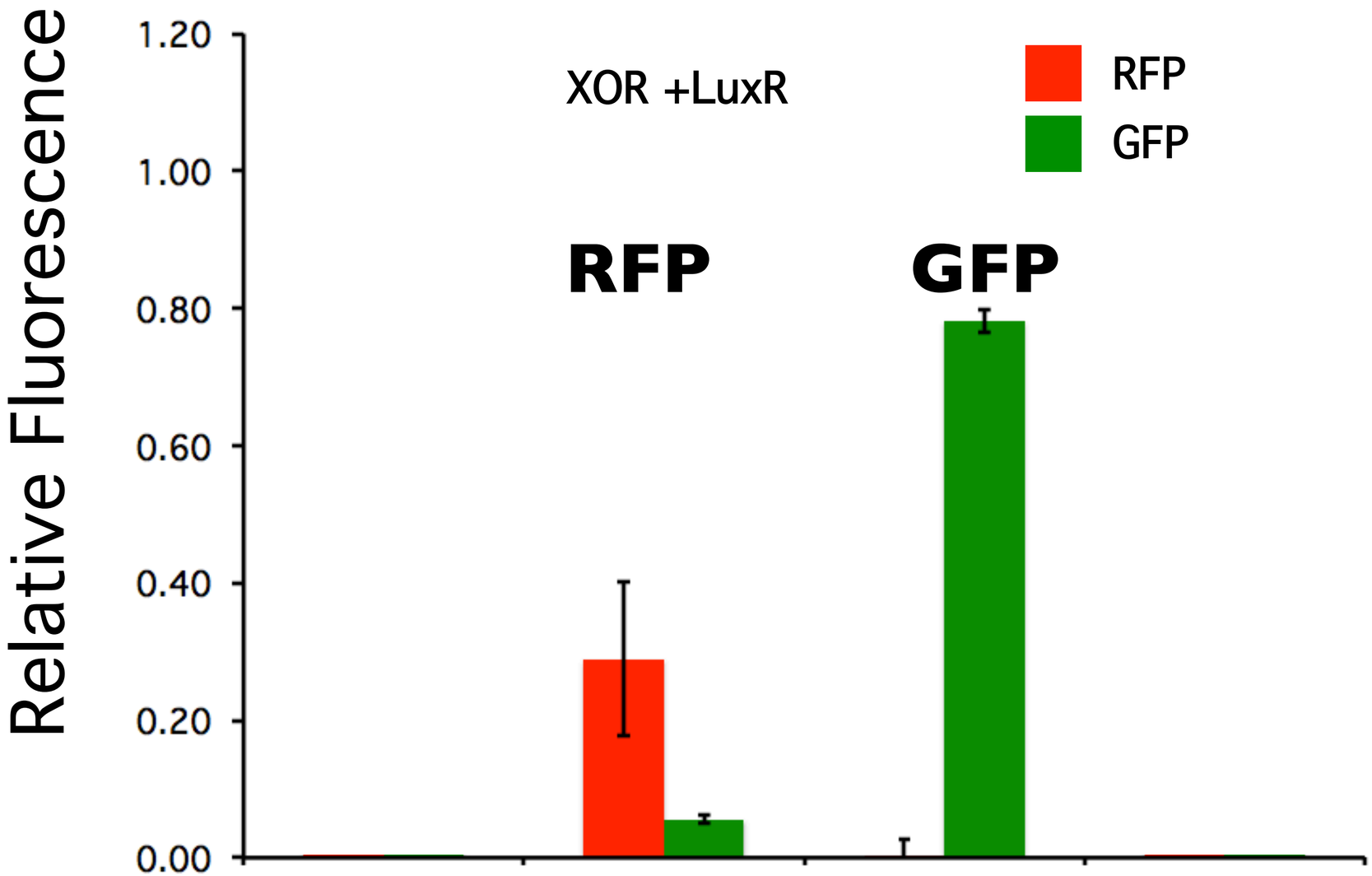

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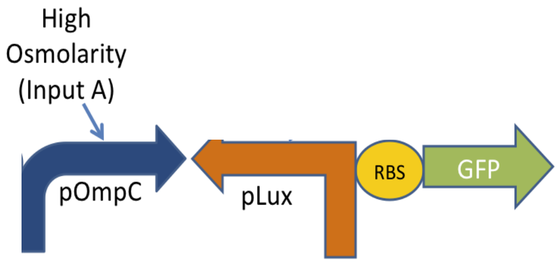
3OC6	-	+	-	+



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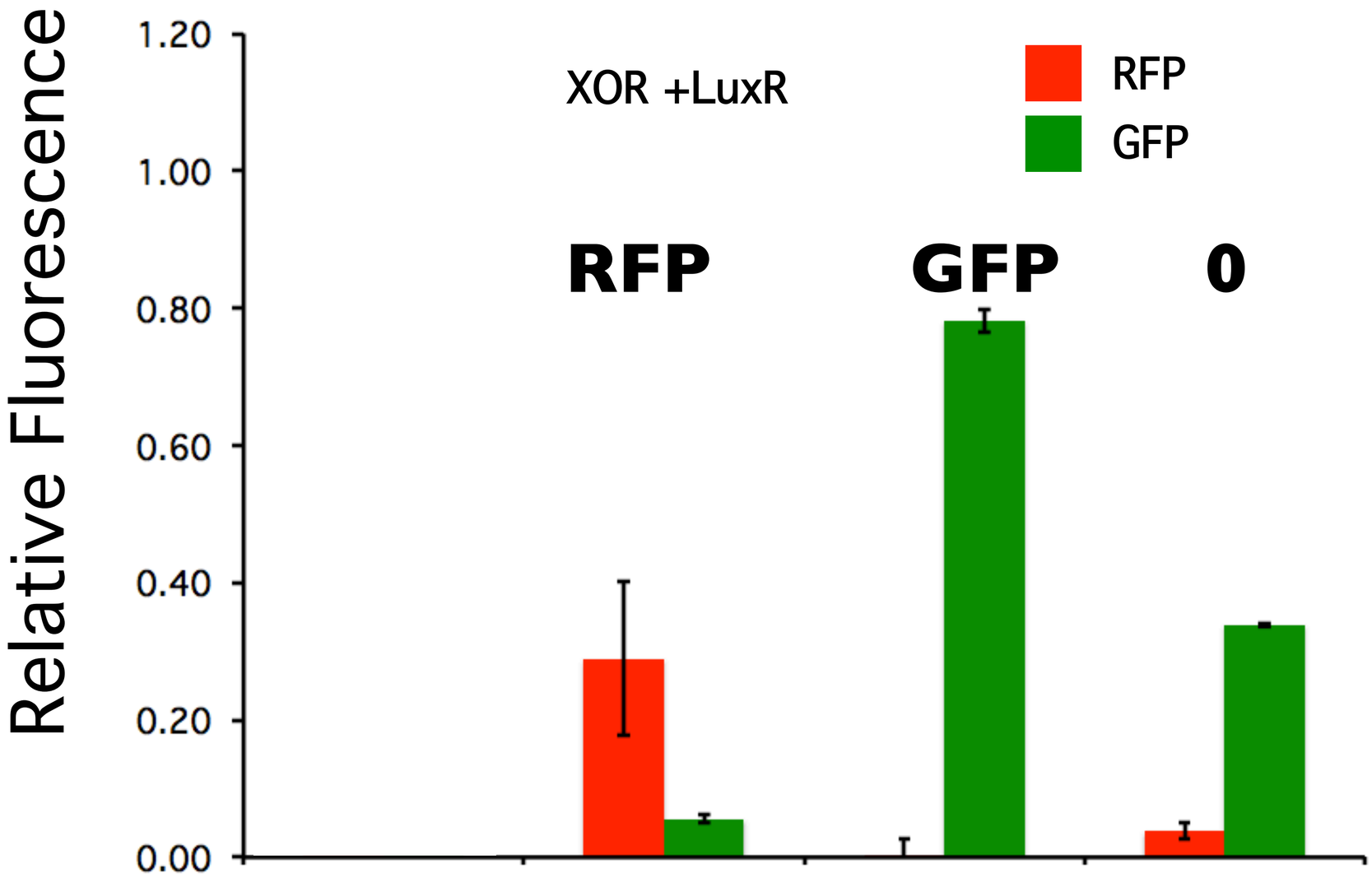

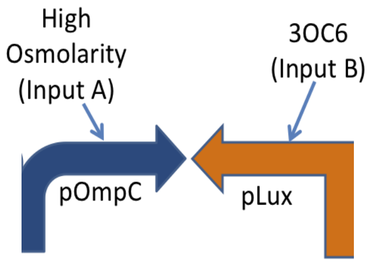

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3OC6	-	+	-	+

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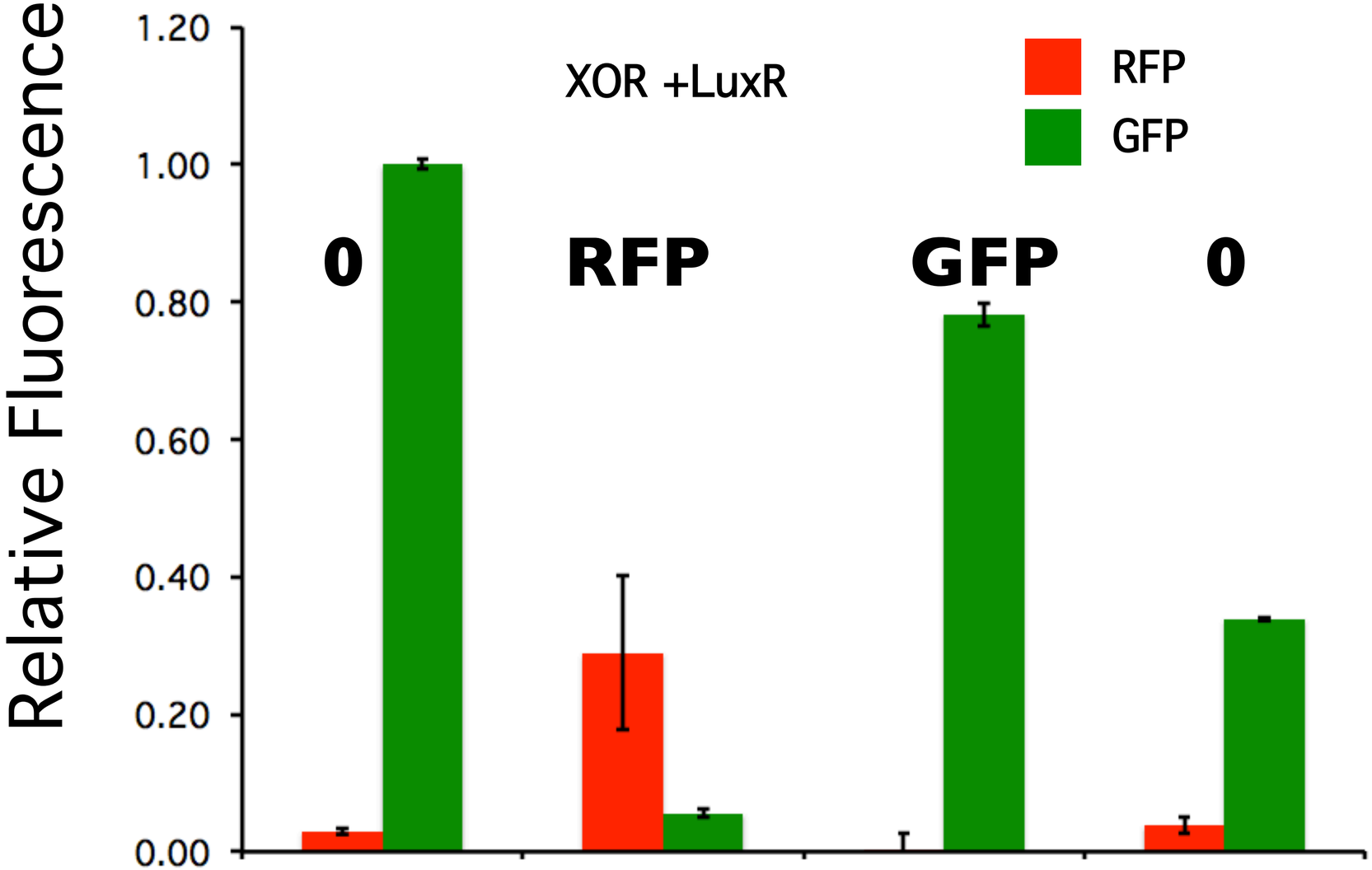

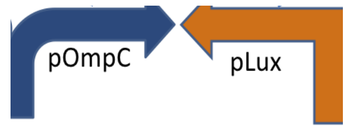

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3OC6	-	+	-	+

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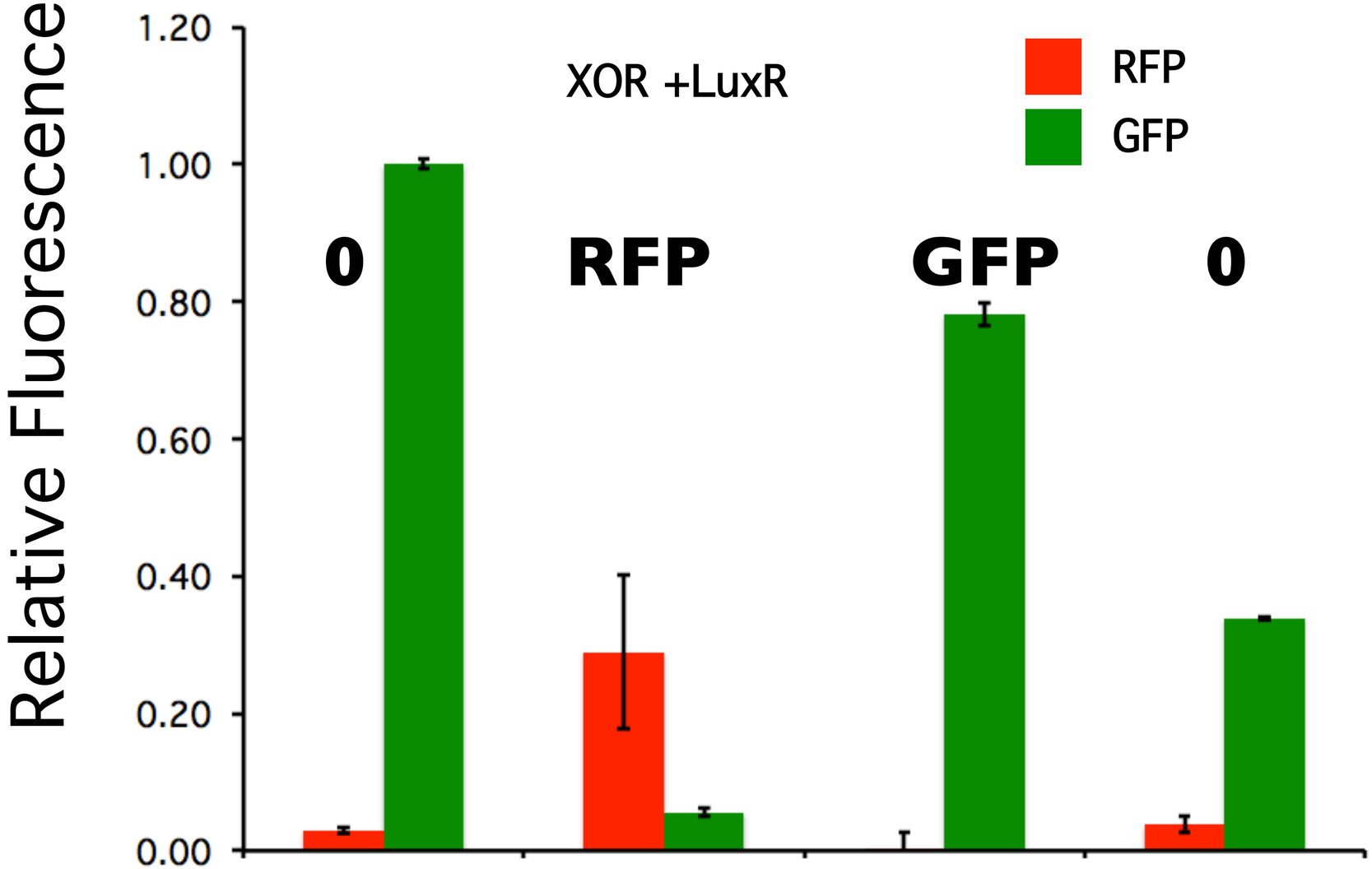
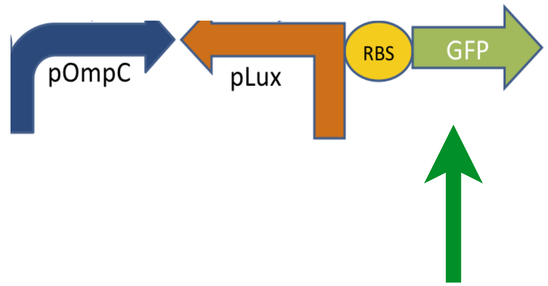
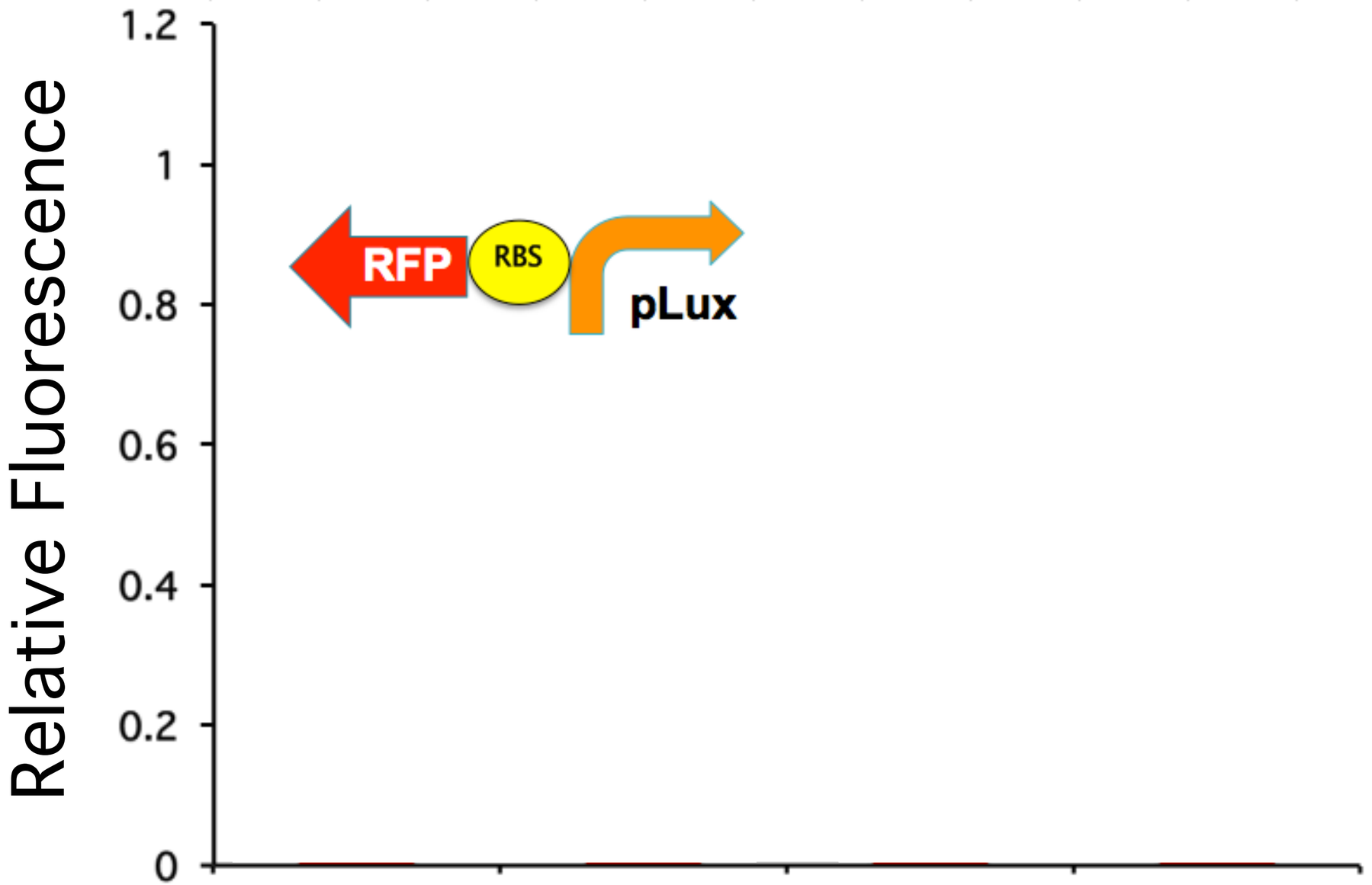




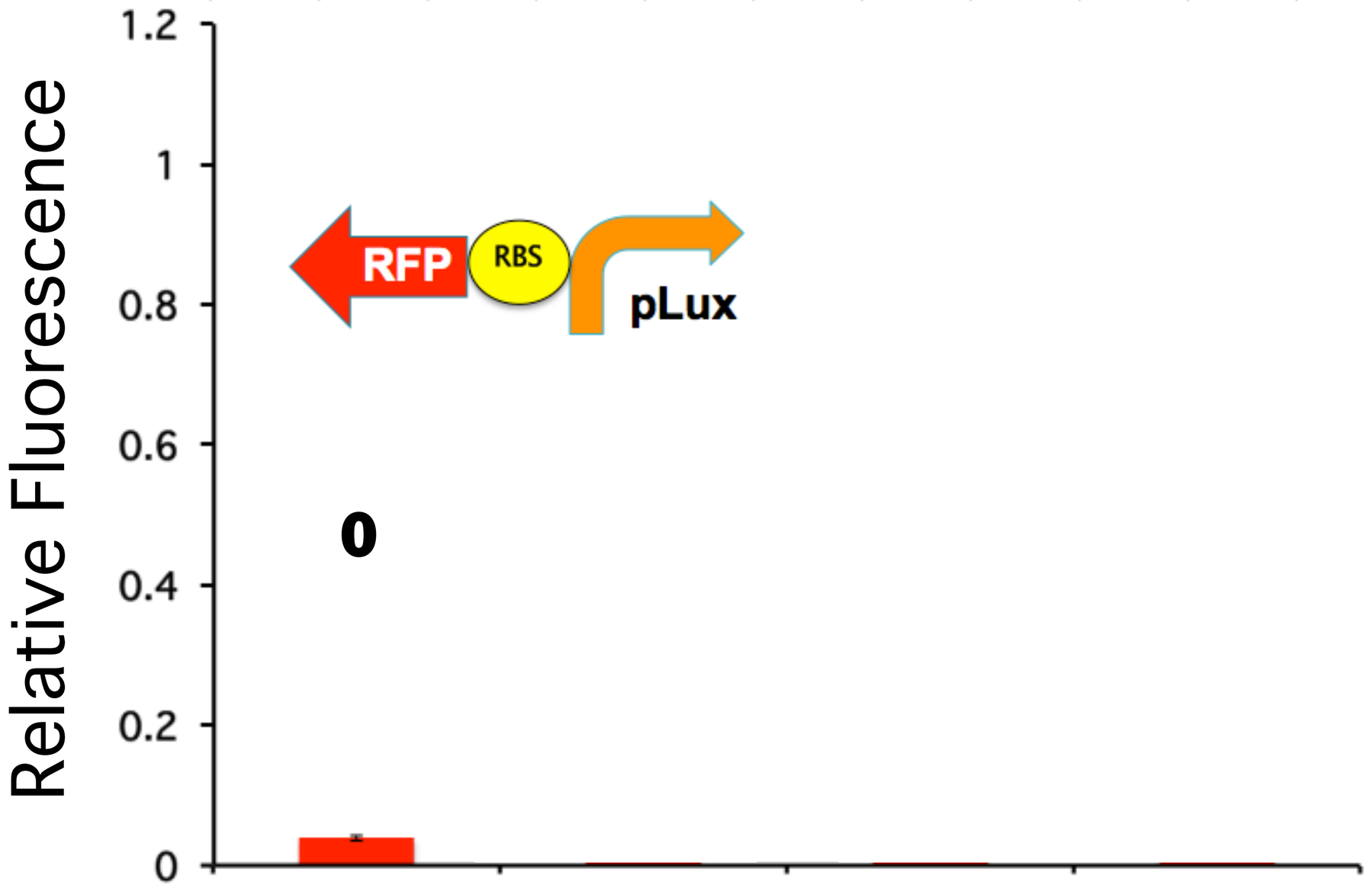
LB	-	-	+	+
3OC6	-	+	-	+

pLux + LuxR Promotes Backwards



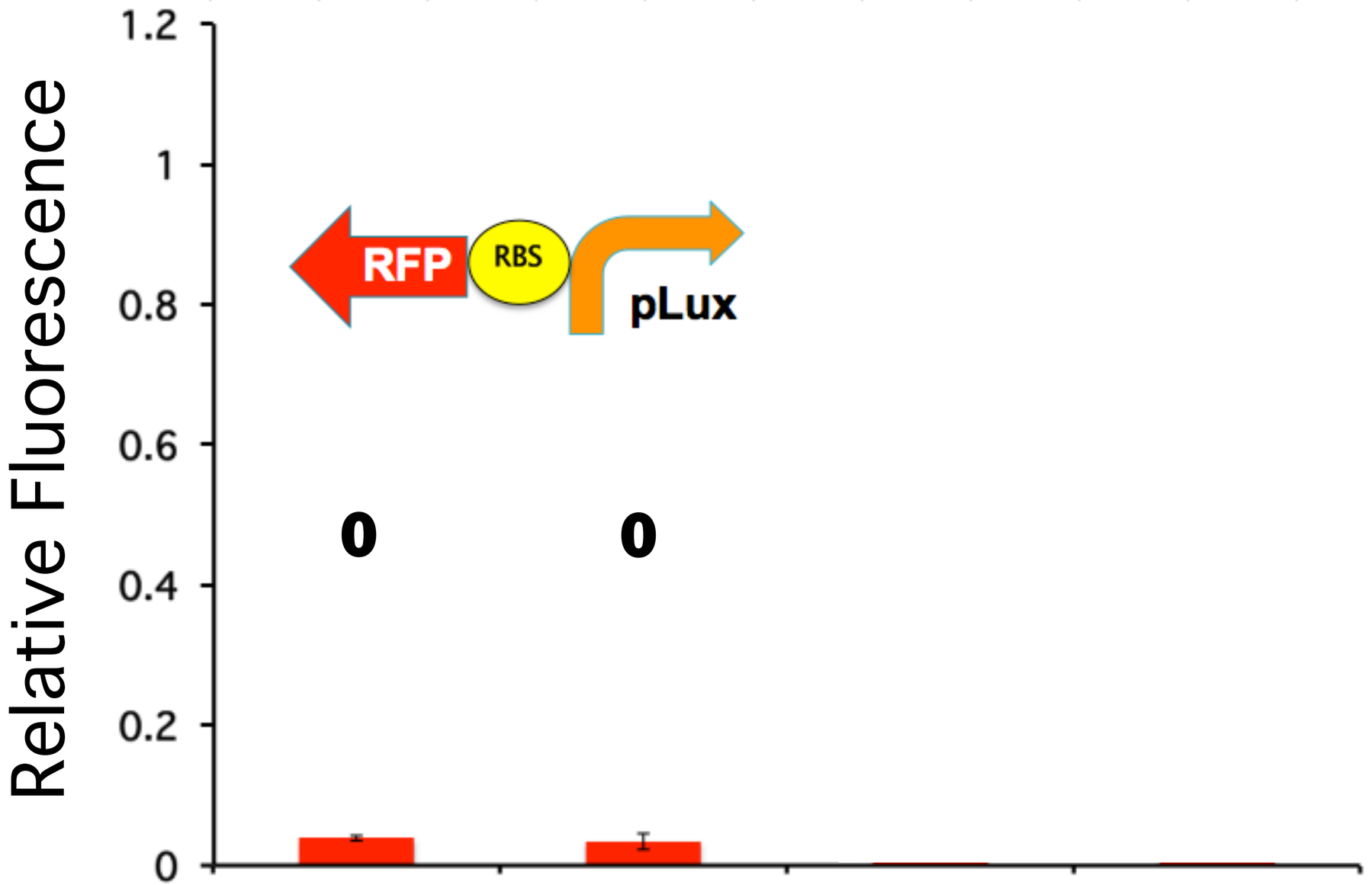
LuxR	-	-	+	+
3OC6	-	+	-	+

pLux + LuxR Promotes Backwards



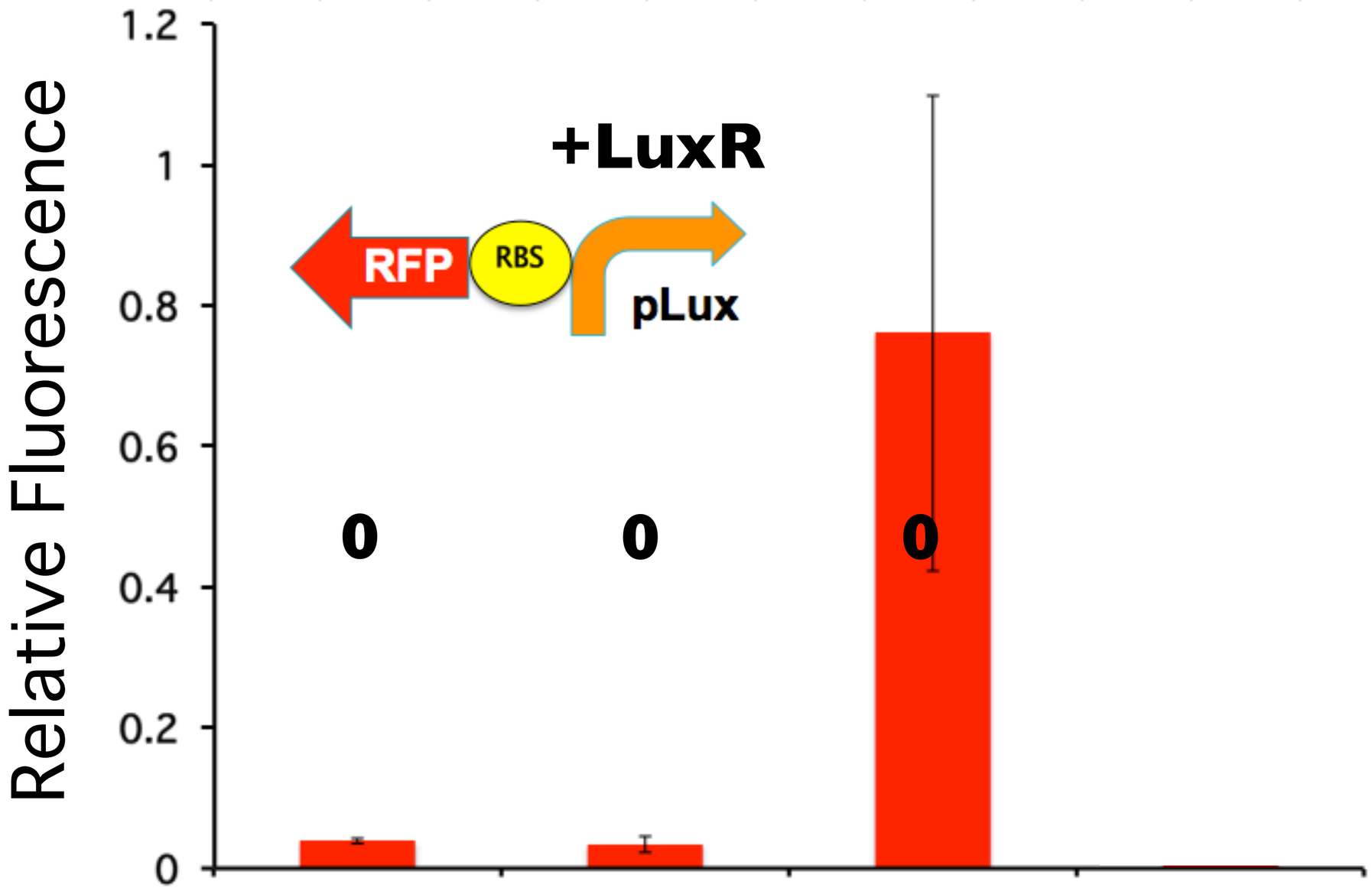
LuxR	-	-	+	+
3OC6	-	+	-	+

pLux + LuxR Promotes Backwards



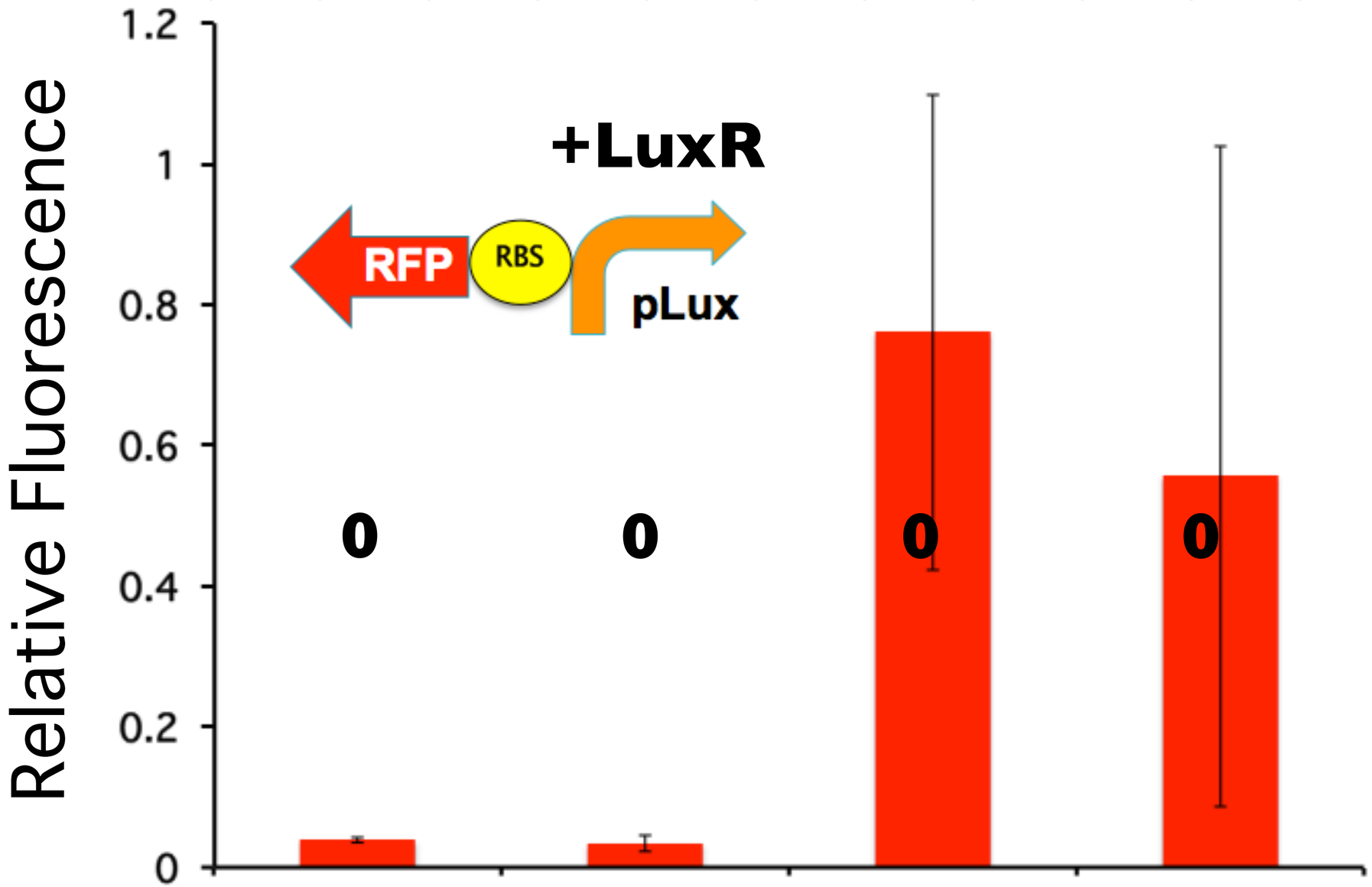
LuxR	-	-	+	+
3OC6	-	+	-	+

pLux + LuxR Promotes Backwards



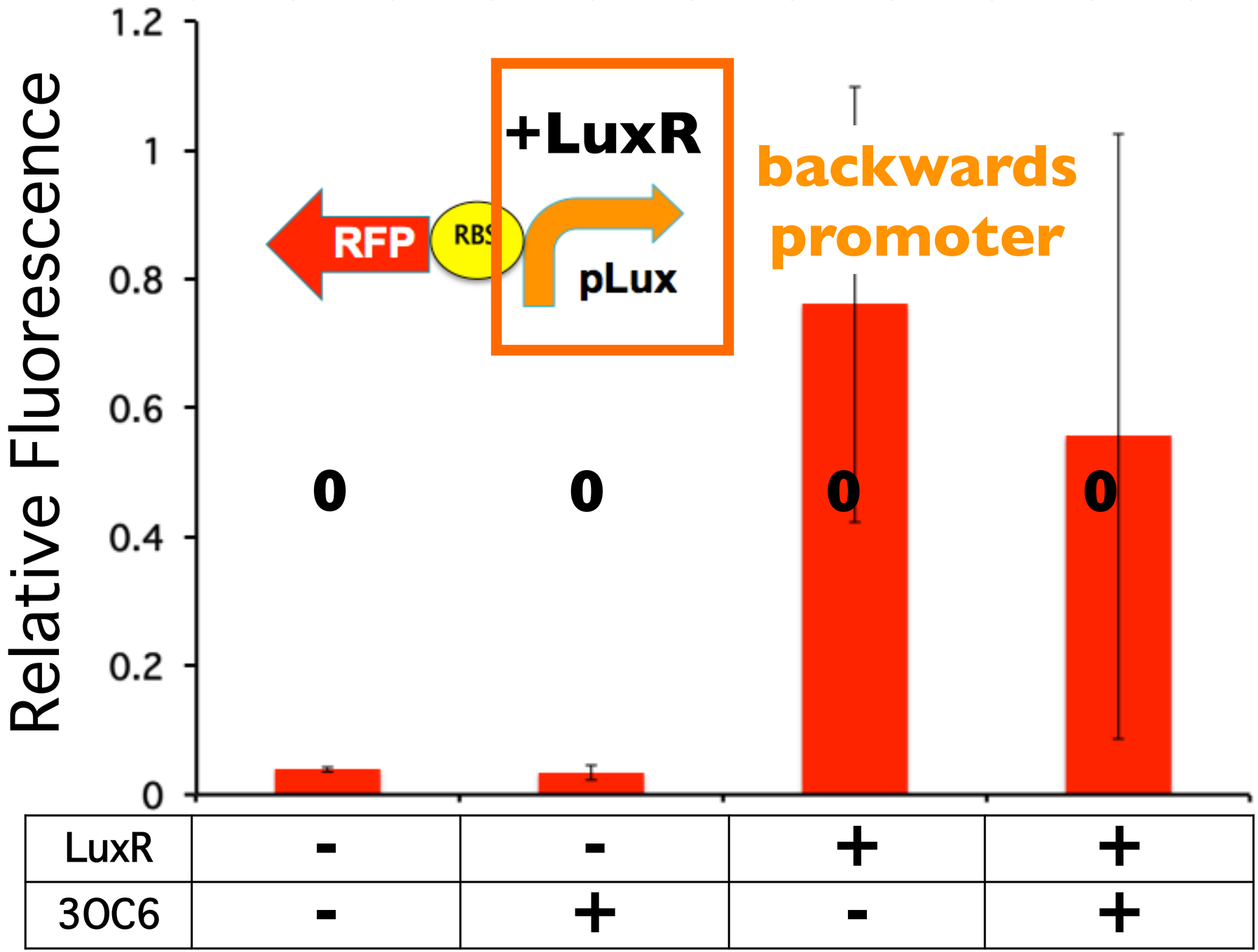
LuxR	-	-	+	+
3OC6	-	+	-	+

pLux + LuxR Promotes Backwards



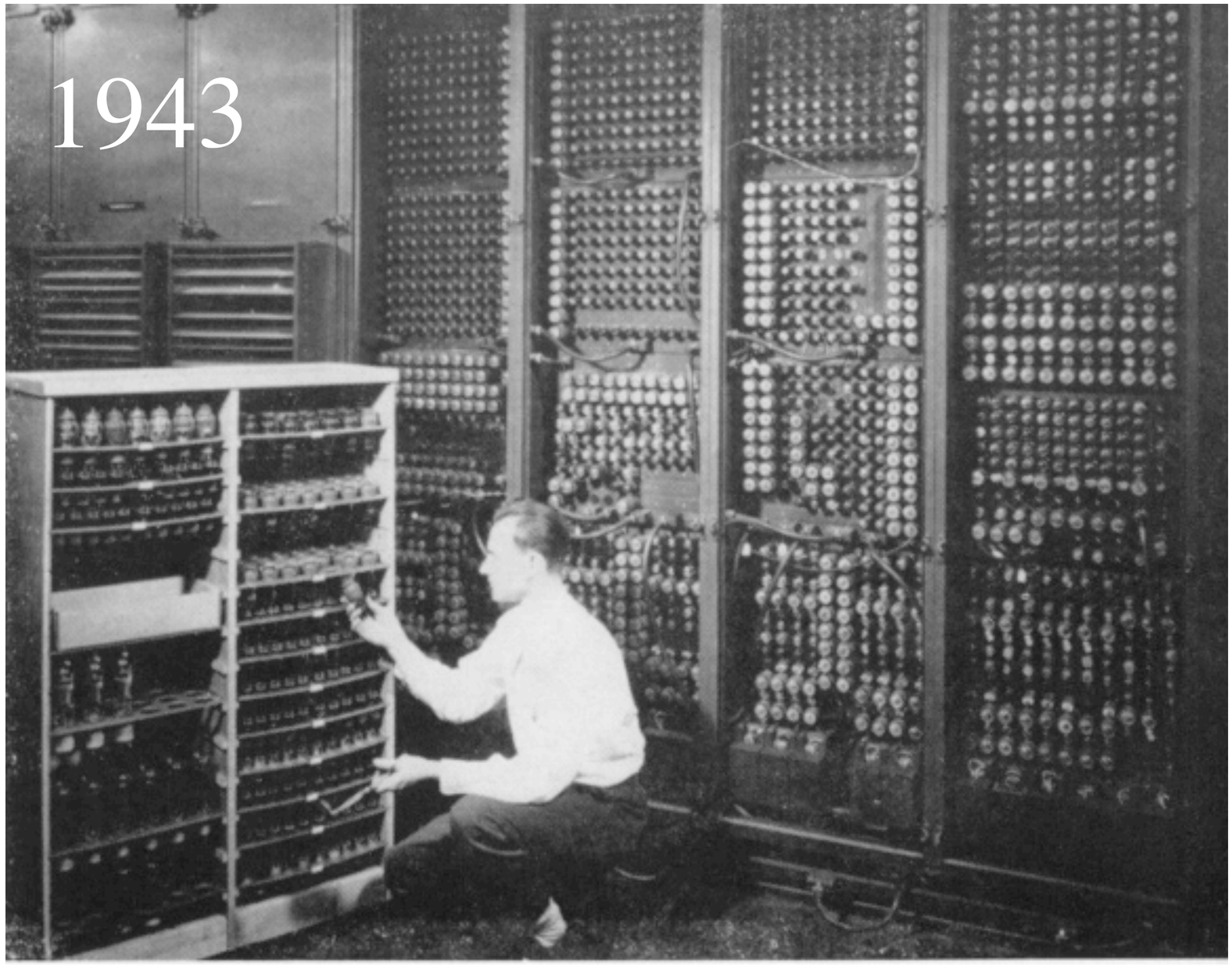
LuxR	-	-	+	+
3OC6	-	+	-	+

pLux + LuxR Promotes Backwards



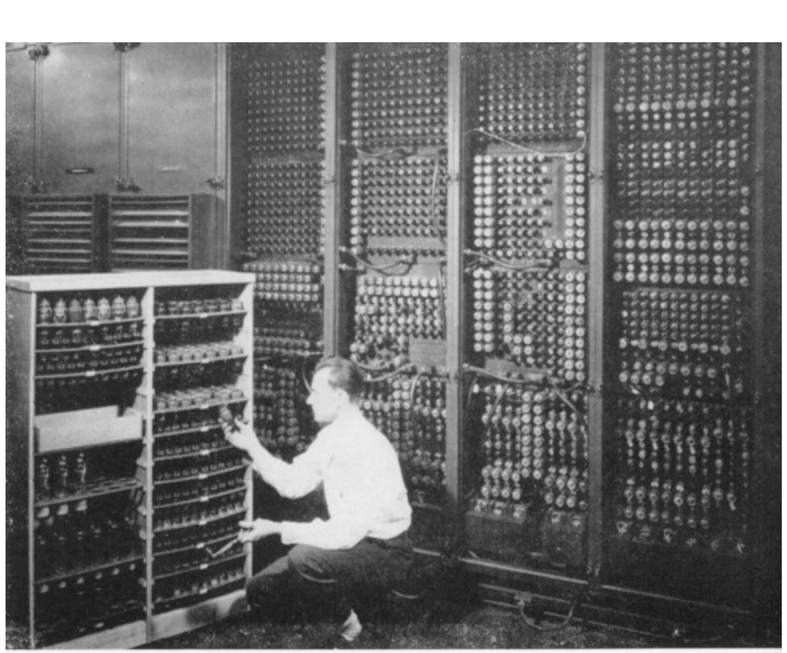
Why build bacterial computers?

Evolution of Computers



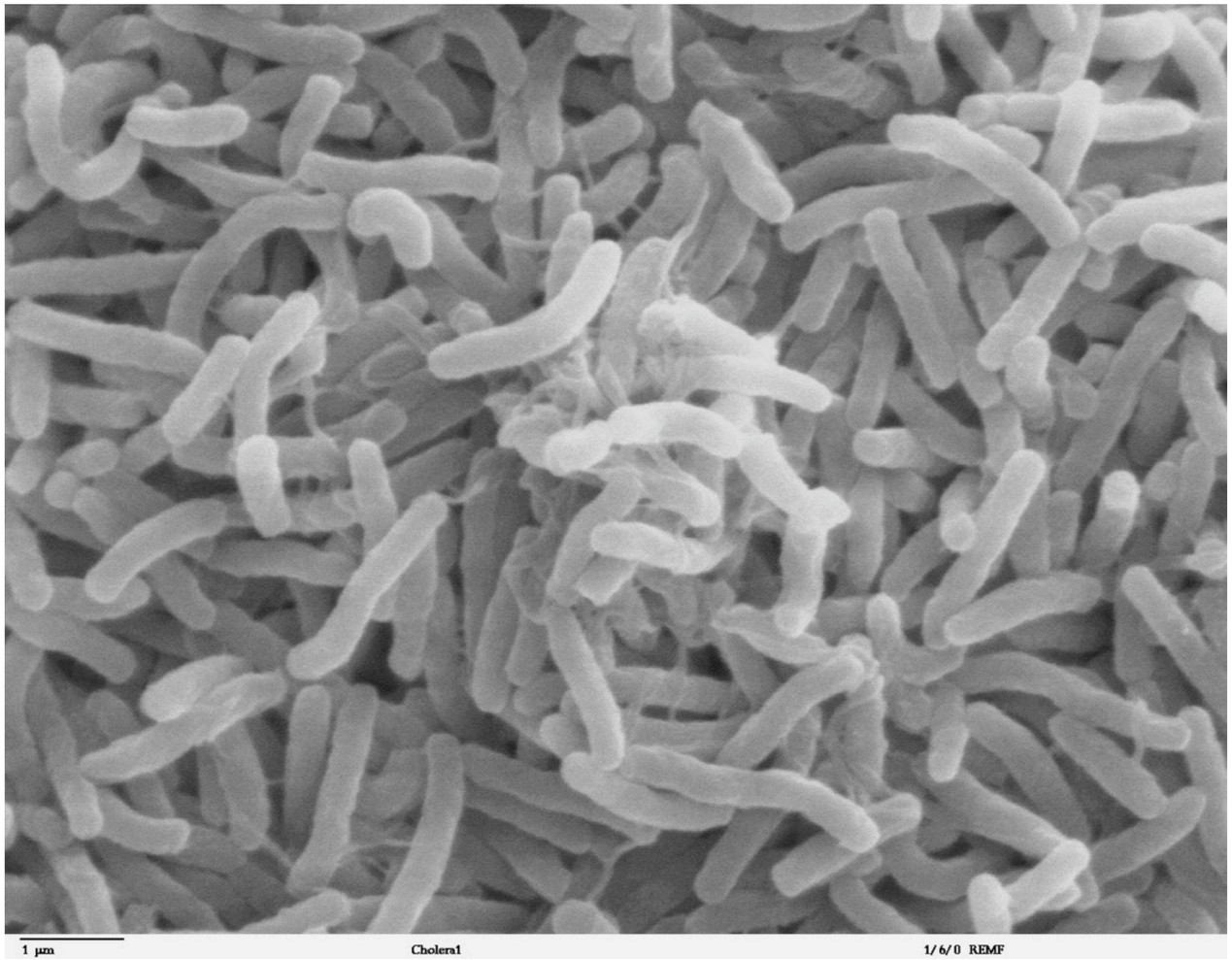
Evolution of Computers

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.

former French President Nicholas Sarkozy

Can HS students do real synthetic biology research?

iGEM 2012 HS is officially over!

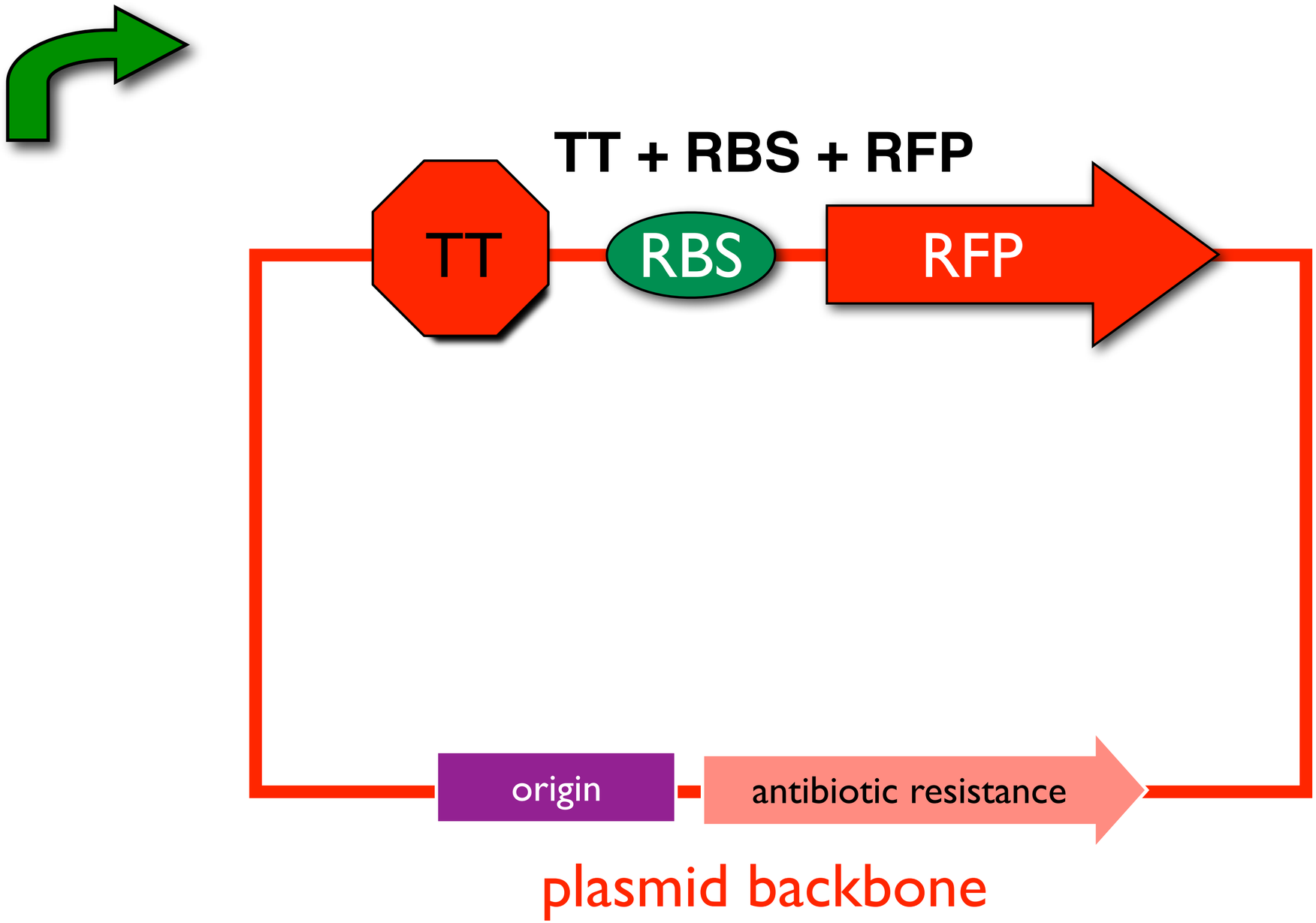
Grand Prize, Winner of the GreenBrick Trophy: Heidelberg LSL

1st Runner Up: NC School of Sci Math

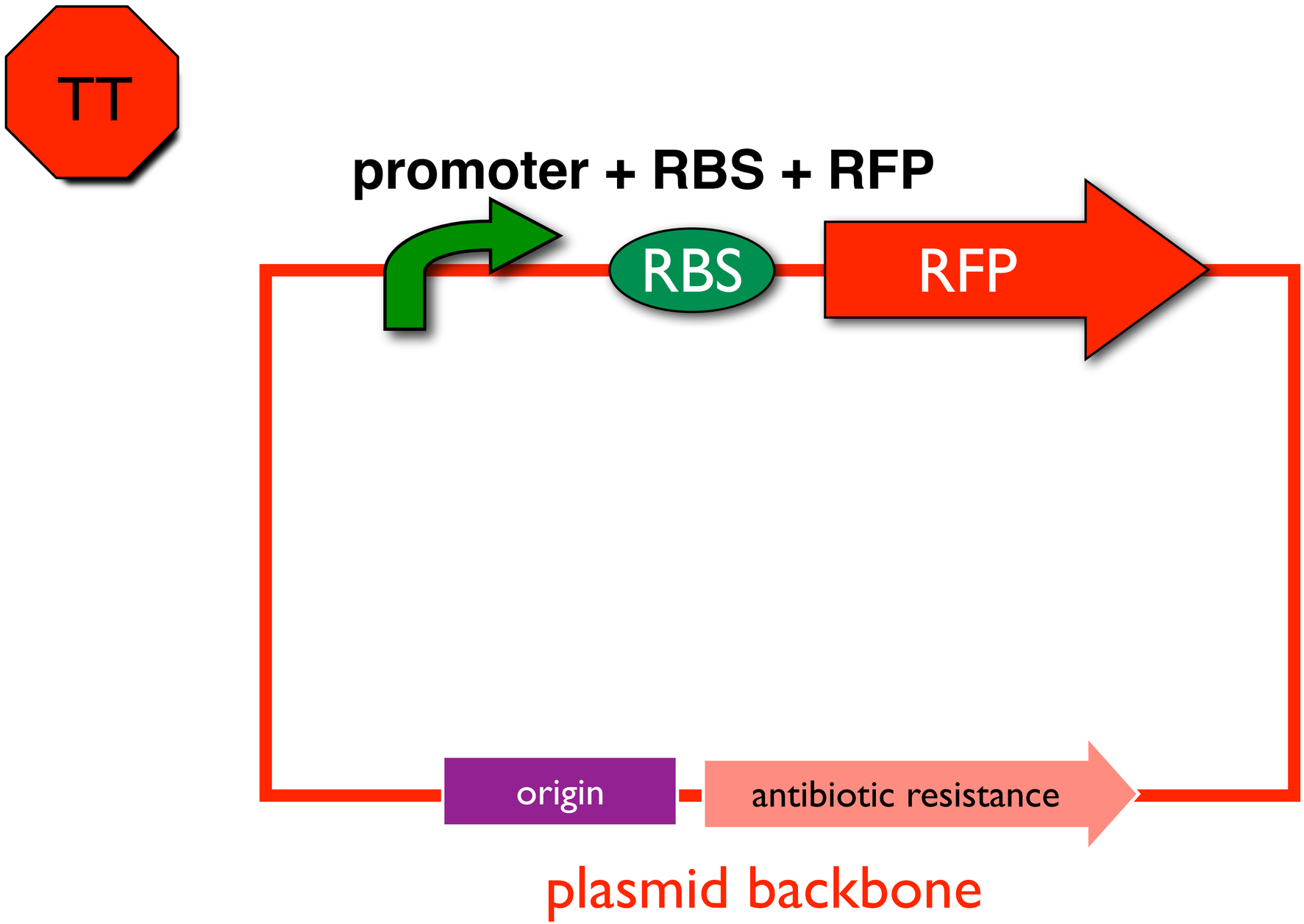
2nd Runner Up: CIDEB-UANL Mexico

To whom much has been given, much is expected.

Golden Gate Assembly Method



Golden Gate Assembly Method



Eco RI

GAATTC
CTTAAG

palindrome

type II

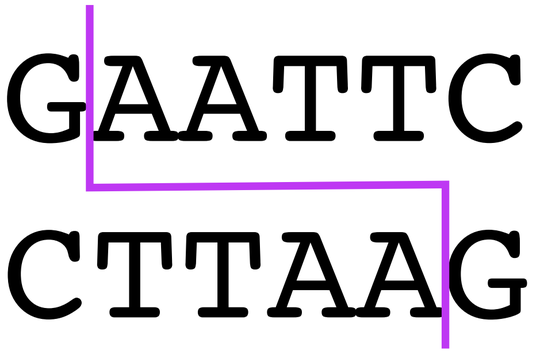
Eco RI

GAATTC
CTTAAG

palindrome

type II

Eco RI



type II

Eco RI

G AATTC

CTTAA G

type II

Bsa I

GAGACC

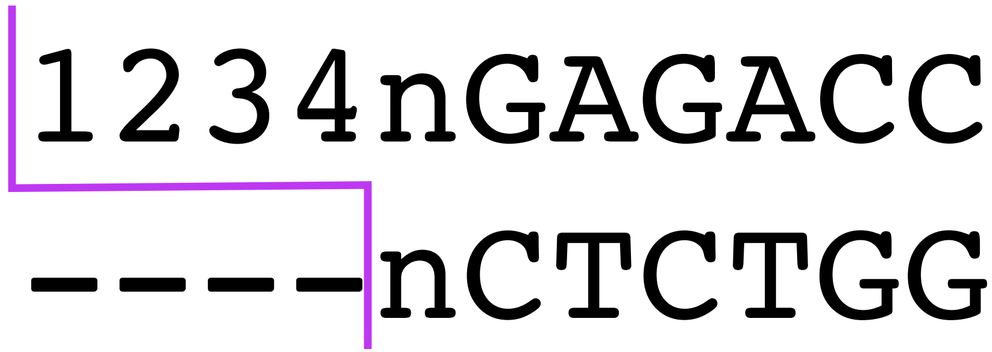
CTCTGG

G

not a palindrome

type IIs

Bsa I



type IIs

Bsa I

```
1234nGAGACC
----      nCTCTGG
```

type IIs

Bsa I

```
GGTCTCn----
CCAGAGn1234
```

type IIs

Bsa I

```
GGTCTCn                ----
CCAGAGn1234
```

type IIs

Bsa I

cuts left

1234nGAGACC

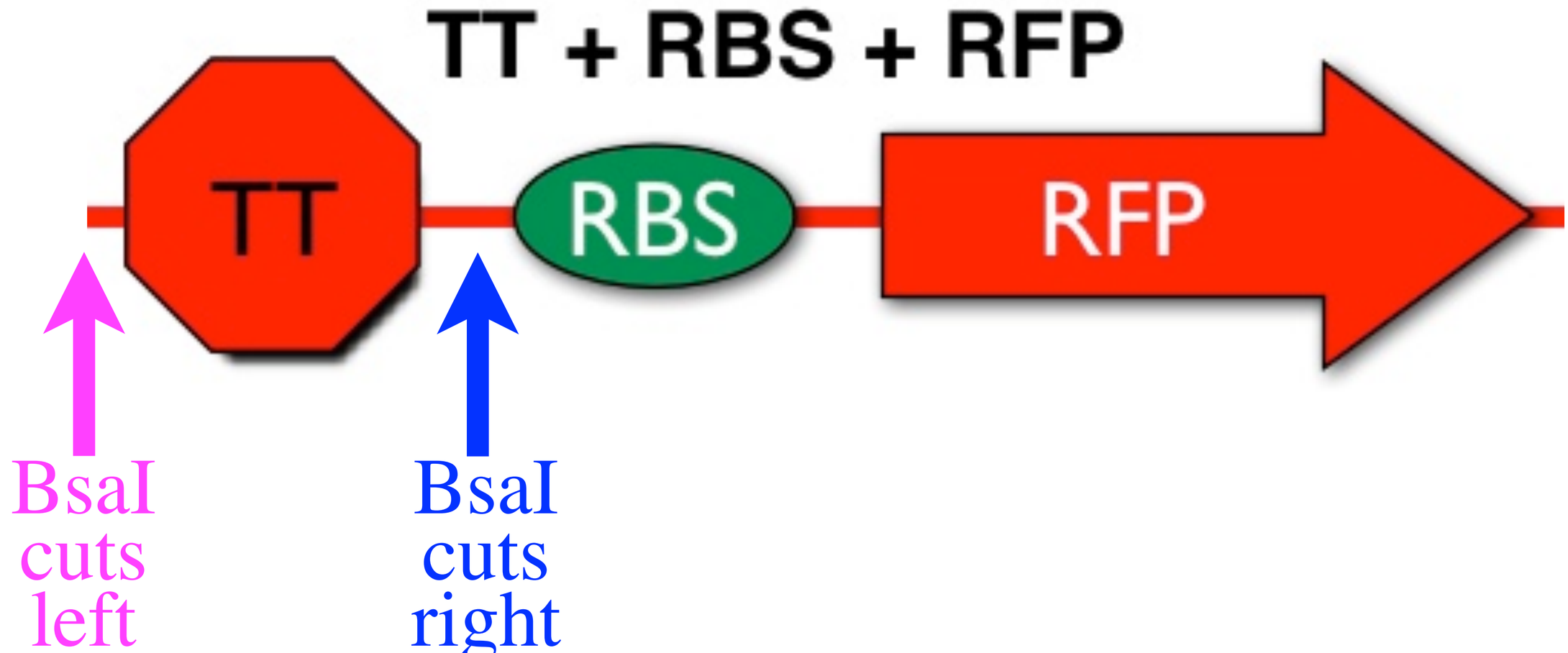
----nCTCTGG

GGTCTCn----

CCAGAGn1234

cuts right

Insert J100091

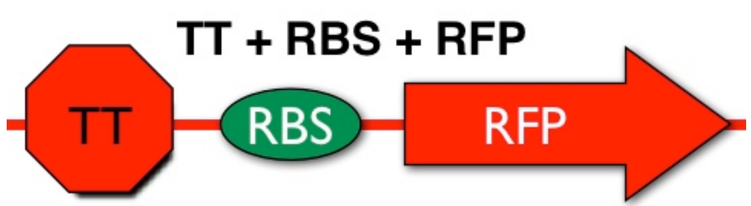


Bsa I

[redacted] CGACtGAGACC(TT)GGTCTCaGCGG [redacted]

[redacted] GCTGaCTCTGG(TT)CCAGAGtCGCC [redacted]

Bsa I



CGACtGAGACC(TT)GGTCTCa

aCTCTGG(TT)CCAGAGtCGCC

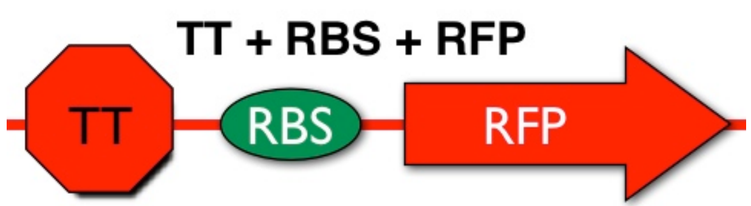
[redacted] GCTG

GCGG [redacted]

[redacted]

[redacted] CGACtGAGACC(TT)GGTCTCaGCGG [redacted]

[redacted] GCTGaCTCTGG(TT)CCAGAGtCGCC [redacted]



CGACtGAGACC(TT)GGTCTCa

aCTCTGG(TT)CCAGAGtCGCC

[redacted] GCTG

GCGG [redacted]

[redacted]

CGAC(promoter)

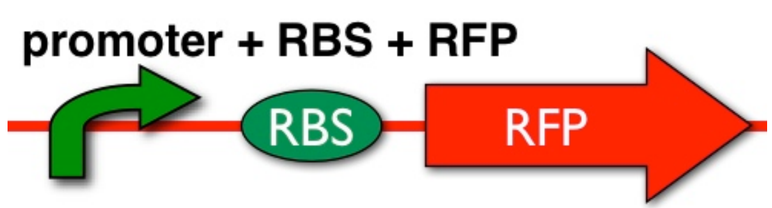
(promoter)CGCC

CGACtGAGACC(TT)GGTCTCa

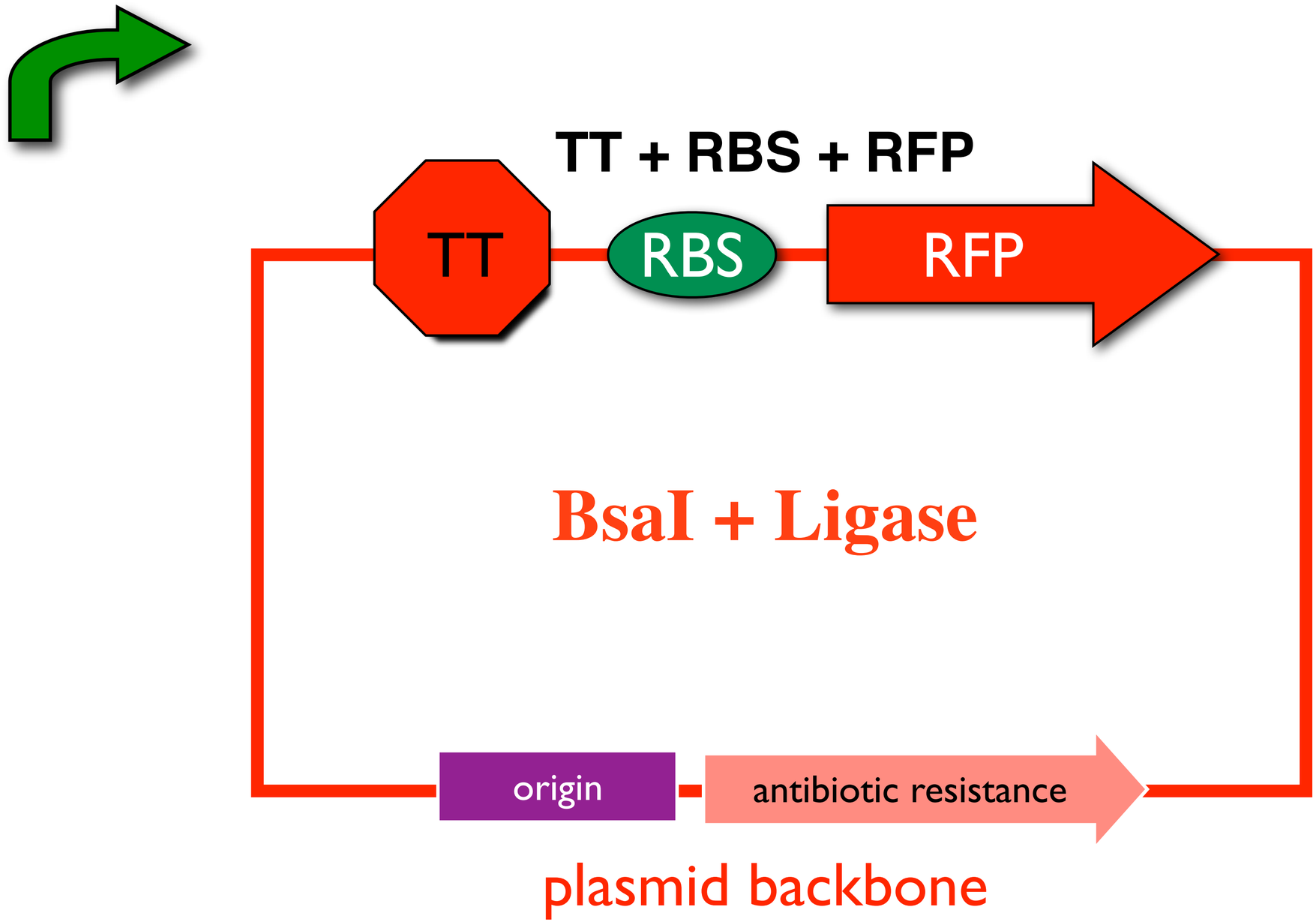
aCTCTGG(TT)CCAGAGtCGCC

[redacted] CGAC(promoter)GCGG [redacted]

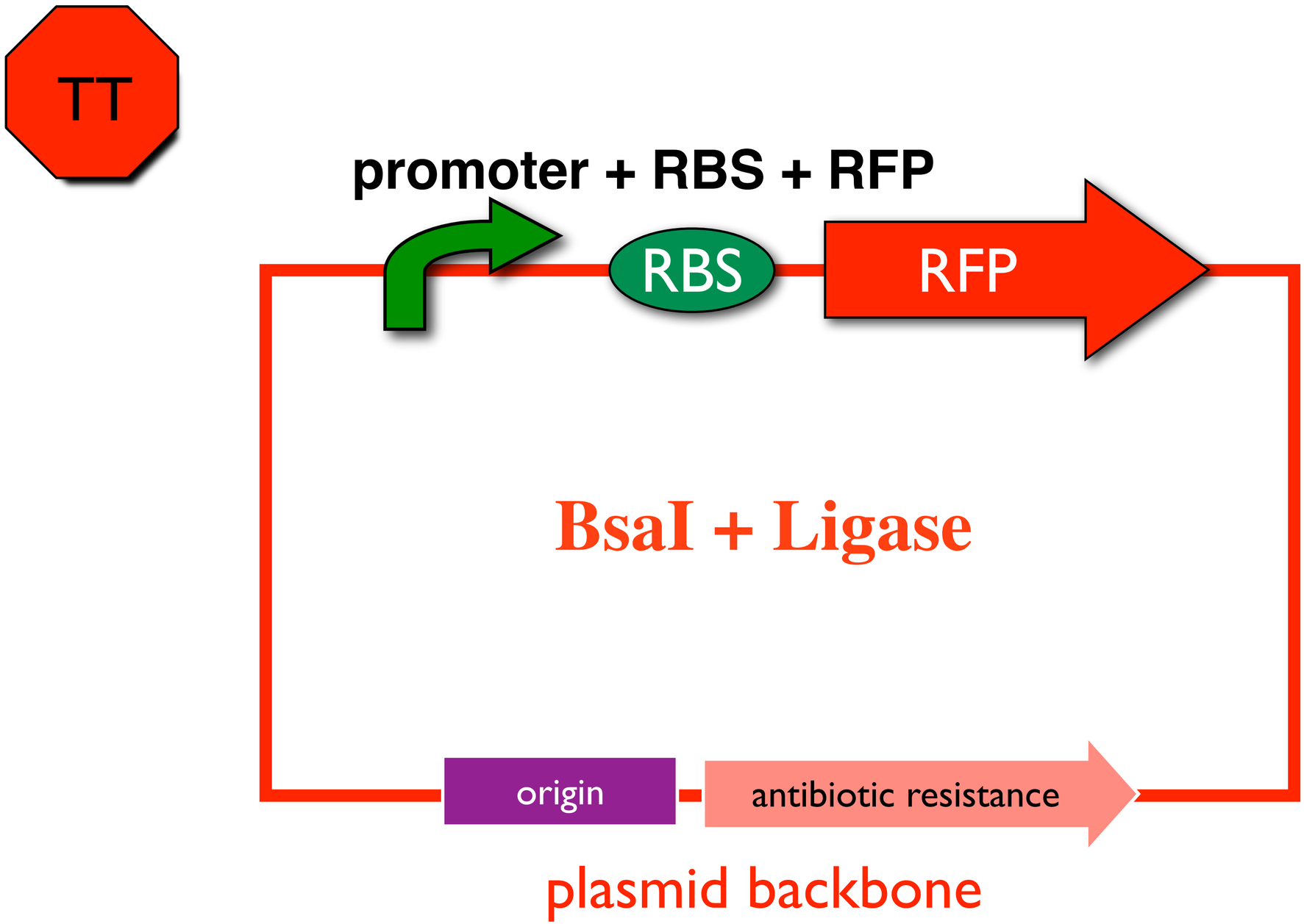
[redacted] GCTG(promoter)CGCC [redacted]



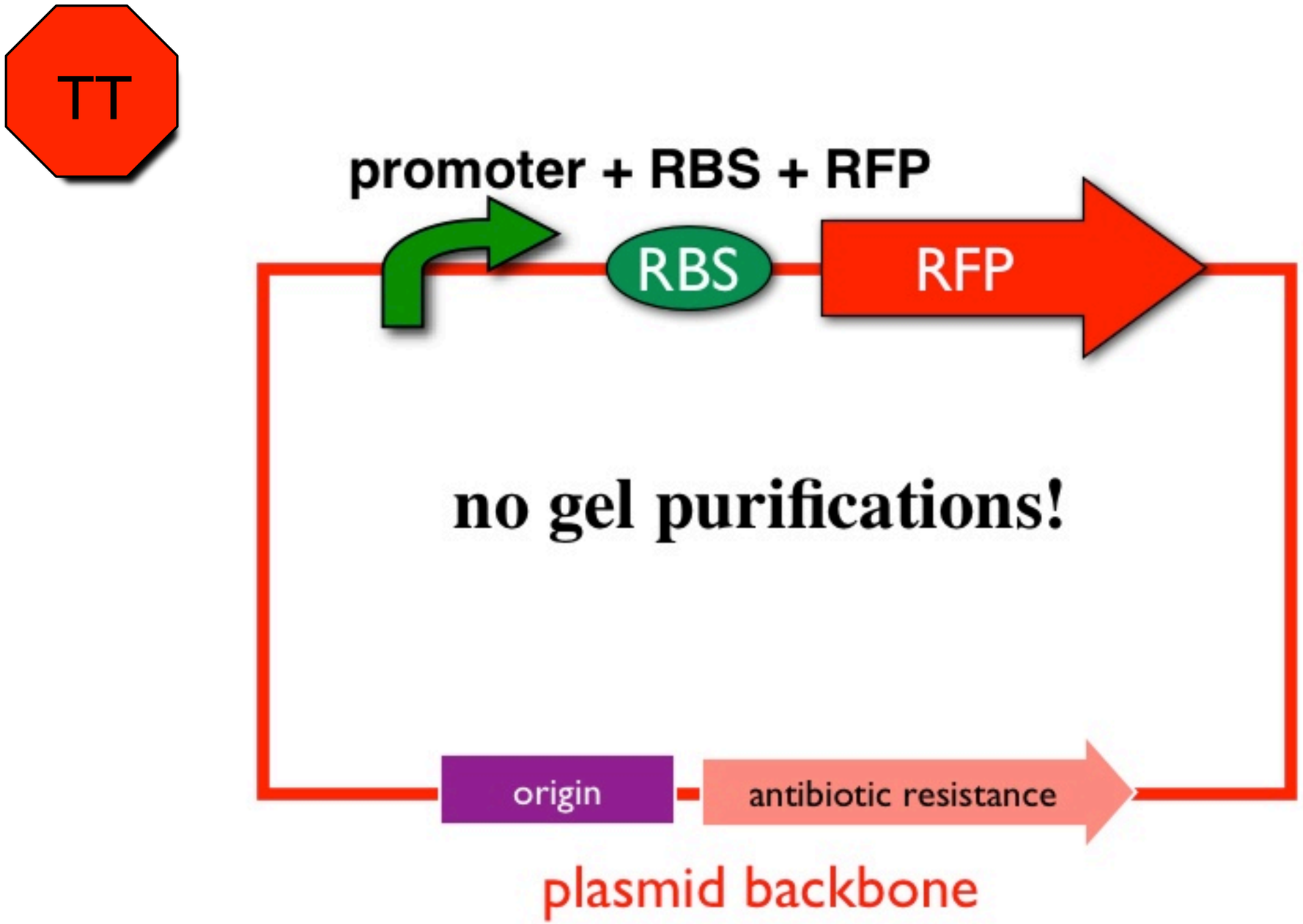
GGA Ligation Method



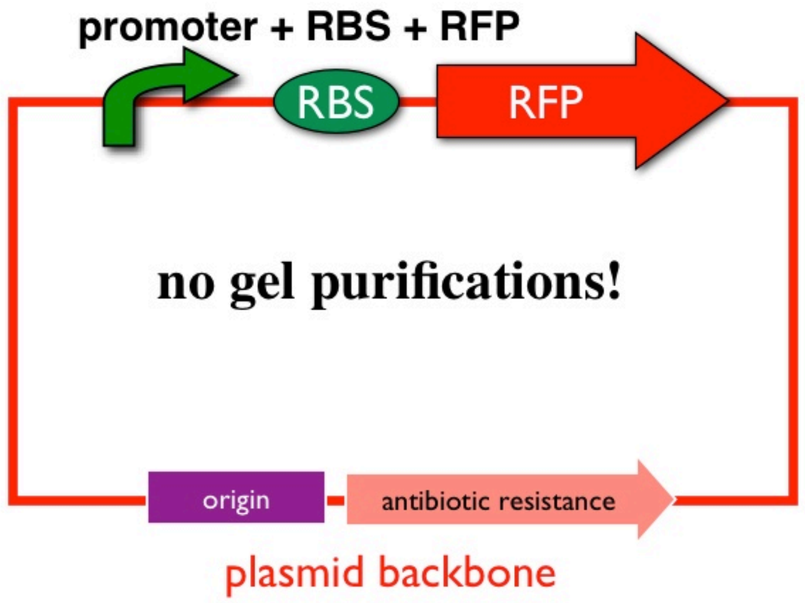
GGA Ligation Method

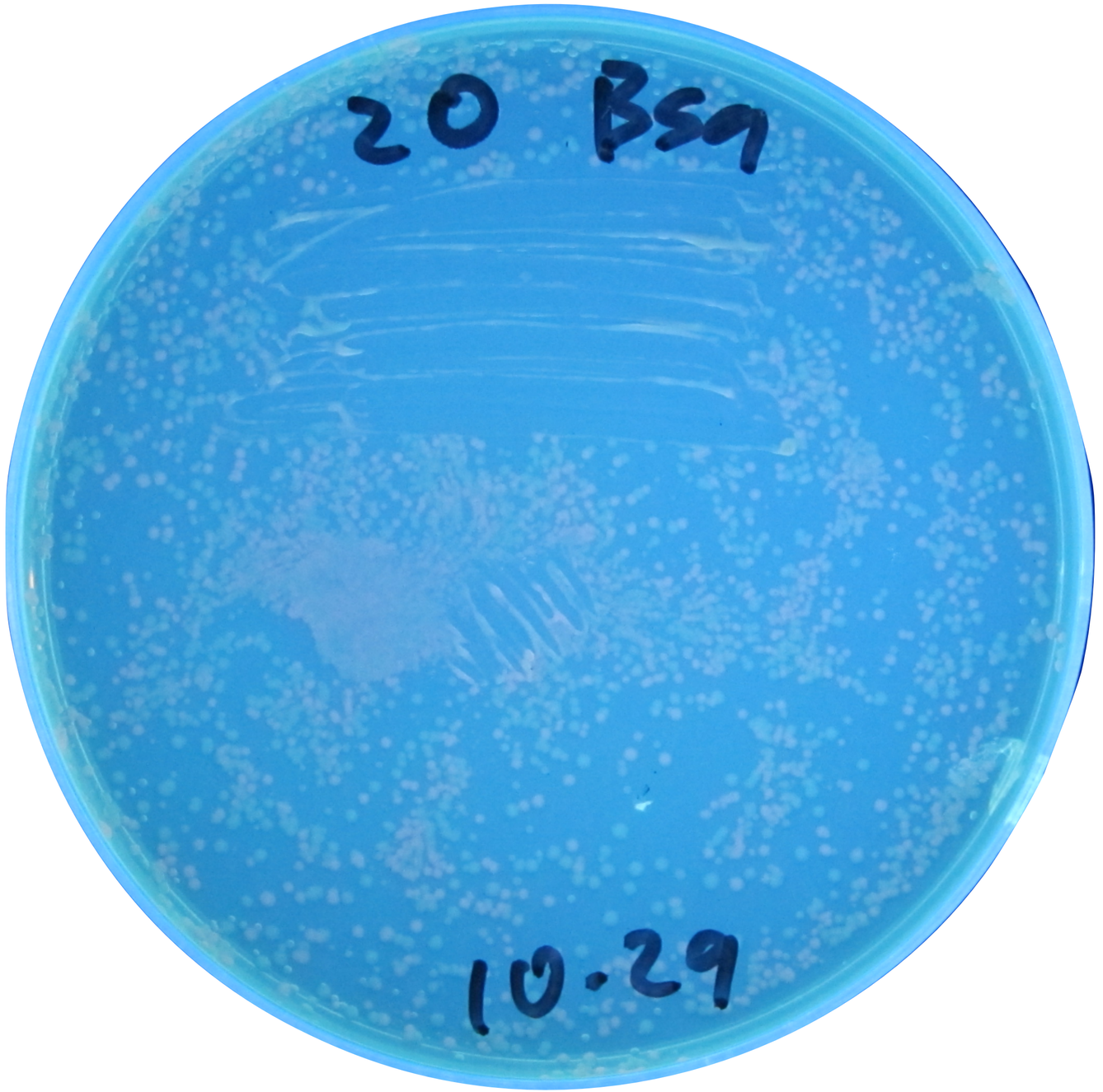


GGA Ligation Method



GGA Ligation Method





Registry of Functional Promoters

Registry of Standard Biological Parts

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Campbell M Lab Parts

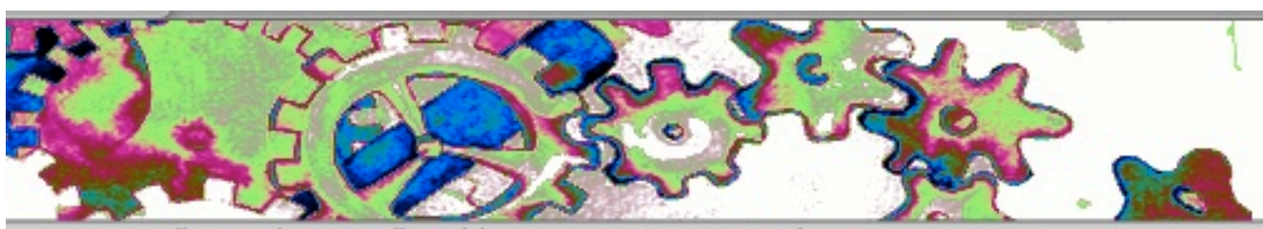
Favorite Campbell M Lab Parts *Edit*

-?-	Name	Type	Description	Designer	Length

Campbell M Lab Parts Sandbox *Edit*

-?-	Name	Type	Description	Designer	Length
	BBa_J100000	Coding	Cre with 8bp restriction sites and 1-Clause 2-SAT Problem Inserted	Eric Sawyer	1069
	BBa_J100001	Composite	pTet+RBS+Cre2SAT1Clause+pLpp+tRNA CCACU	Eric Sawyer	1357
	BBa_J100002	Composite	pTet+RBS+Cre2SAT1Clause+pLpp+tRNA CGGUC	Eric Sawyer	1357
	BBa_J100003	Generator	pTet+RBS+Cre2SAT1Clause	Eric Sawyer	1149
	BBa_J100004	Reporter	pTet+LoxP+RBS+RFP+LoxP	Eric Sawyer	870
	BBa_J100005	Other	Palindromic Stop Sequence	Eric Sawyer	221
	BBa_J100006	Intermediate	LoxP+Stop Sequence+LoxP	Eric Sawyer	305
	BBa_J100007	Intermediate	pLac+RBS+LoxP+Stop Sequence+LoxP	Eric Sawyer	533
	BBa_J100008	Composite	pLpp-tRNA CCACU-pLpp-tRNA CUAGU	Eric Sawyer	408
	BBa_J100009	Composite	pLpp-tRNA CCACU-pLpp-tRNA CGGUC	Eric Sawyer	408
	BBa_J100010	Composite	pLpp-tRNA CUAGU-pLpp-tRNA CGGUC	Eric Sawyer	408
	BBa_J100011	Composite	pLpp-tRNA CCACU-pLpp-tRNA CUAGU-pLpp-tRNA CGGUC	Eric Sawyer	616
	BBa_J100012	Intermediate	RBS-RFP-RBS	Eric Sawyer	747
	BBa_J100013	Coding	LuxI with 1 Clause 2-SAT Problem	Eric Sawyer	638
	BBa_J100014	Coding	LuxI with 2 Clause 2-SAT Problem	Eric Sawyer	652
	BBa_J100015	Composite	1 Clause 2-SAT Problem with Frameshifted LuxI and a GFP Reporter	Eric Sawyer	2757
	BBa_J100016	Composite	2 Clause 2-SAT Problem with Frameshifted LuxI and a GFP Reporter	Eric Sawyer	2771
	BBa_J100017	Composite	TT+pLux+RBS+LuxI(2-SAT 2 clause)+RBS+GFP+pLac+RBS+LuxR+tRNAs	Eric Sawyer	3395
	BBa_J100018	Protein_Domain	First Half of AspC gene	Catherine Doyle	448
	BBa_J100019	Protein_Domain	First half of ilvE gene	Julia Fearrington	457
	BBa_J100020	Protein_Domain	Second Half of AspC	Catherine Doyle	869
	BBa_J100021	Protein_Domain	First Half of PyrE	Catherine Doyle	488
	BBa_J100022	Protein_Domain	Second Half of PyrE	Catherine Doyle	280
	BBa_J100025	Protein_Domain	First half of CAT gene	James Harden	434
	BBa_J100026	Protein_Domain	second half ilvE gene	Julia Fearrington	574
	BBa_J100027	Protein_Domain	second half of TyrB	James Harden	288
	BBa_J100028	Other	placeholder insert for BsaI Golden Gate Assembly of promoter	Malcolm Campbell	877
	BBa_J100029	Regulatory	The promoter of rpoDPhs	Maggie Baay	76
	BBa_J100030	Regulatory	phoA is an inducible promoter induced by phosphate starvation.	Scott Hall	76
	BBa_J100031	Regulatory	Constitutive promoter C on Gene 1 of T7, transcribes RNA Pol.	Caroline Vrana	100
	BBa_J100032	Regulatory	proUP3 promoter	Molly Marshall	90
	BBa_J100033	Regulatory	dnakP1 promoter: Heat shock inducible	Chris Peek	101
	BBa_J100034	Regulatory	groE promoter	Margaret Stebbins	44
	BBa_J100036	Regulatory	Promoter induced by DNA damage	Erich Baker	52
	BBa_J100039	Regulatory	GalP1 Promoter-Induced By Galactose	Anaiah Toby	75
	BBa_J100040	Coding	LuxI with 3 clause 2-SAT problem	Eric Sawyer	684
	BBa_J100041	Composite	LuxI/GFP with 3 clause 2-SAT problem	Eric Sawyer	2803
	BBa_J100042	Coding	LuxI with 3 clause 3-SAT problem	Eric Sawyer	702
	BBa_J100043	Composite	LuxI/GFP with 3 clause 3-SAT problem	Eric Sawyer	2821
	BBa_J100044	Coding	LuxI with 4 clause 2-SAT problem	Eric Sawyer	704
	BBa_J100045	Composite	LuxI/GFP with 4 clause 2-SAT problem	Eric Sawyer	2823
	BBa_J100046	RNA	lpp+tRNA CCAUC (10 bp anticodon loop)	Eric Sawyer	201
	BBa_J100047	Protein_Domain	TyrB2	Julia Fearrington	
	BBa_J100048	Protein_Domain	TyrB1	Julia Fearrington	930
	BBa_K091231	Composite	LuxR producer and XOR gate	Malcolm Campbell	2772
	BBa_K091232	Composite	LuxR producer and RFP(rev) + RBS(rev) + pLux (for)	Malcolm Campbell	1916

Student Sample



Registry of Standard Biological Parts

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BBa J100033 Main Page Part Design Physical DNA Hard Information Experience Tools

Part:BBa_J100033

Designed by Chris Peek Group: Campbell_M_Lab (2011-09-01)

Regulatory

DNA Planning

Experience:

Get This Part

dnakP1 promoter: Heat shock inducible

dnaKP1 is naturally off, but is induced when E. coli is heat shocked, resulting in transcription downstream from this promoter.

Sequence and Features

Format: Subparts | Ruler | SS | DS Search: Length: 101 bp Context: Part only Get selected sequence

```
      1          11         21         31         41         51         61         71         81         91

1     aaatttctgc gcaaaagcac aaaaaatttt tgcatctccc ccttgatgac gtggtttacg accccattta gtagtcaacc gcagtgagtg agtctgcaaa
      tttaaagacg cgttttcgtg ttttttaaaa acgtagaggg ggaactactg caccaaatgc tggggtaaat catcagttgg cgtcactcac tcagacgttt

101   a
      t
```

Assembly Compatibility: 10 12 21 23 25

Student Sample

Registry of Standard Biological Parts

Go Search

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BBa J100033 Main Page Part Design Physical DNA Hard Information Experience Tools

Part:BBa_J100033:Experience

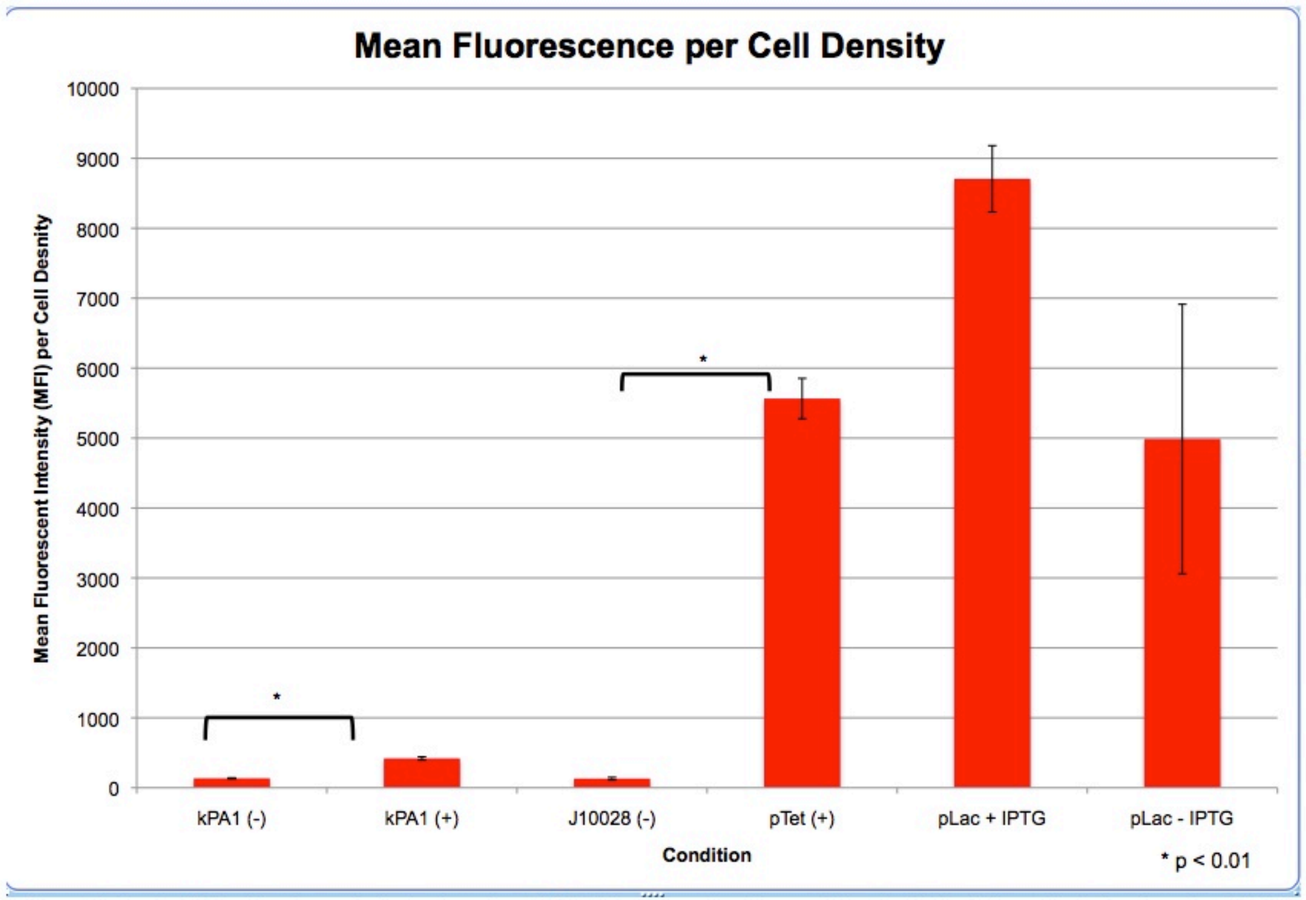
Designed by Chris Peek Group: Campbell_M_Lab (2011-09-01)

Regulatory

DNA Planning
Experience:
Get This Part

This experience page is provided so that any user may enter their experience using this part.
Please enter how you used this part and how it worked out.

Applications of BBa_J100033 [edit]



A: Experimental: cells containing dnaKP1 without heat shock (incubated at 37°C) B: Experimental: cells containing dnaKP1 with heat shock (incubated at 40°C) C: Negative control: part j100028 without pTet promoter D: Positive control: part j100028 with pTet promoter (always on) E: pLac promoter (part j715039) with inducer (IPTG) F: pLac

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
3) Dedication/Tenacity
4) Dependability
5) Loyalty
6) Positive Attitude
7) Professionalism
8) Self-Confidence
9) Self-Motivated
10) Willingness to Learn

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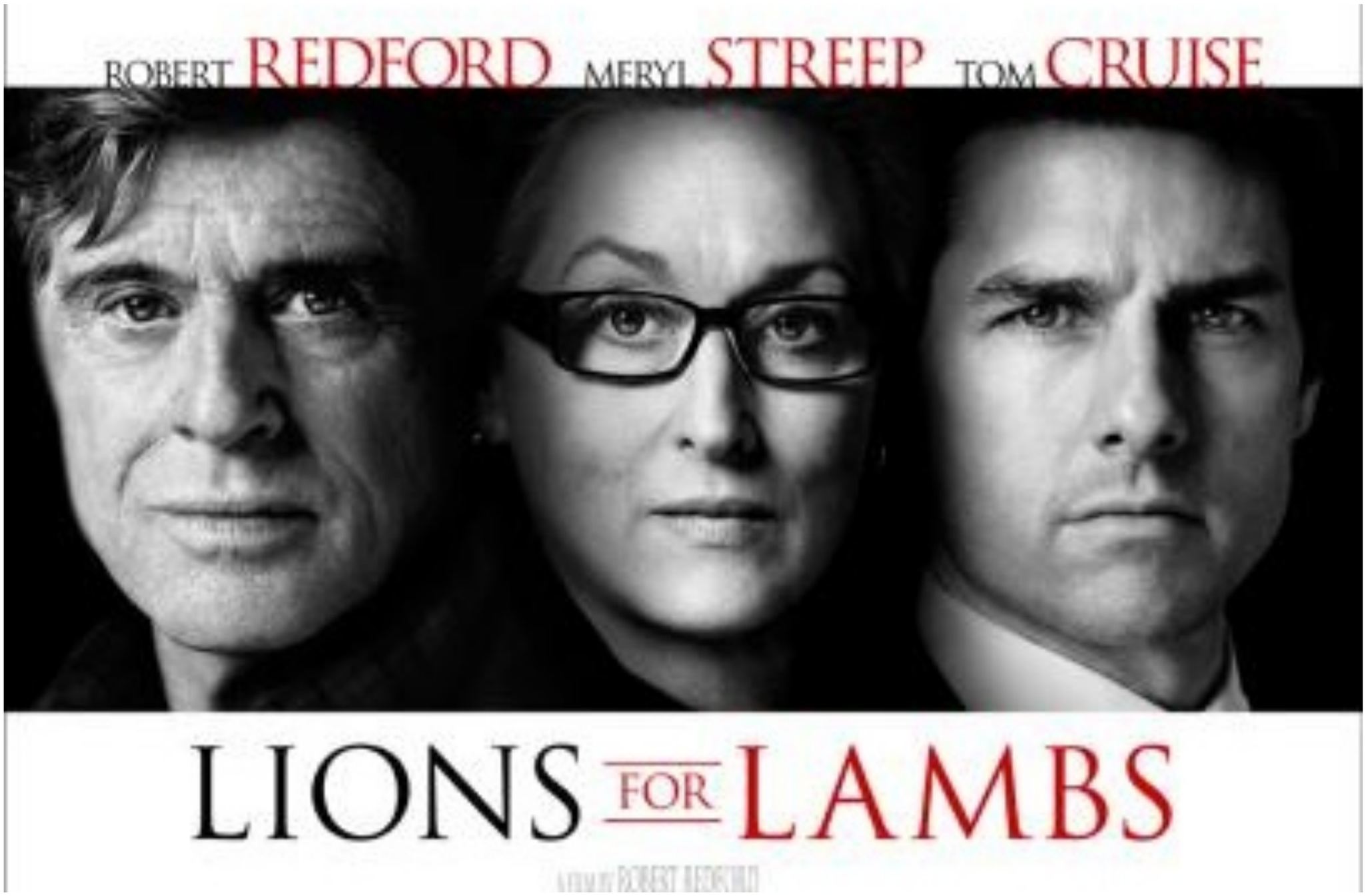
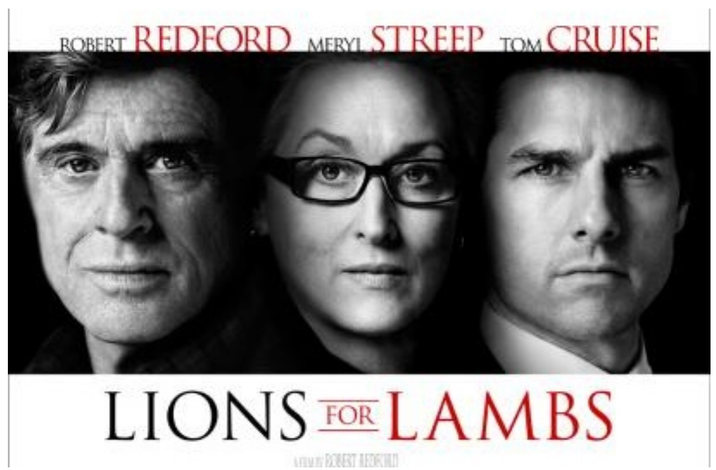
Your College Education Put Into Focus



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**

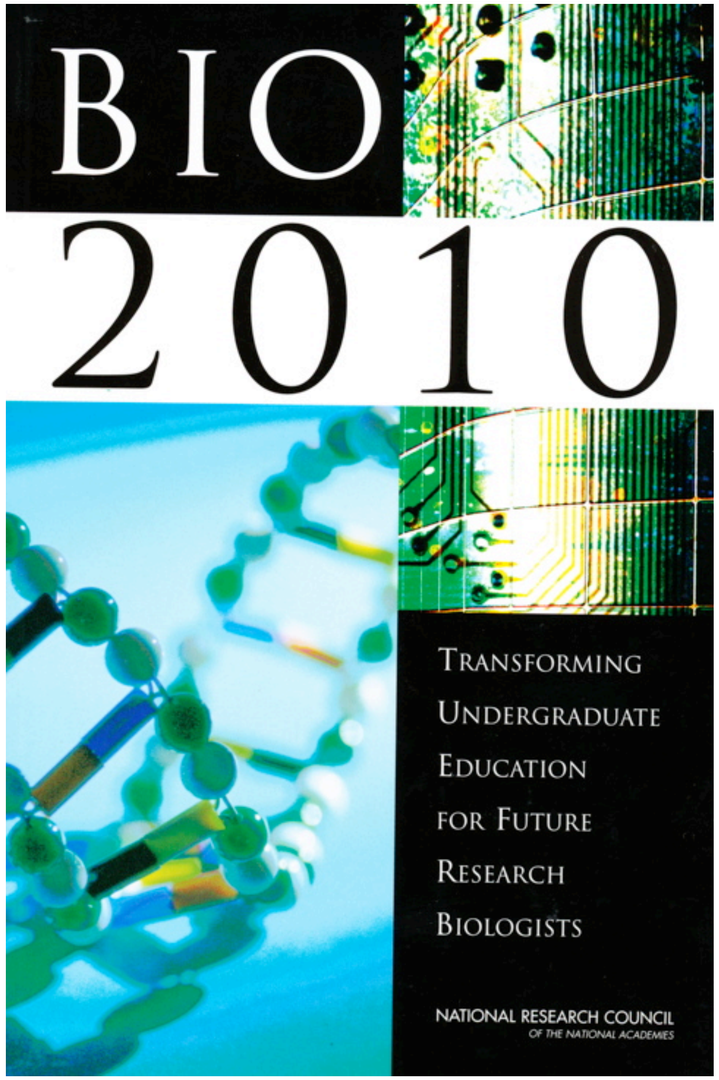
If we currently cover all the important stuff….

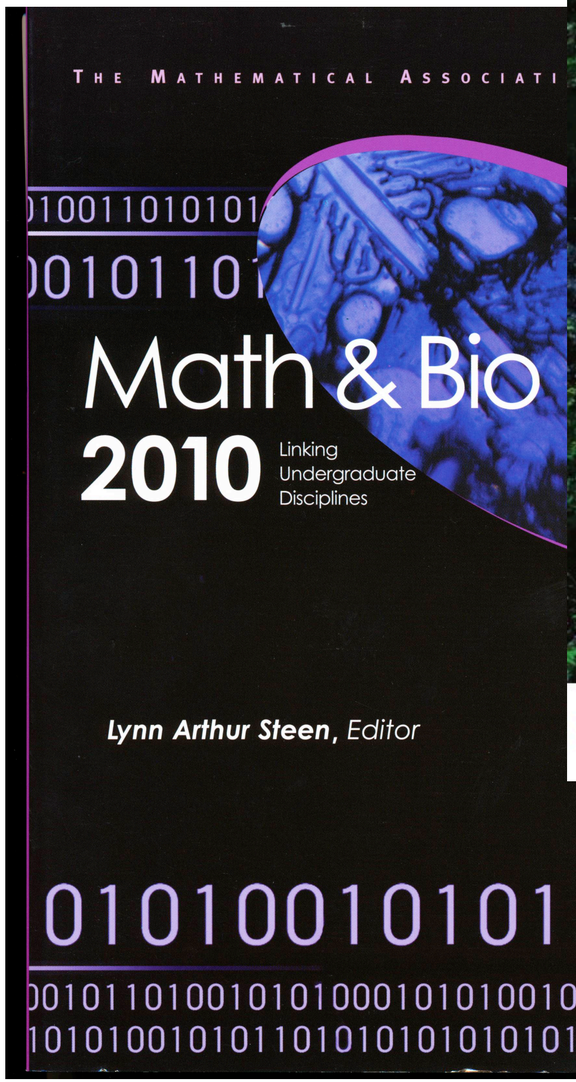
…how can we add more content?

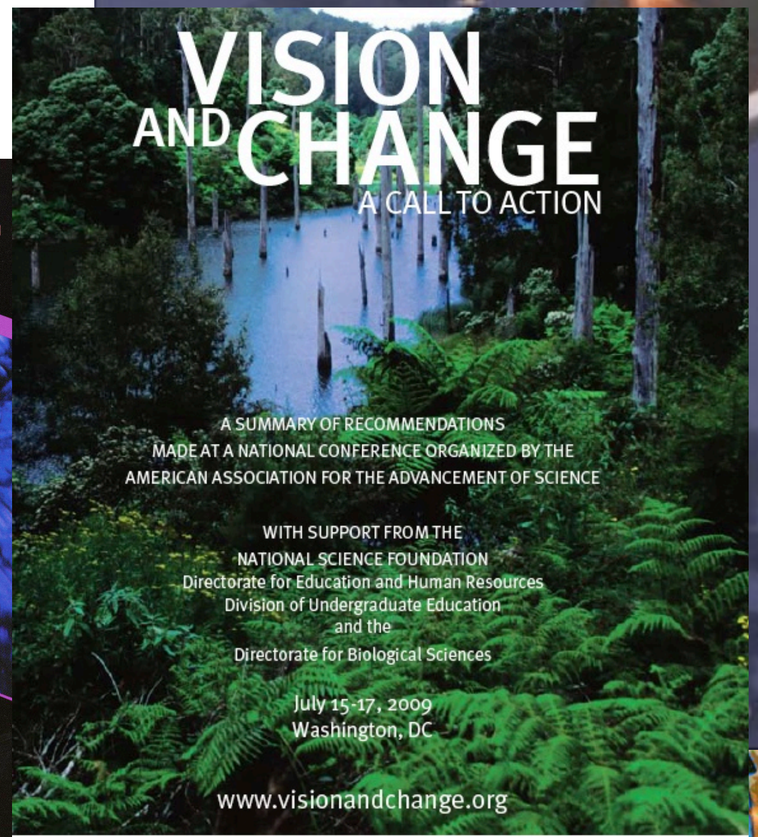
Too much content for the containers

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

Five Levels of Organization

Molecular

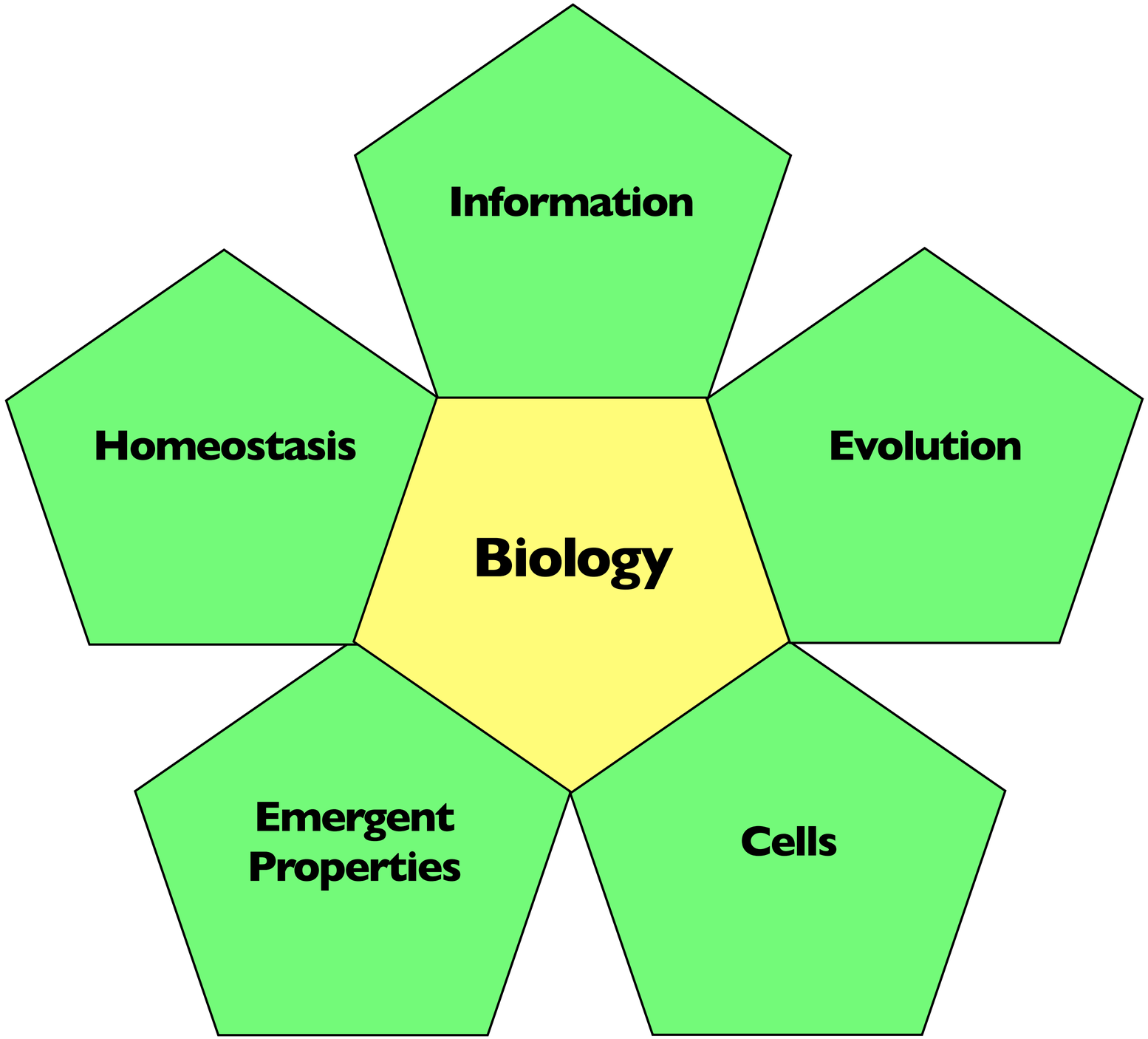
Cellular

Organismal

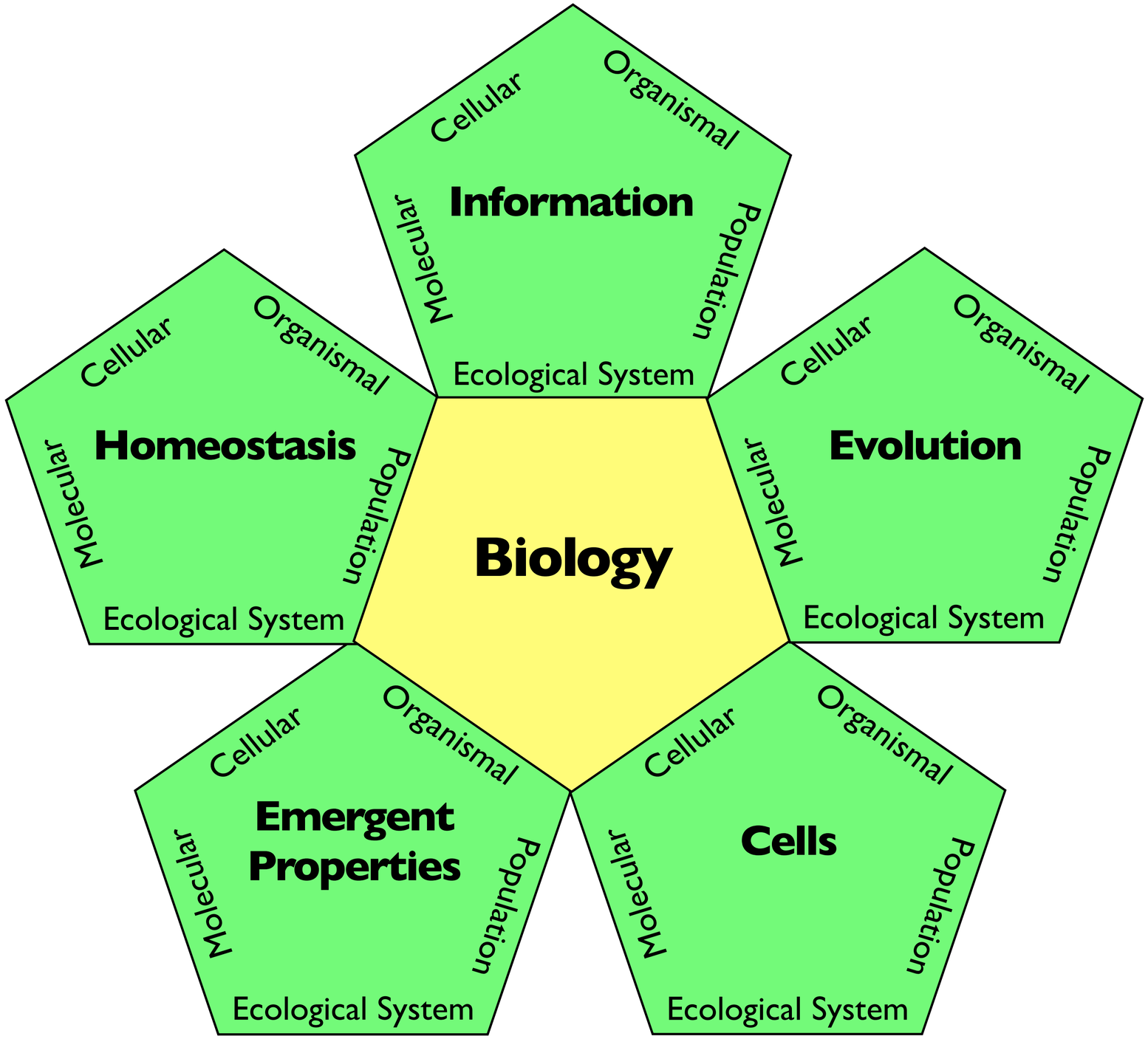
Population

Ecological System

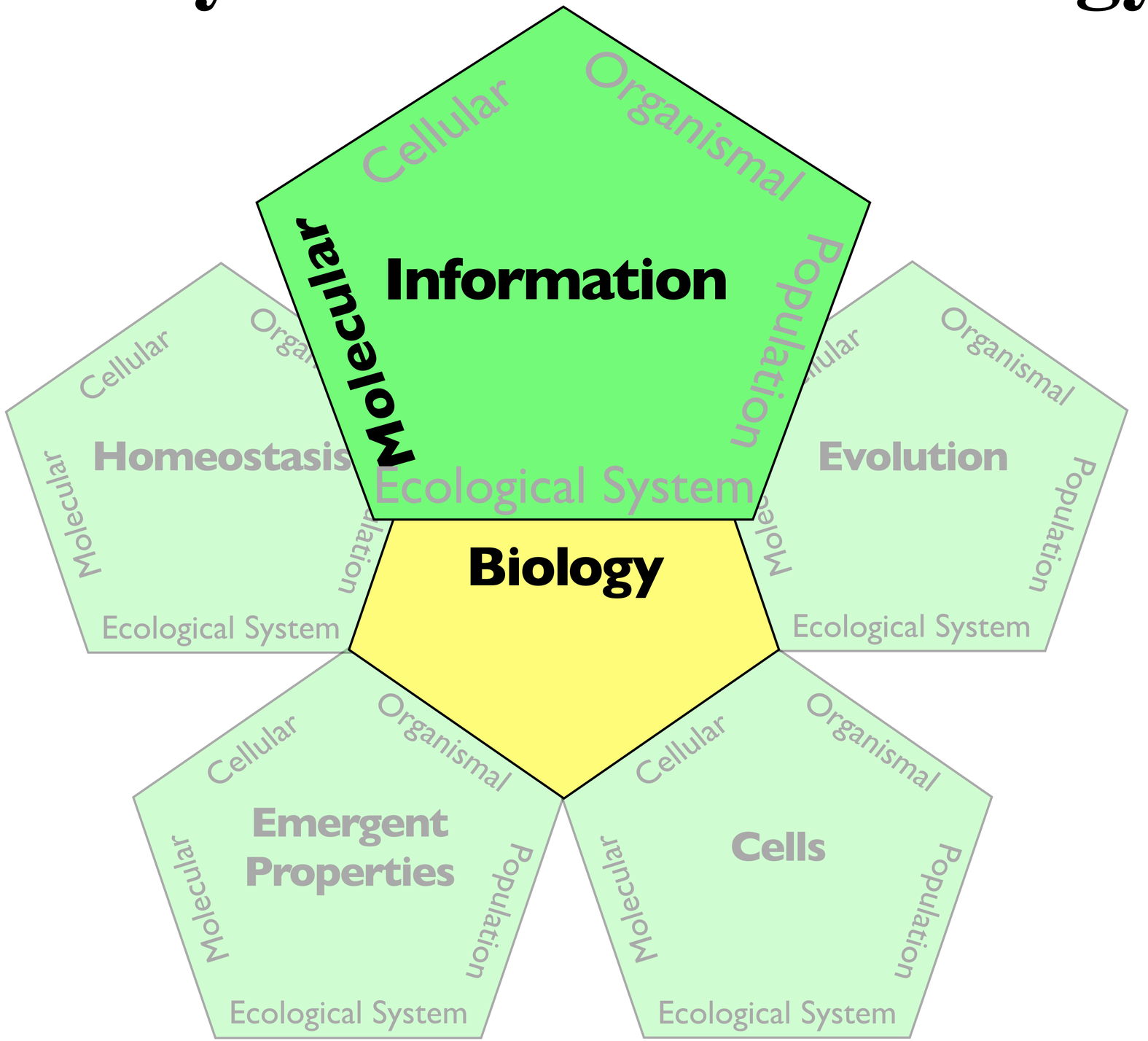
Five Big Ideas of Biology



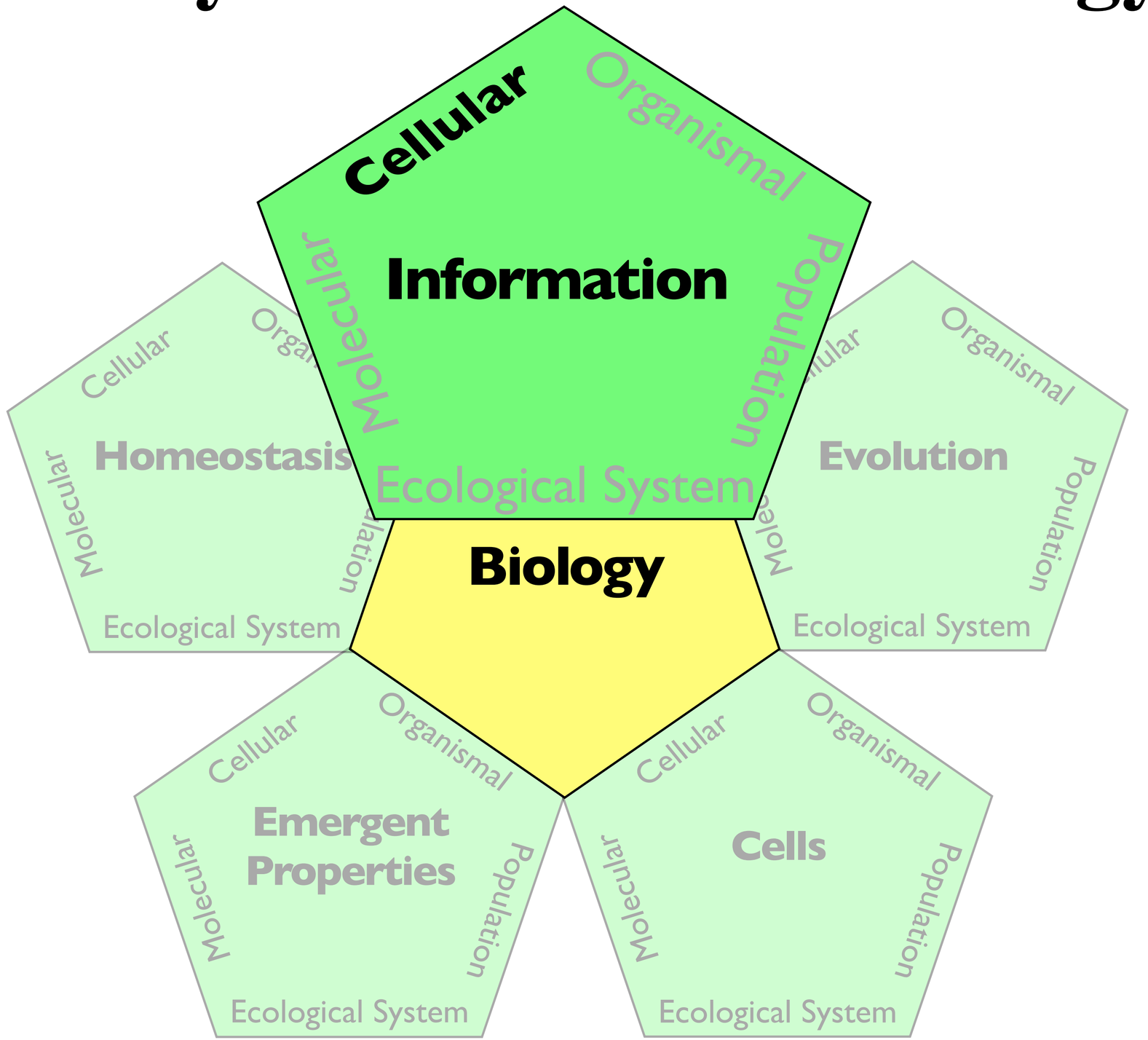
Five by Five Matrix of Biology



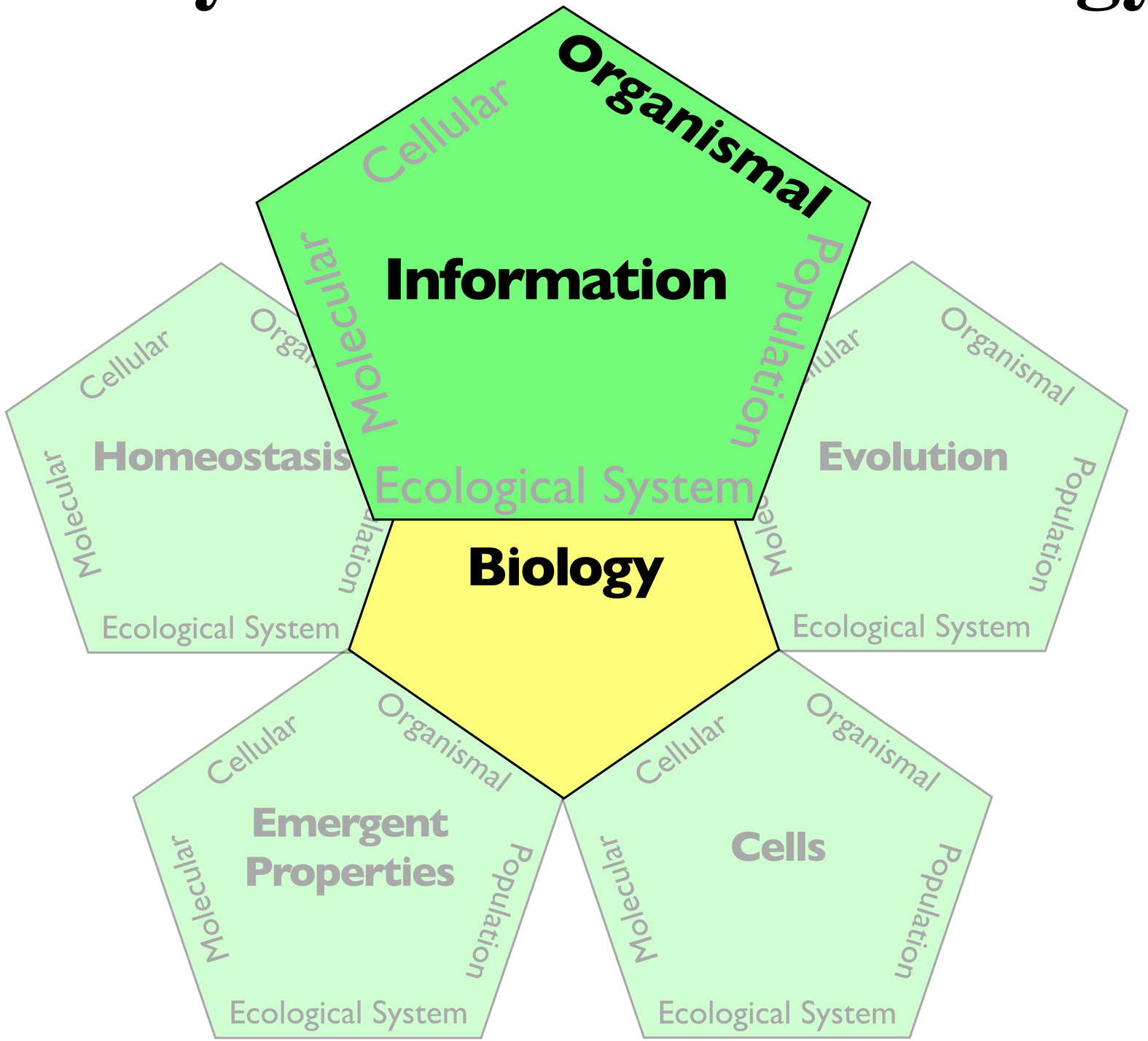
Five by Five Matrix of Biology



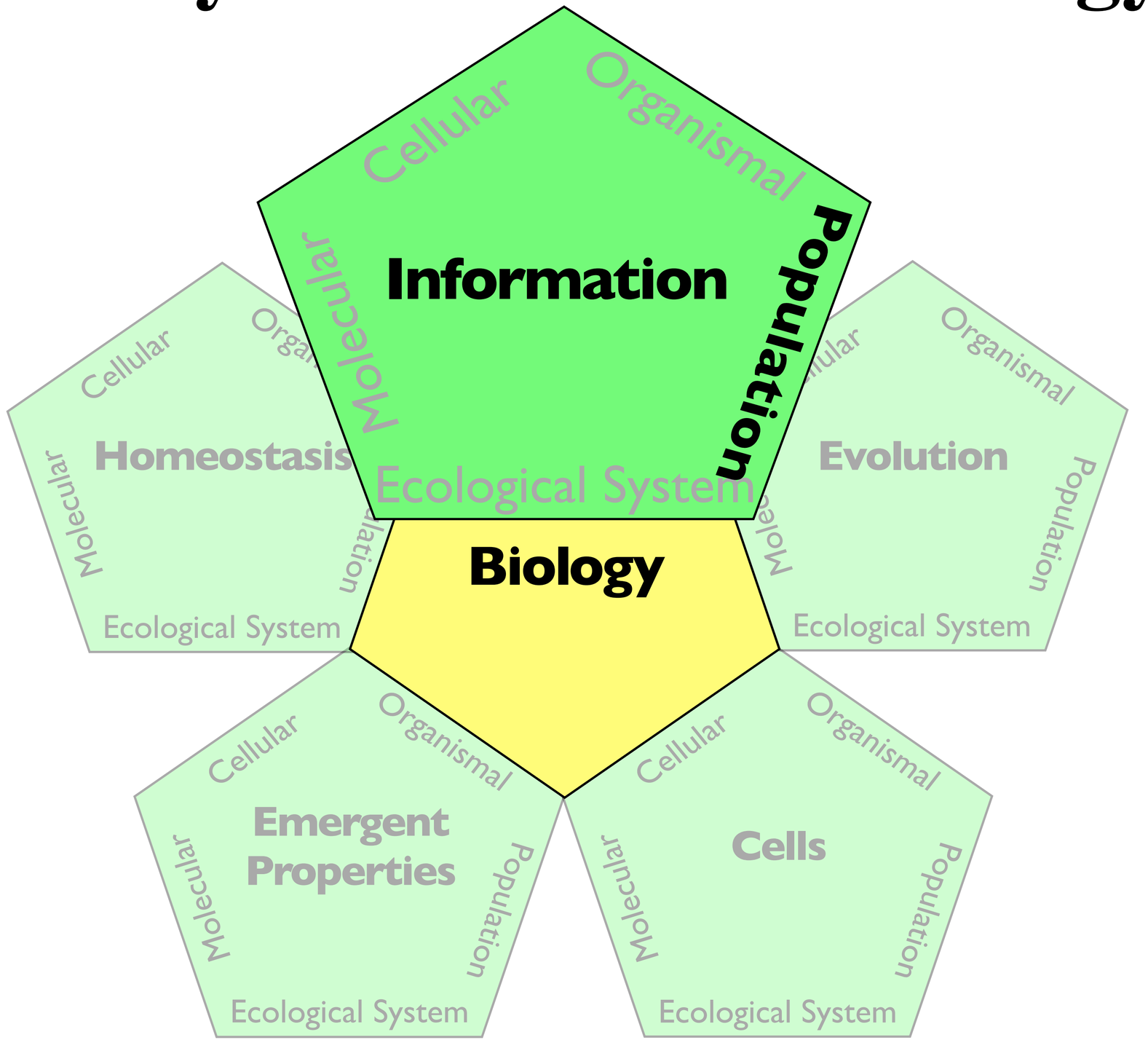
Five by Five Matrix of Biology



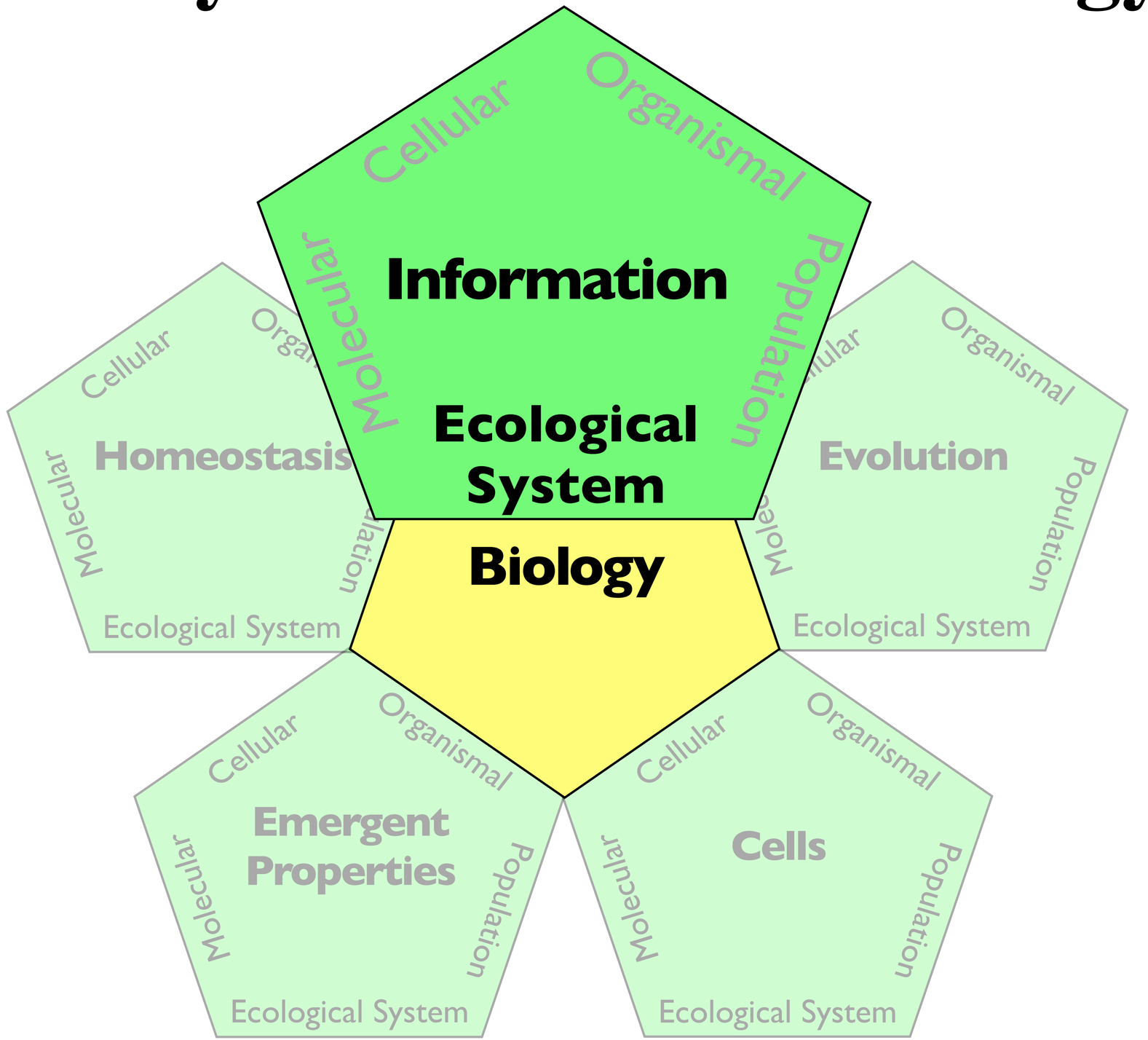
Five by Five Matrix of Biology



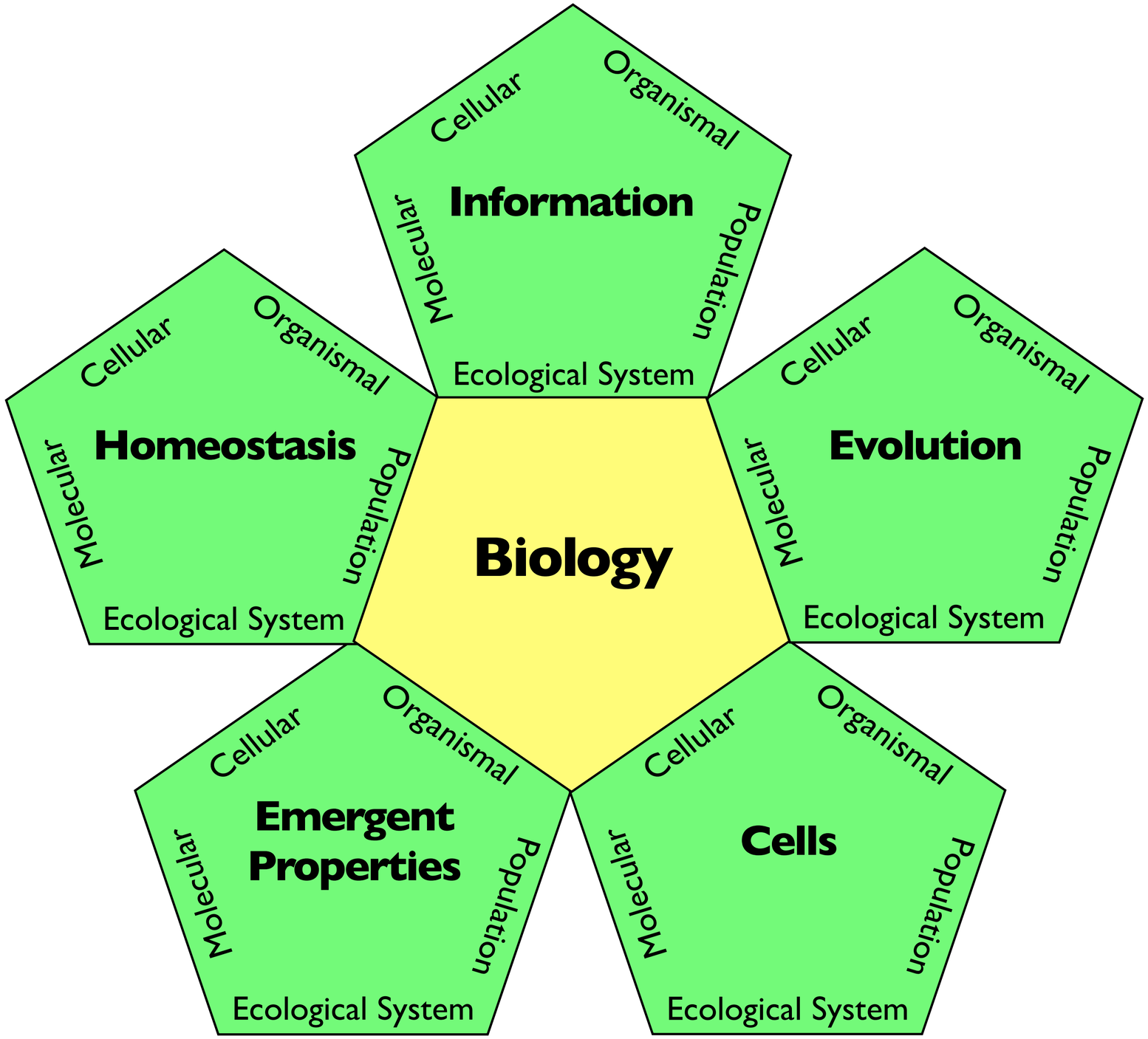
Five by Five Matrix of Biology



Five by Five Matrix of Biology



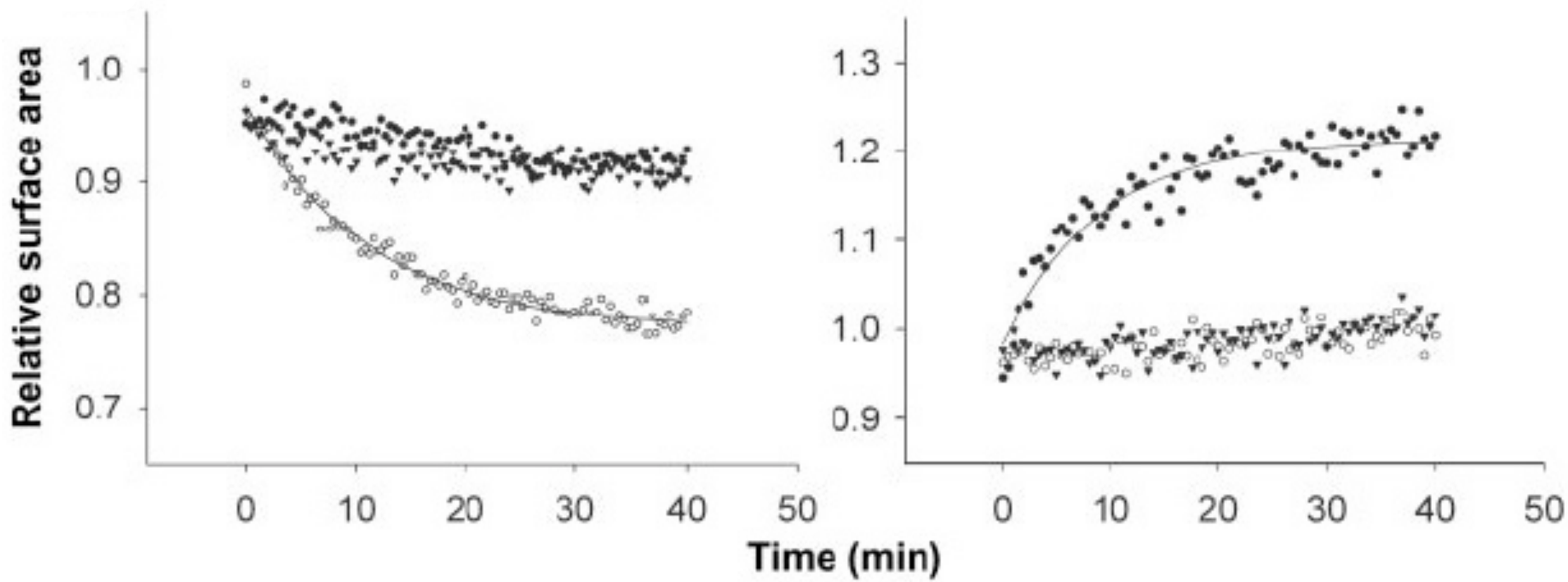
Five by Five Matrix of Biology



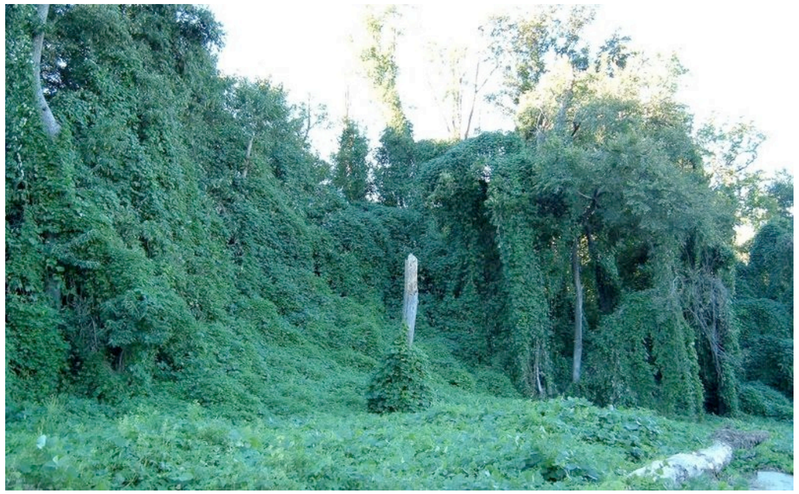
BioMath Explorations

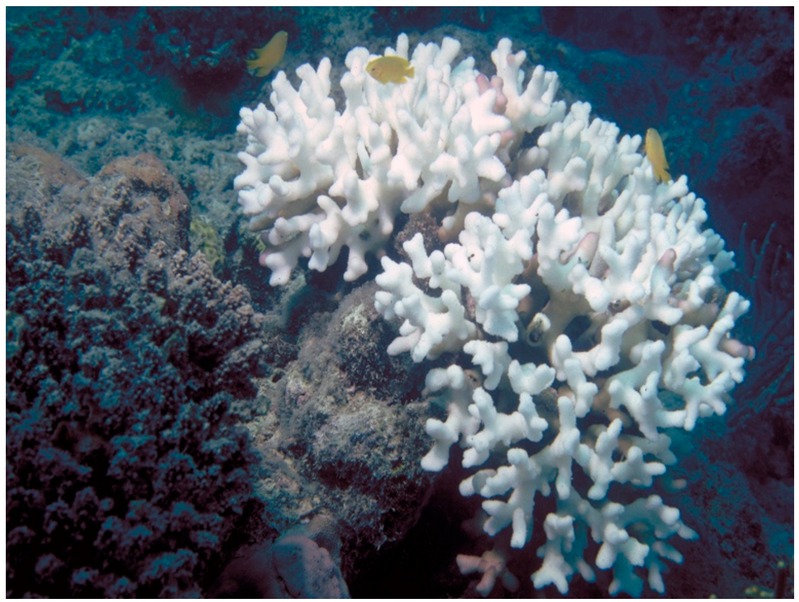
BioMath Exploration 6.3

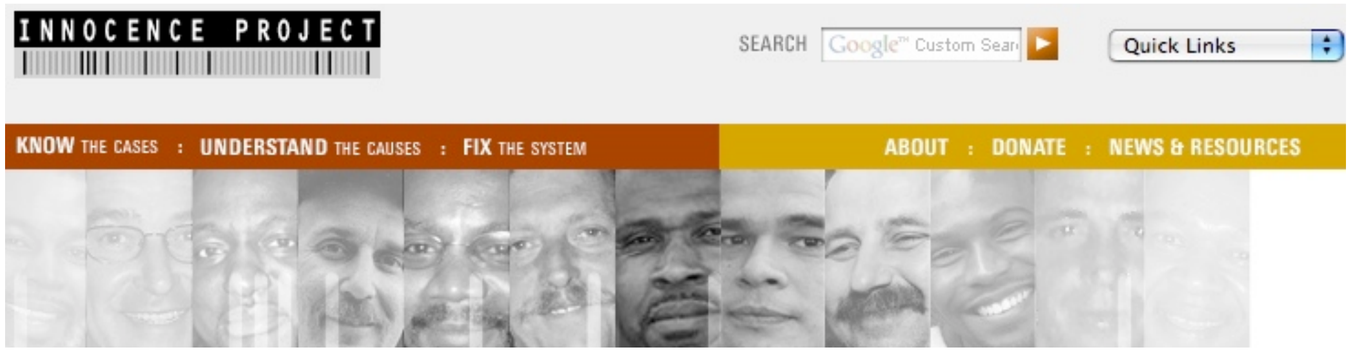
How can you fit exponential curves to data?



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?

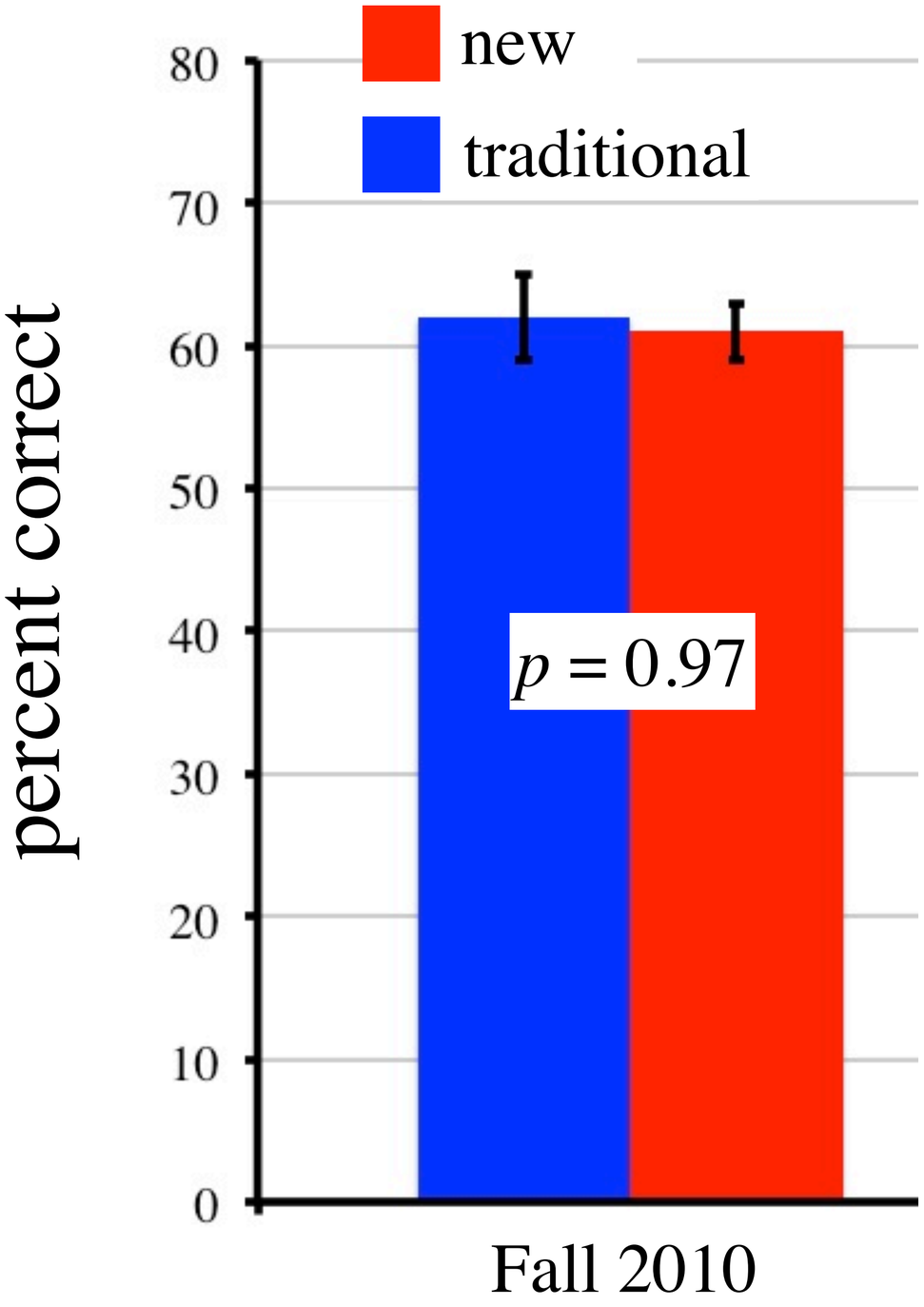
Who owns your DNA?

"Never mistake activity for achievement."

John Wooden

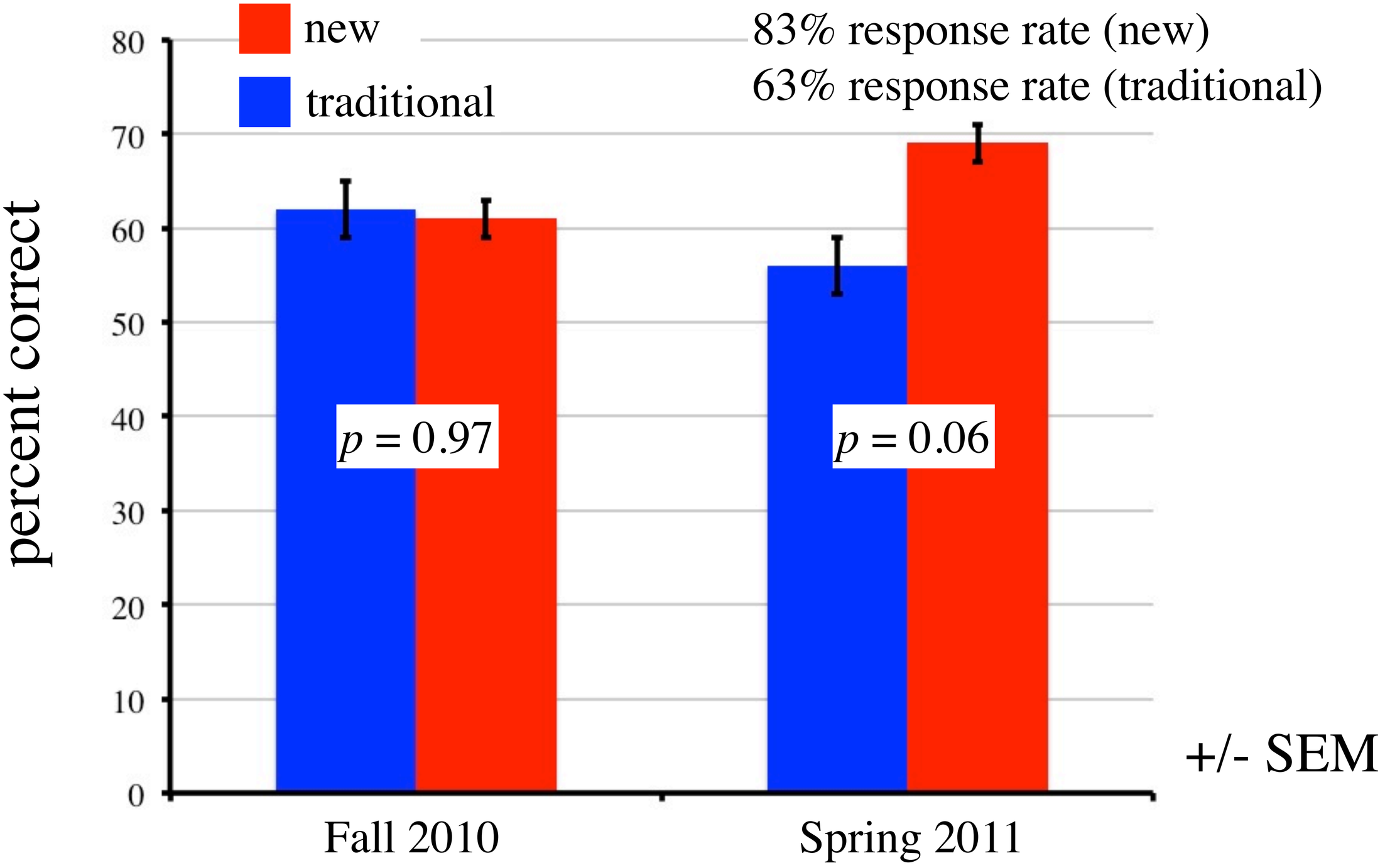
Did my students learn less content?

Student Content Assessment



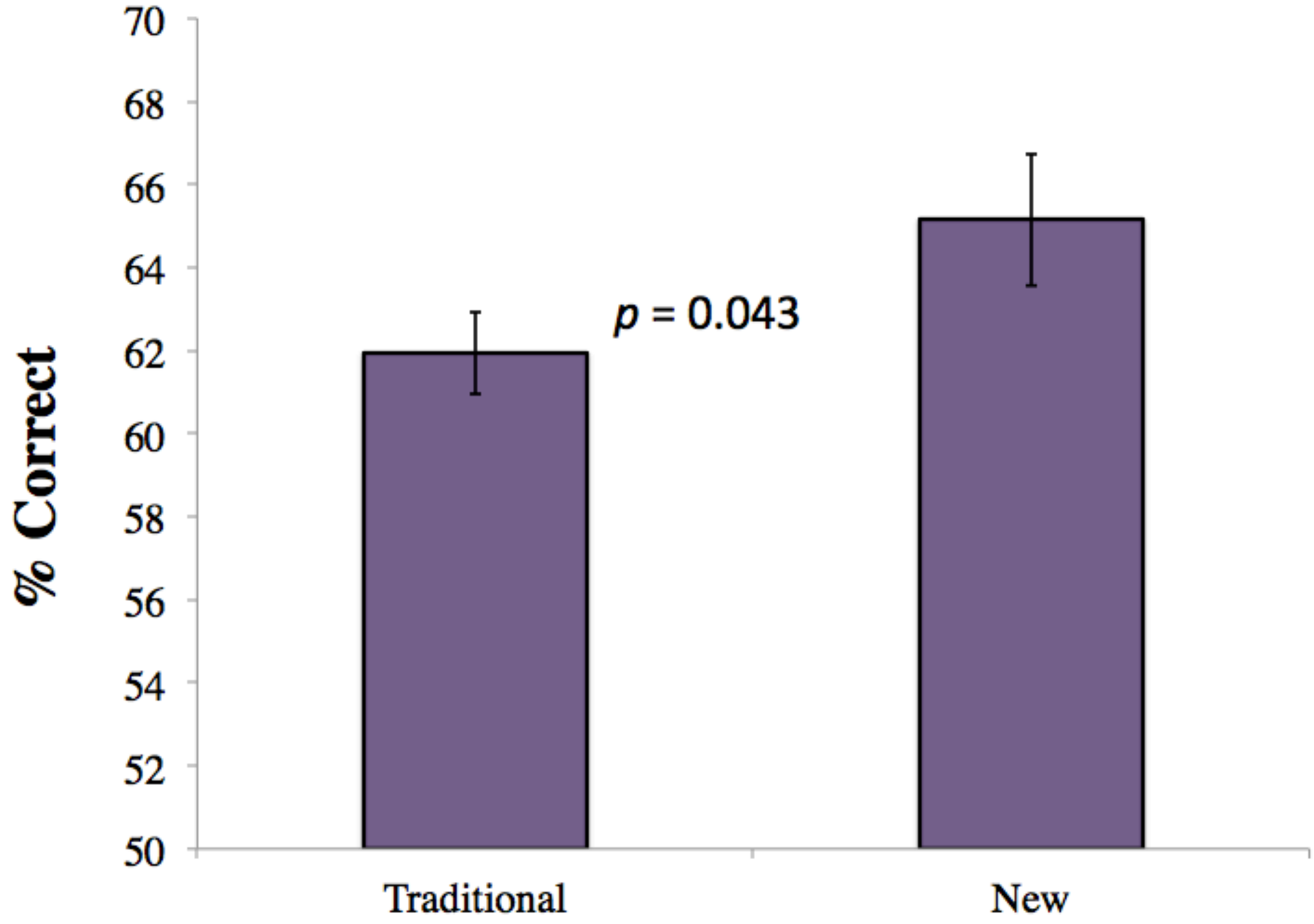
+/- SEM

Student Content Assessment

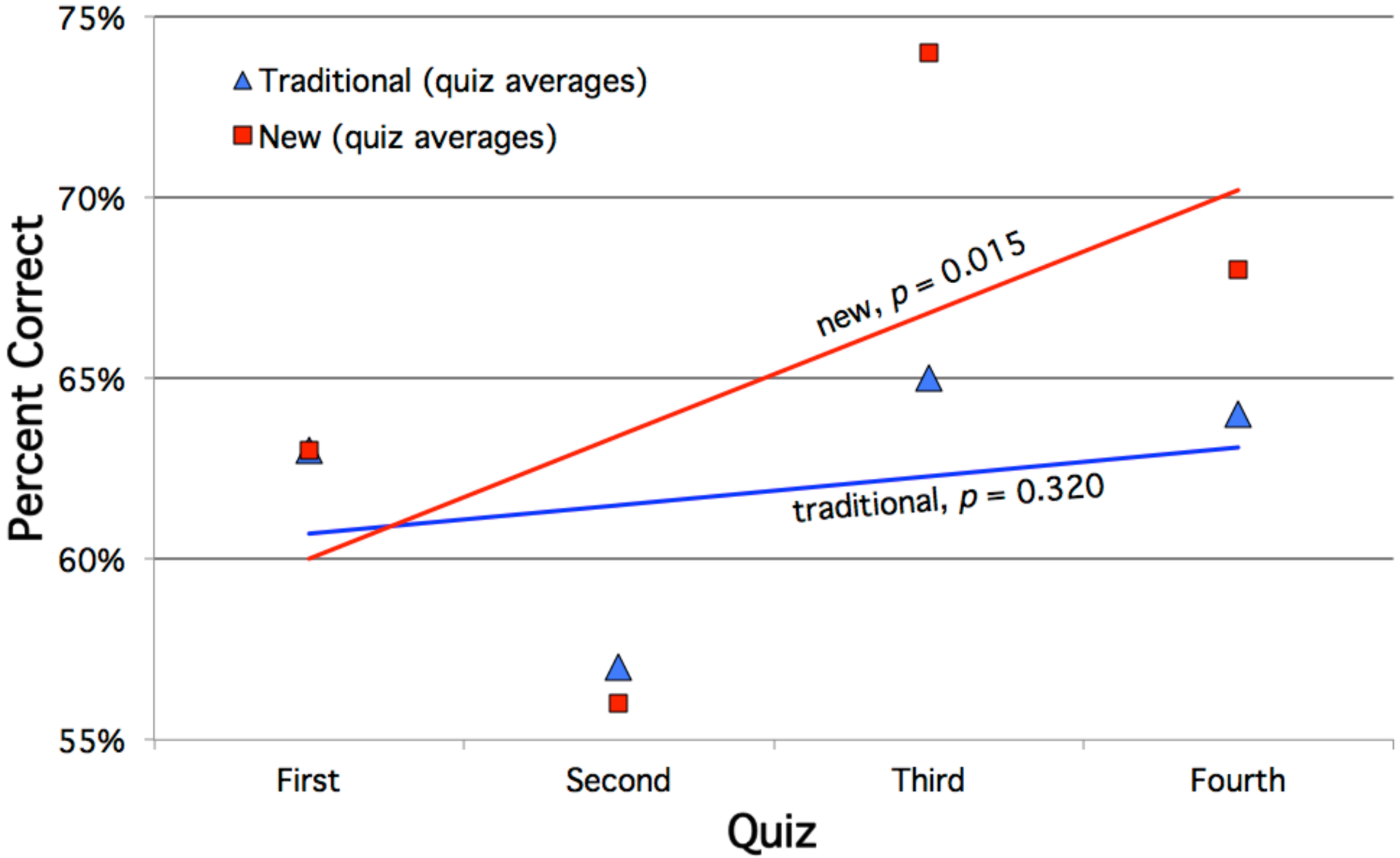


Can my students analyze data better?

Student Skills Assessment

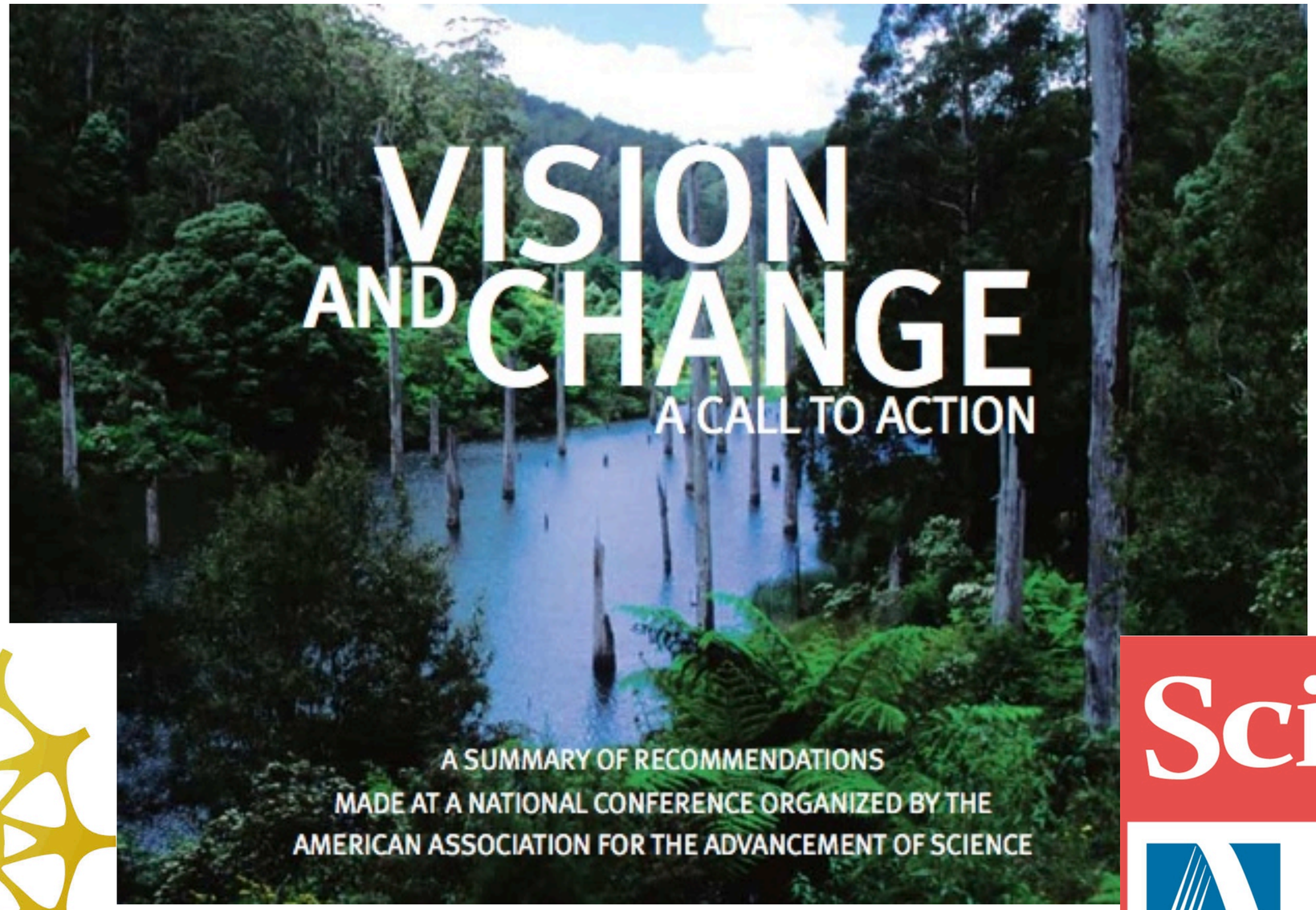


Student Skills Assessment



Why bother changing?

National Recognition of Need to Change



NSF

Science

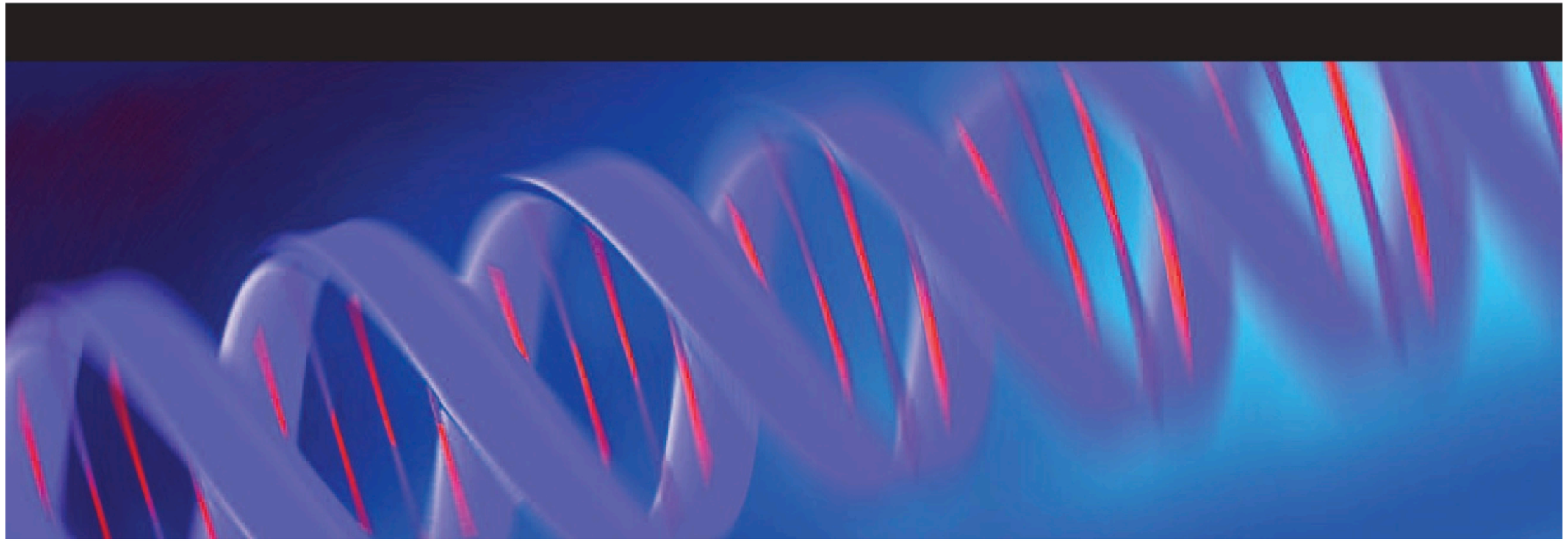
AAAS

AP Biology is Changing to Match Our Design

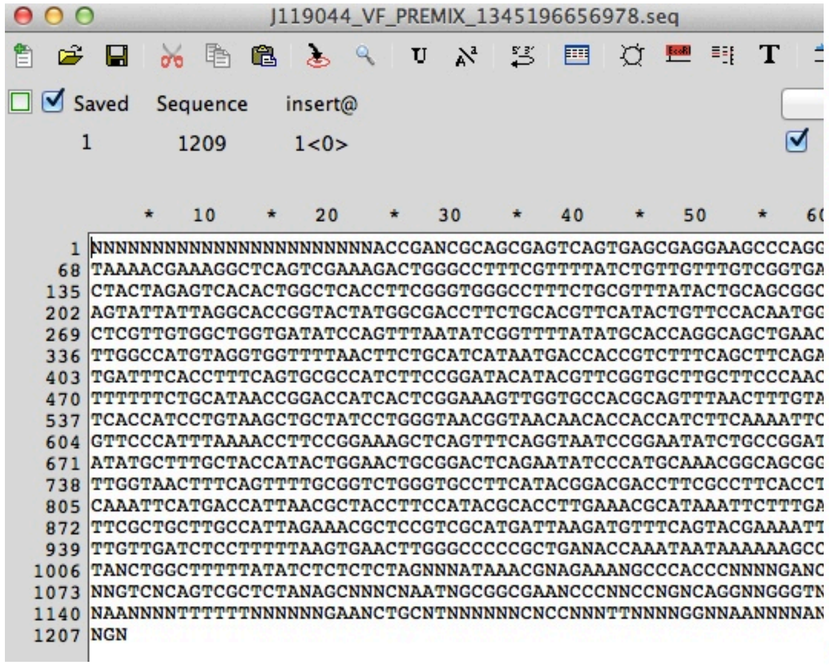
AP® BIOLOGY

Curriculum Framework

2012–2013



Lab on Information and Evolution



TAS2R38 Gene: FASTA Sequence

141,673,573 5′-

CCTTTCTGCACTGGGTGGCAACCAGGTCTTTAGATTAGCCAACTAGAGAAGAGAAC

TGACATCATGTTGACTCTAACTCGCATCCGCACTGTGTCCTATGAAGTCAGGAGTA

TGGAGTTTGCAGTGGGGTTTCTGACCAATGCCTTCGTTTTCTTGGTGAATTTTTGC

CTGAGCAACAGTGATTGTGTGCTGCTGTGTCTCAGCATCAGCCGGCTTTTCCTGCA

TATCCAGCTTACCCACTTCCAGAAGTTGAGTGAACCACTGAACCACAGCTACCAAC

TTGCAAACCAAGCCAACCTCTGGCTTGCTGCCTGCCTCAGCCTGCTTTACTGCTCC

ACCTTCCTGATCTGCTTGGCAAGCTGGGTCTCCAGGAAGATCTCCCAGATGCTCCC

CATCTGCACTGTCCTCTGTGTTTGGTGCTTTTTTAGCAGACCTCACTTCACAGTCA

ACAATACAAGGCTCAACTGGCAGATTAAAGATCTCAATTTATTTTATTCCTTTCTC

CCTCCTTTCCTATTGTTTCTGGTTTCTTCTGGGATGCTGACTGTCTCCCTGGGAAC

CTATACCAGAAACTCTCGTGACCCCAGCCTGGAGGCCCACATTAAAGCCCTCAAGT

TCTTTGTGATATCATCCTGTGCTGCCTTCATCTCTGTGCCCCTACTGATTCTGTG

GTTTGTGTTGGGATAATGGCAGCTTGTCCCTCTGGGCATGCAGCCATCCTGATCT

AGCTGTGATGACCATTCTGCTCTGGGCTCAGAGCAGCCTGAAGGTAAGAGCCGAC

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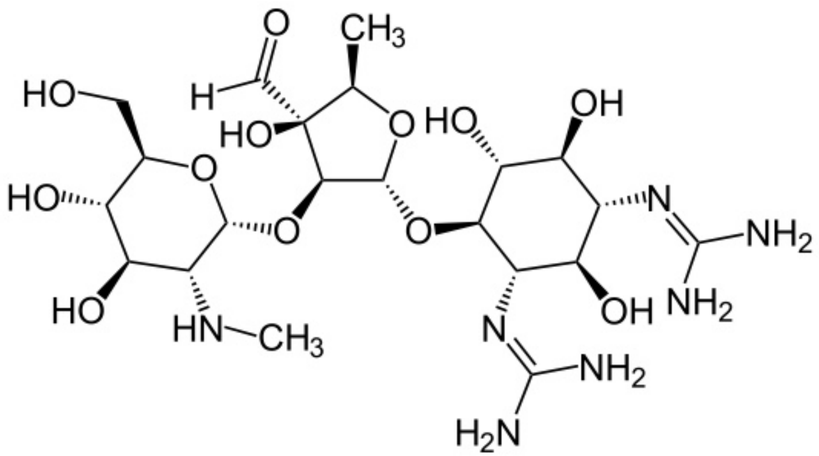
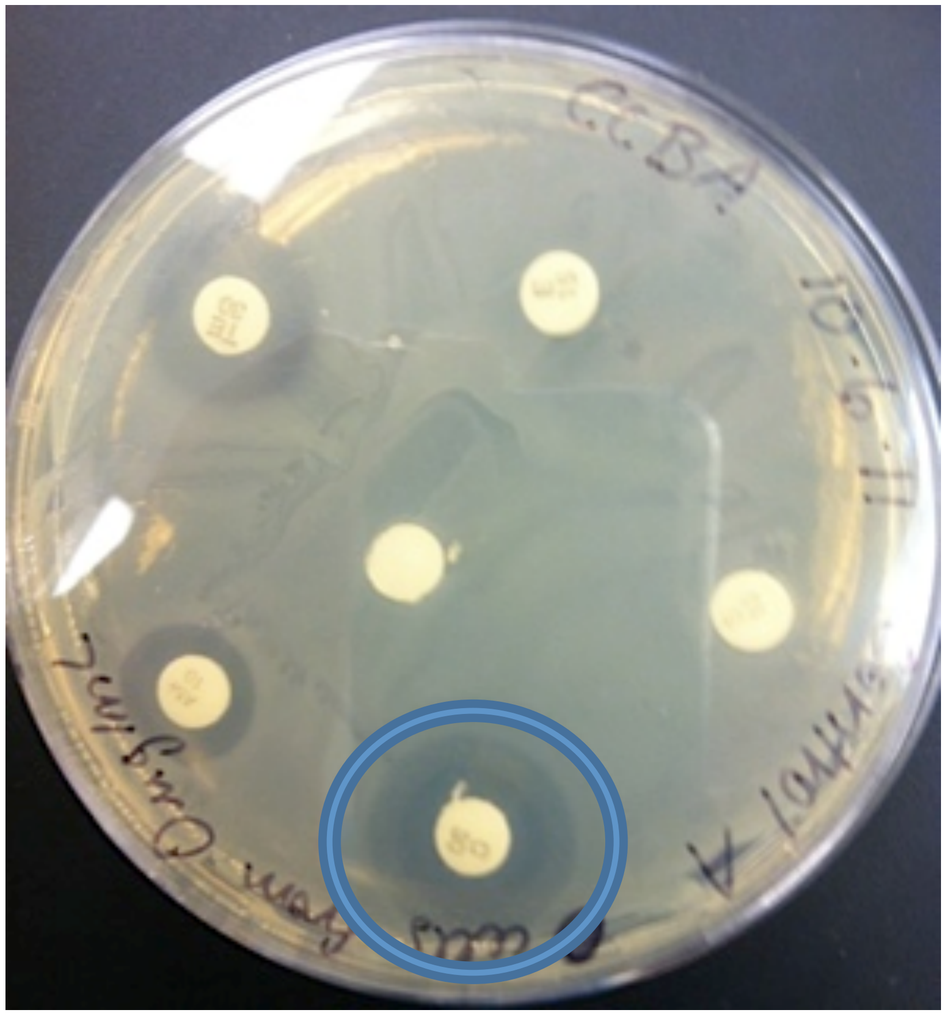
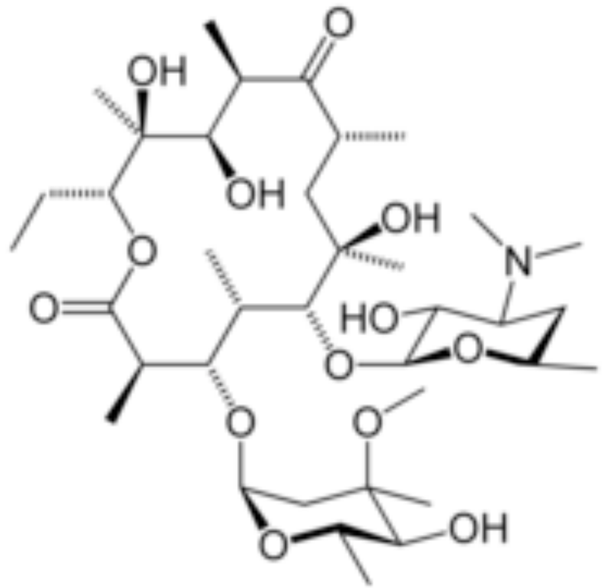
-3′ 141,672,431

Evolution of Antibiotic Resistance

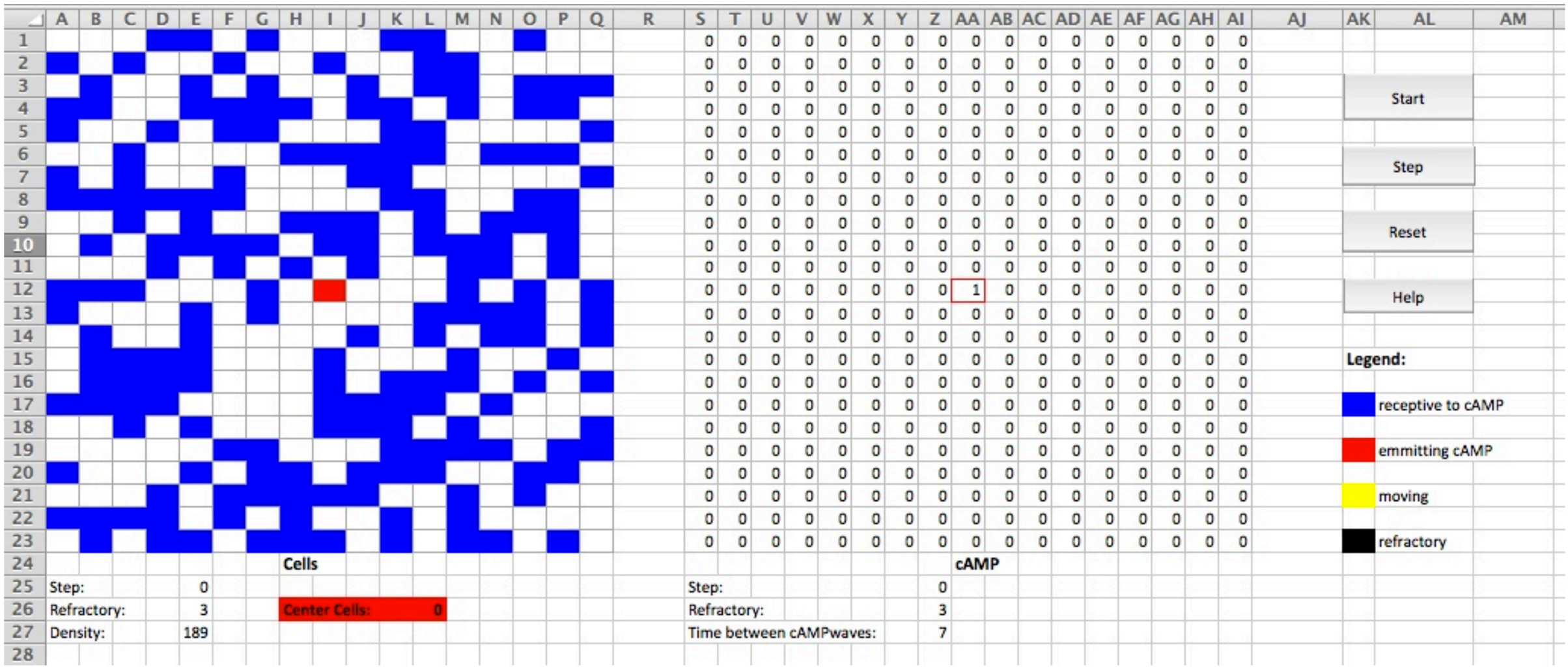






Emergent Properties in Slime Mold

Computer Simulation to Deduce Timing



Reduce Lab Manual, Increase Student Input

1) pre-assignments
2) ask questions
3) outline the goals
4) let them design experiments

September 20	Information Learning Objectives		**Before Lab...** 1) 4 pm day before lab, boil oligos 2) Answer 4 Questions 3) View the receiving plasmid J100091 **During Lab...** 4) use the Loligator to get oligos ready for ligation 5) do GGA ligation for oligos 6) transform *E. coli* cells 7) design promoter experiment (with controls) 8) CATME peer review	Lab Manual Week #4

Assessment Instruments:

- CATME.org
- synthetic biology pre/post quiz
- skills test (analyze and interpret new data)
- oral and written lab reports
- iBOP Bingo

Reduce Lab Manual, Increase Student Input

September 20	Information Learning Objectives		**Before Lab...** 1) 4 pm day before lab, boil oligos 2) Answer 4 Questions 3) View the receiving plasmid J100091 **During Lab...** 4) use the Loligator to get oligos ready for ligation 5) do GGA ligation for oligos 6) transform *E. coli* cells 7) design promoter experiment (with controls) 8) CATME peer review	Lab Manual Week #4

www.bio.davidson.edu/113/113labscedule2012.html

What did my students think about this approach to intro bio?

“The method of learning, placing emphasis on the interpretation of data, has helped me not only in this class, but also in others.”

anonymous student course evaluation, Dec. 2010

“I found it much more beneficial using this approach compared to straight memorization. It allowed me to gain interpretation skills I was lacking before.”

anonymous student course evaluation, Dec. 2010

“The data-driven approach is brilliant. It alleviates the issues that I’ve always had of asking, ‘How do we know that? What’s the supporting data?’ ”

anonymous student course evaluation, Dec. 2010

“Emphasis on big picture and understanding how to pull information from real data was an easier and more beneficial format than memorization of facts (which used to be a struggle for me).”

anonymous student course evaluation, Dec. 2010

Acknowledgements

Faculty: Laurie Heyer, Jeff Poet, Todd Eckdahl, Karmella Haynes, Pat Sellers, Mark Barsoum

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.

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Genome Consortium for Active Teaching (**GCAT**)
Davidson College James G. Martin Genomics Program
MWSU SGA, Foundation & Summer Research Institute

Three Rules for Student Research

1. Everyone must learn.

Three Rules for Student Research

1. Everyone must learn.
2. Everyone must have fun.

Three Rules for Student Research

1. Everyone must learn.
2. Everyone must have fun.
3. We try to contribute to science.

1. Research Open Access Highly accessed
45482 Accesses
Solving a Hamiltonian Path Problem with a bacterial computer
Jordan Baumgardner, Karen Acker, Oyinade Adefuye, Samuel Crowley, Will D
Heard, Andrew T Martens, Nickolaus Morton, Michelle Ritter, Amber Shoecraft
Amanda Valencia, Mike Waters, A Malcolm Campbell, Laurie J Heyer, Jeffrey L
Journal of Biological Engineering 2009, **3**:11 (24 July 2009)
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Journal of Biological Engineering 2008, **2**:8 (20 May 2008)
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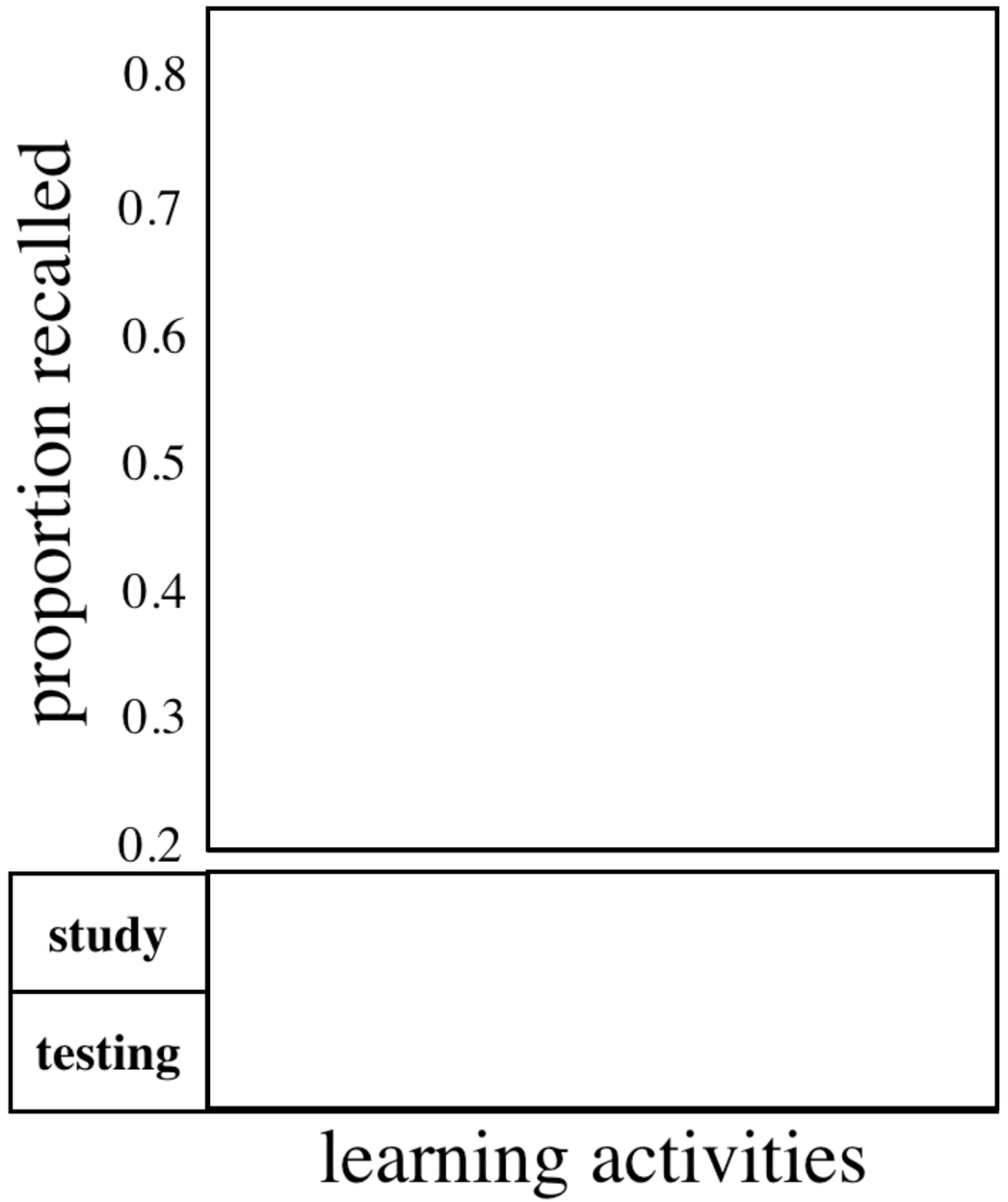
Reshma P Shetty, Drew Endy, Thomas F Knight
Journal of Biological Engineering 2008, **2**:5 (14 April 2008)
Abstract | Full text | PDF | PubMed | Cited on BioMed Central

JOURNAL OF BIOLOGICAL ENGINEERING

25 undergraduate co-authors

Paper of the year, 2008 &2009

What is the most effective way to study?



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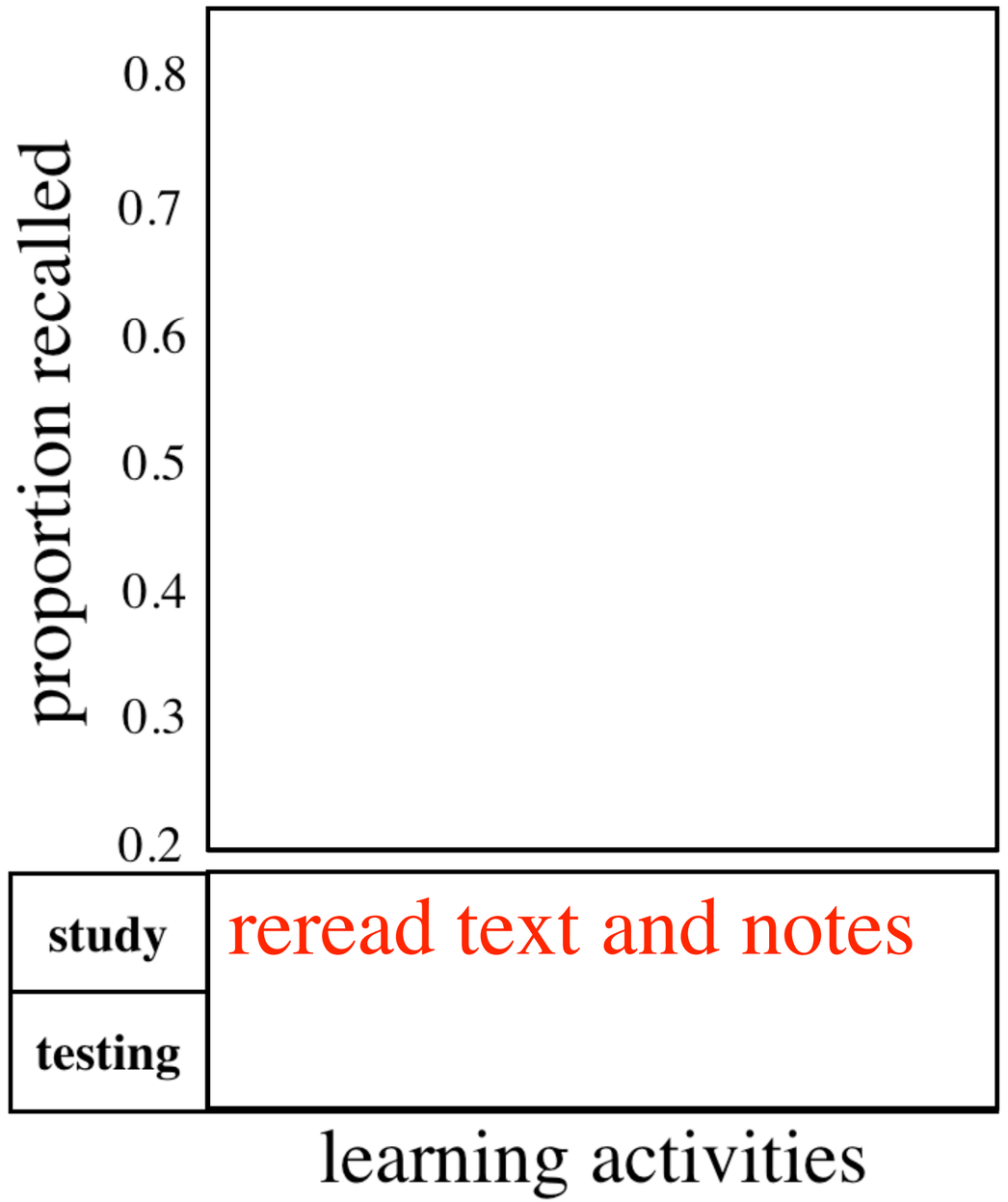

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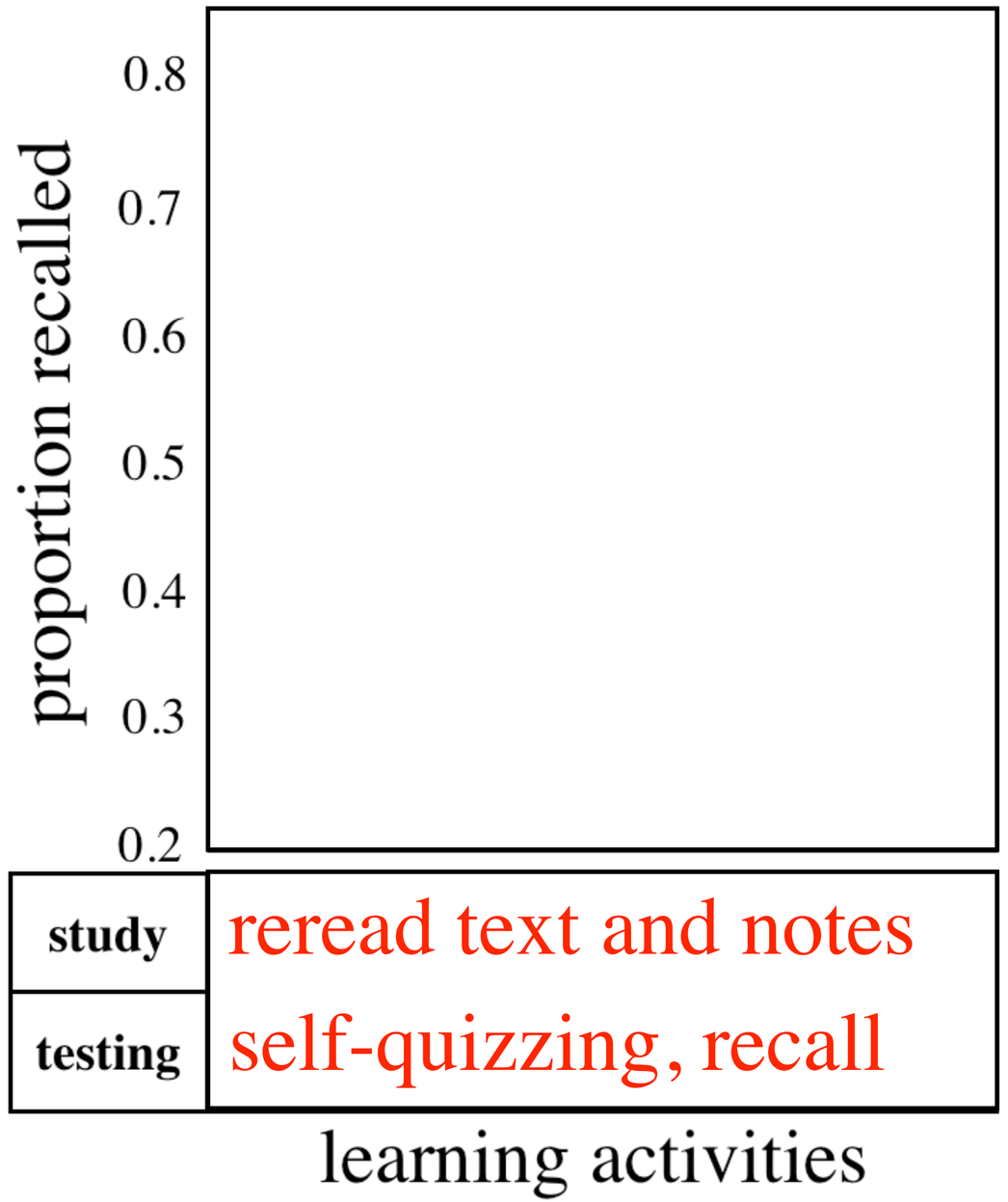
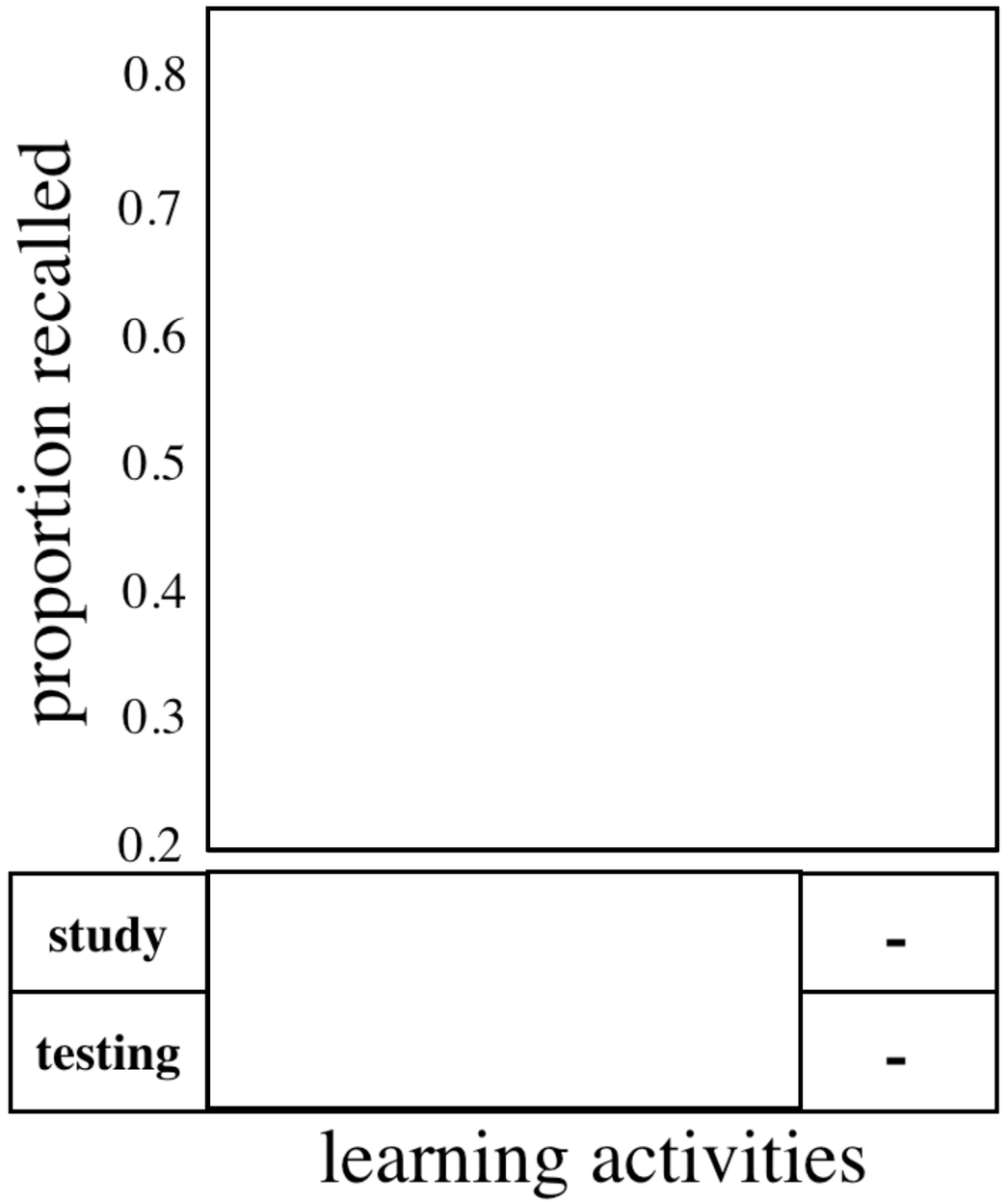
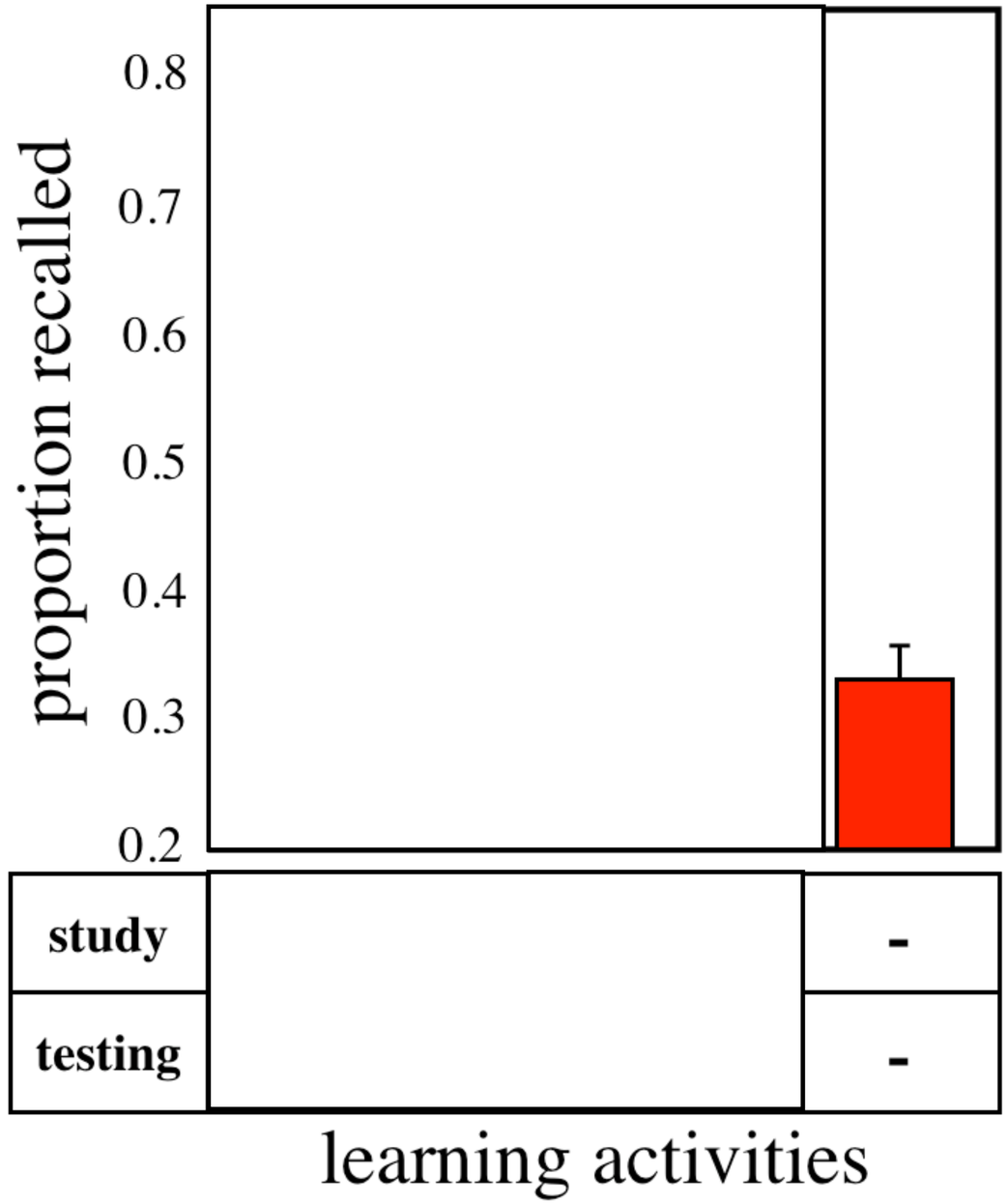


What is the most effective way to study?



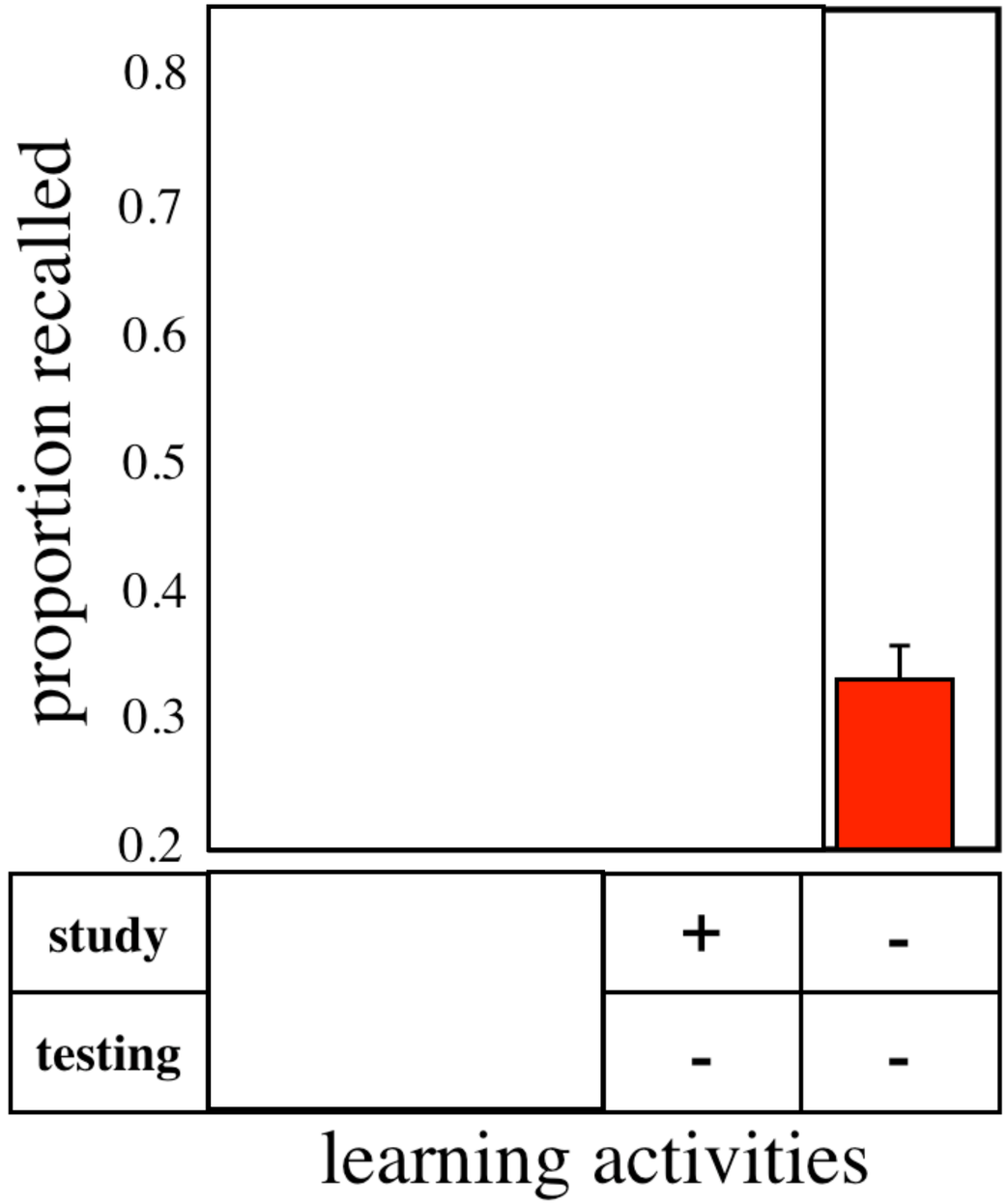
What do we call this condition in an experiment?

What is the most effective way to study?



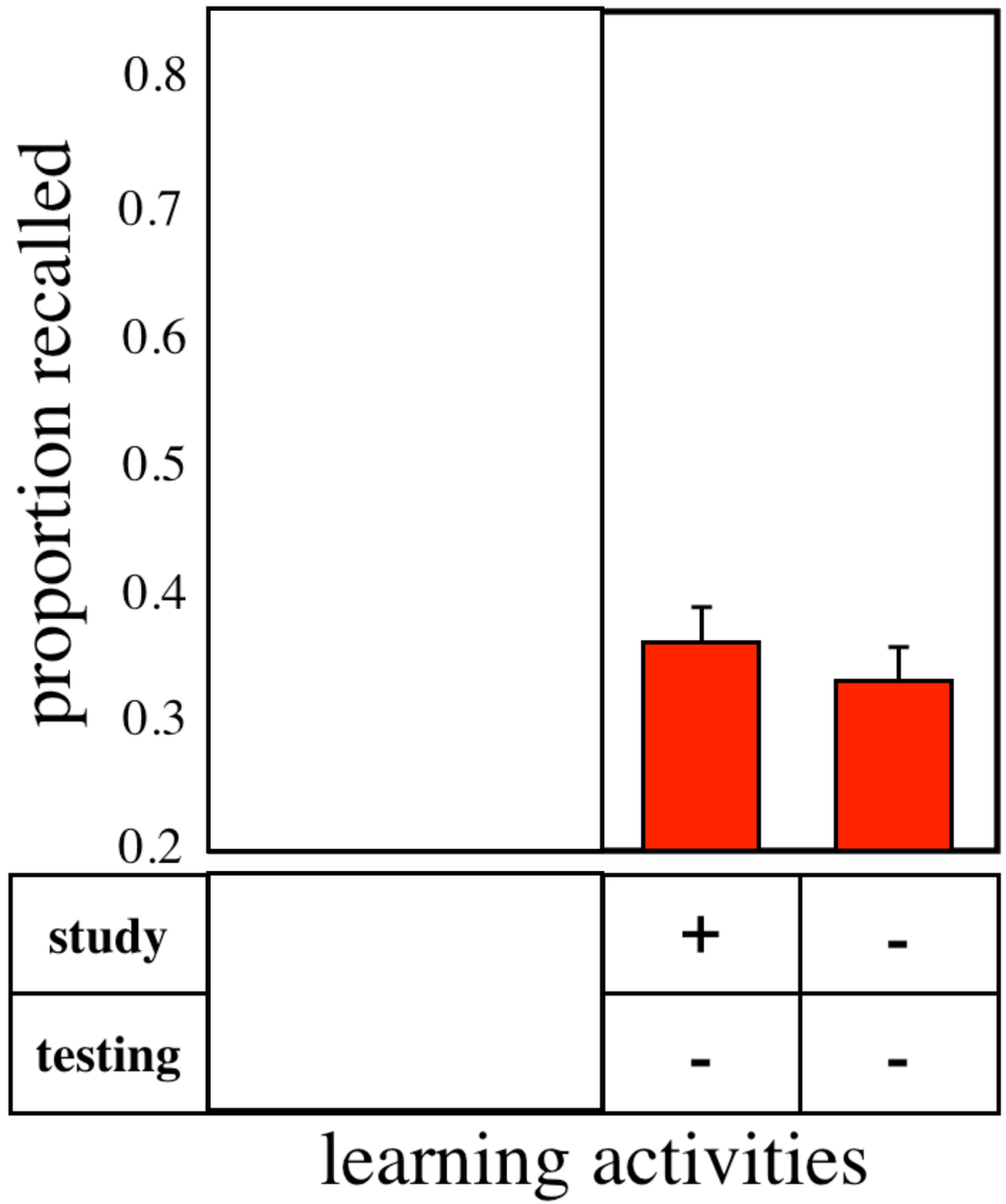
Students got 30% correct if they did not study at all.

What is the most effective way to study?



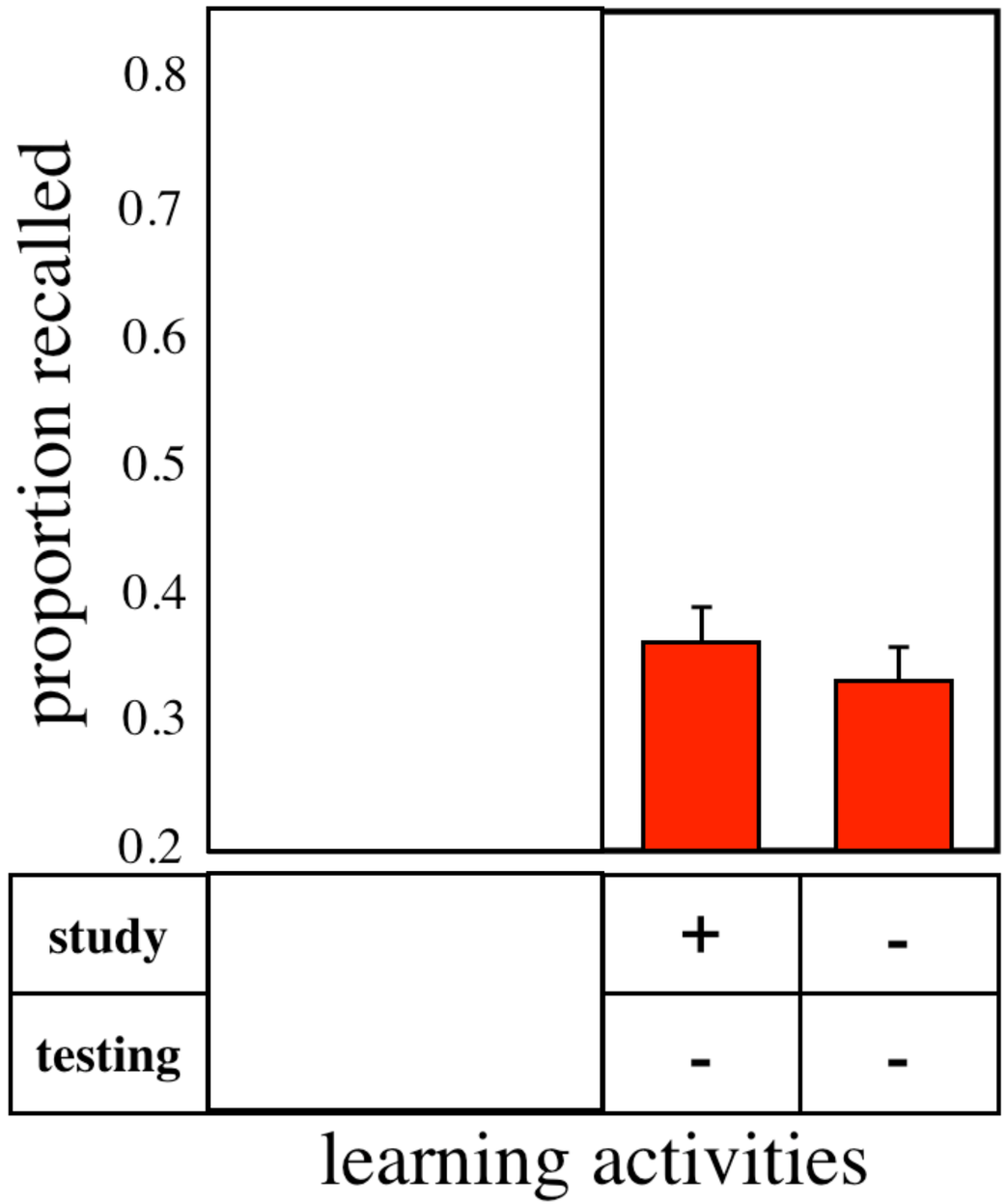
What would you predict with study?

What is the most effective way to study?



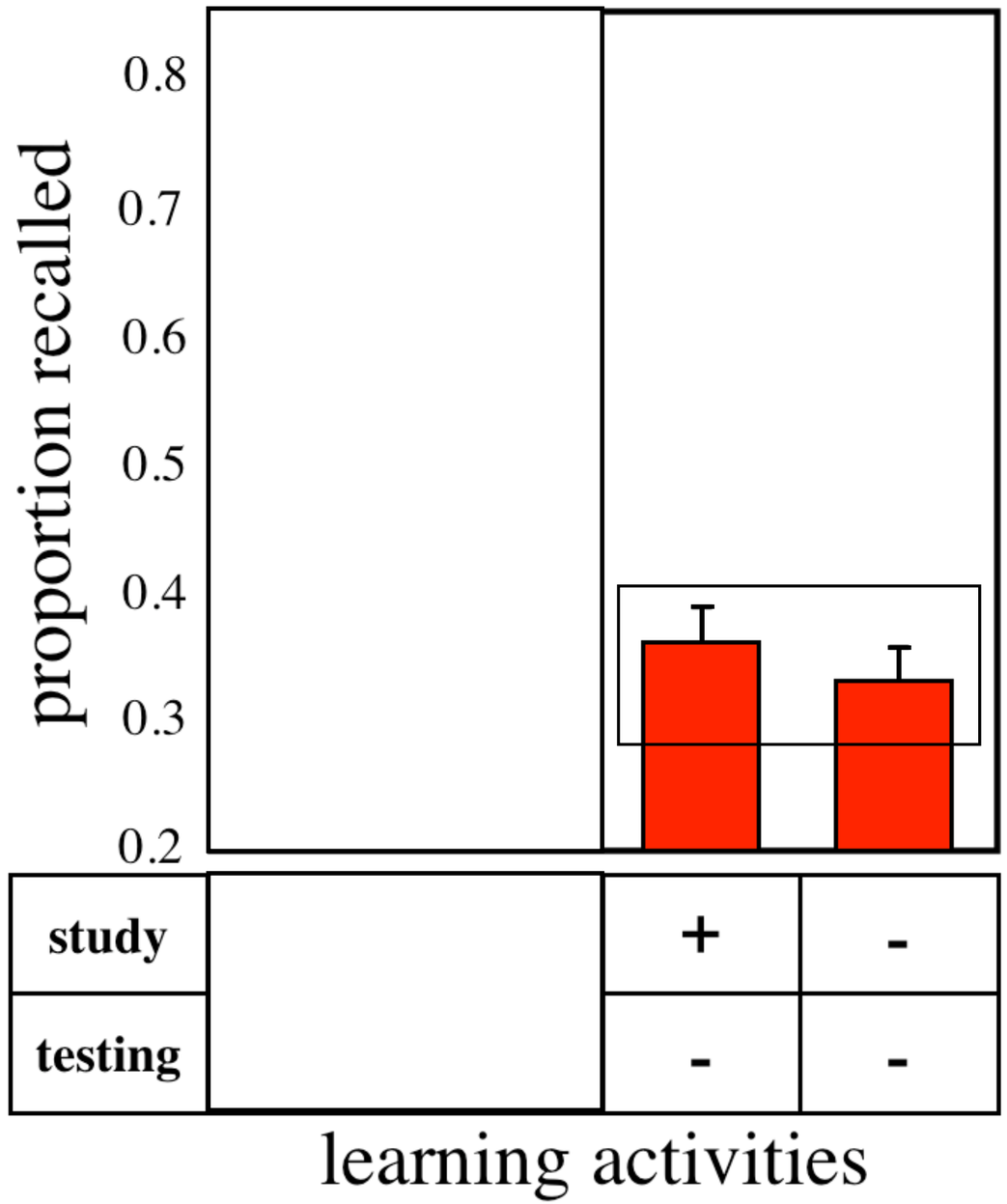
Surprised?

What is the most effective way to study?



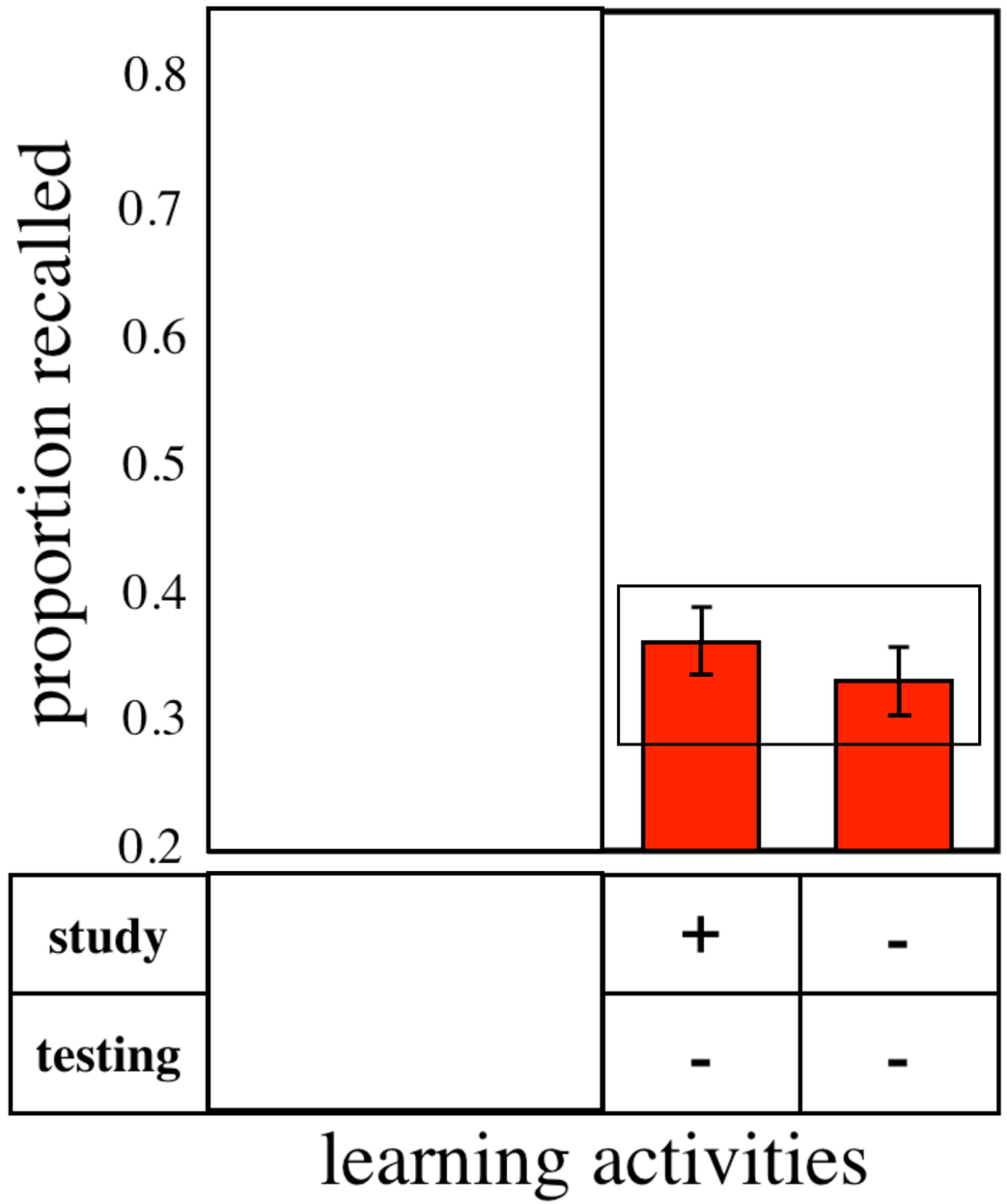
Are these different?

What is the most effective way to study?



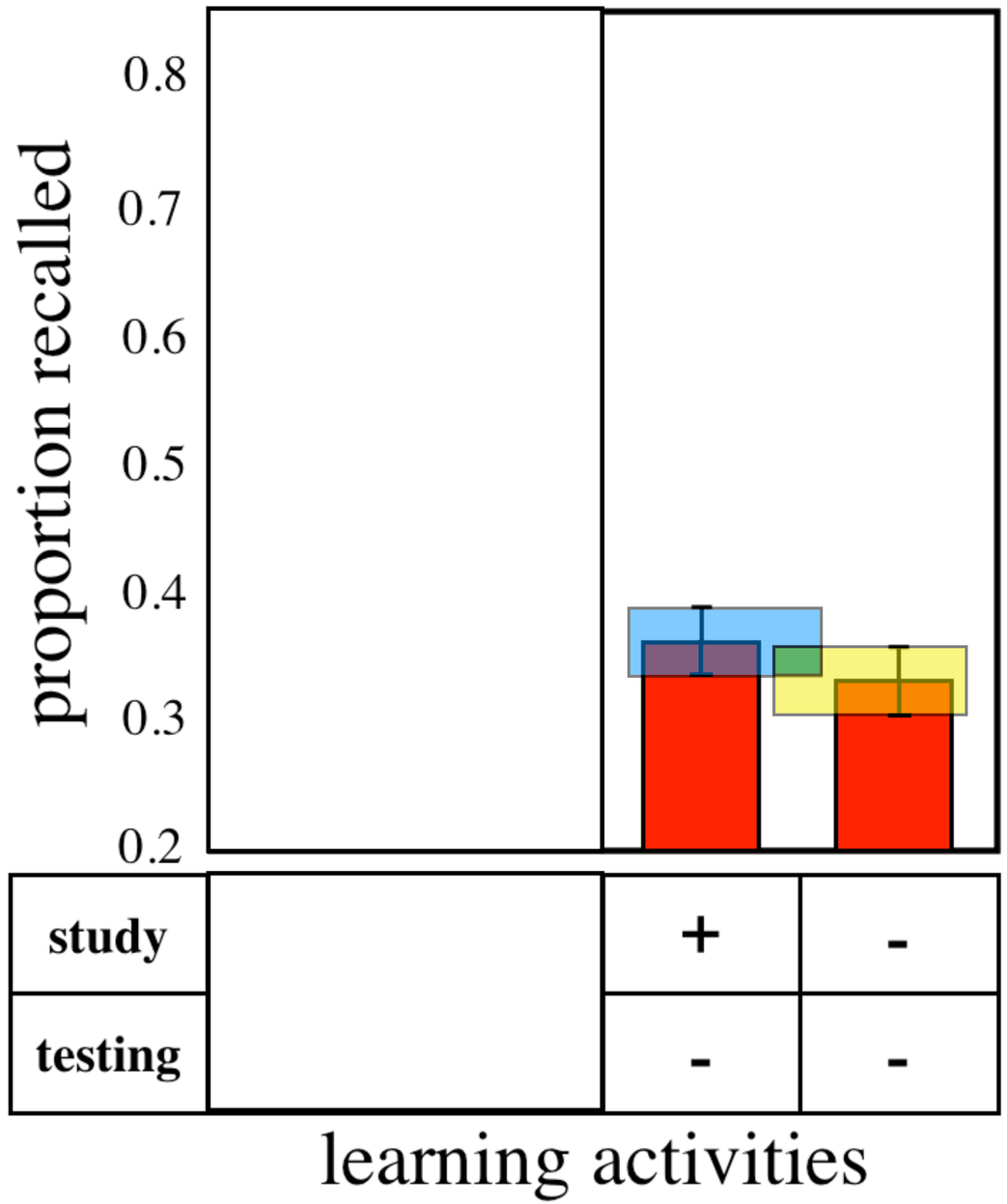
Are these different?

What is the most effective way to study?



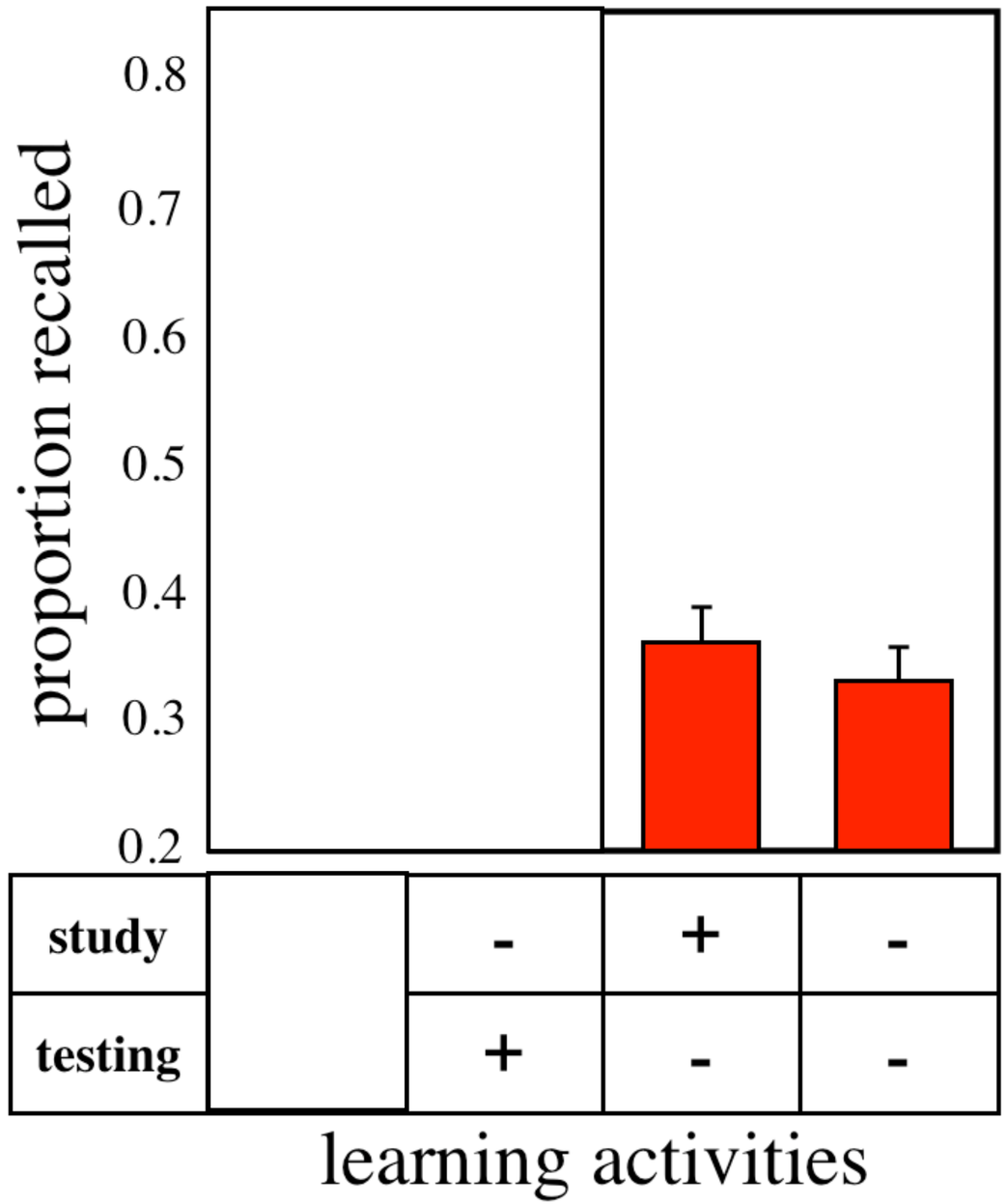
Are these different?

What is the most effective way to study?



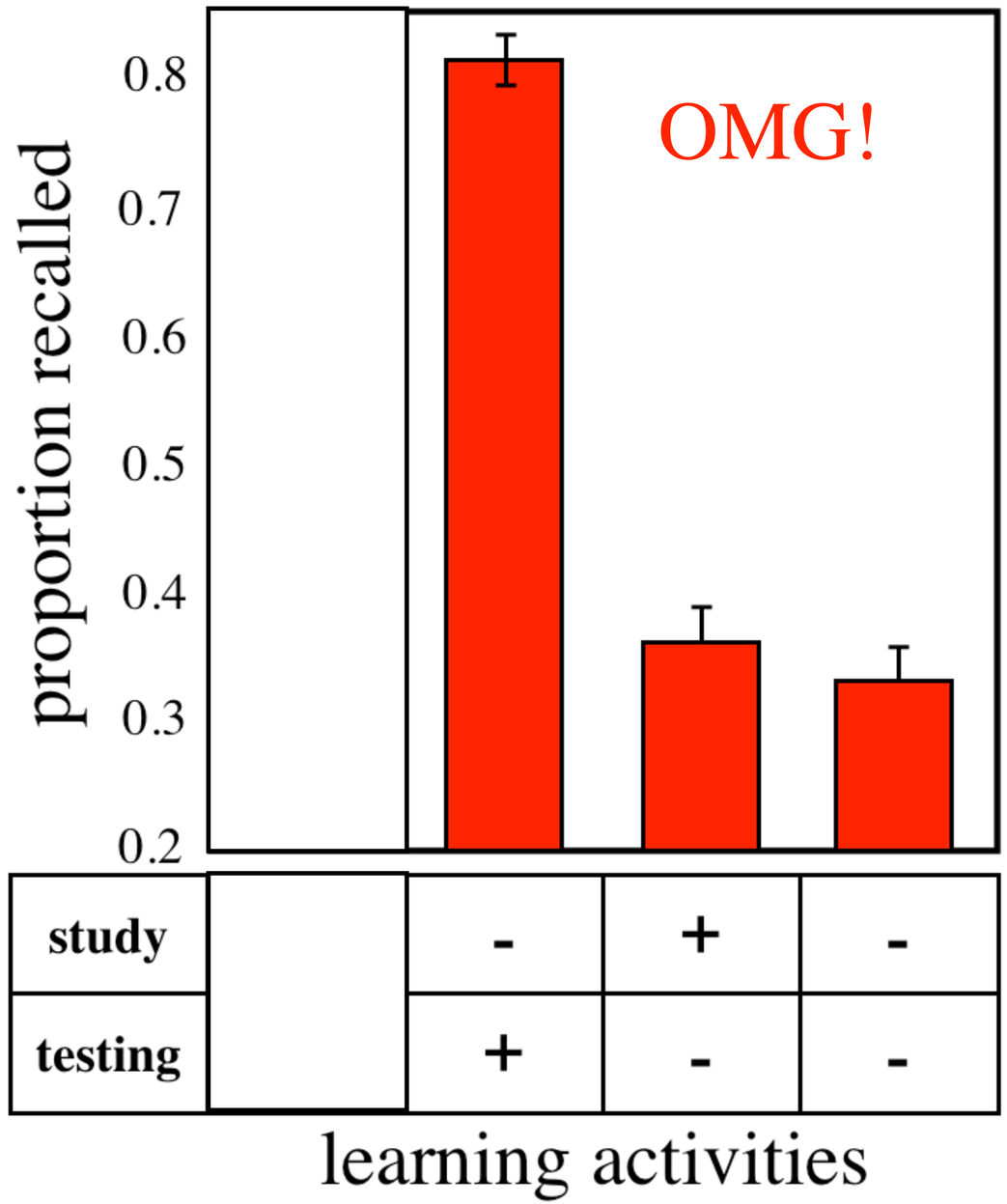
These two averages are not significantly different!

What is the most effective way to study?

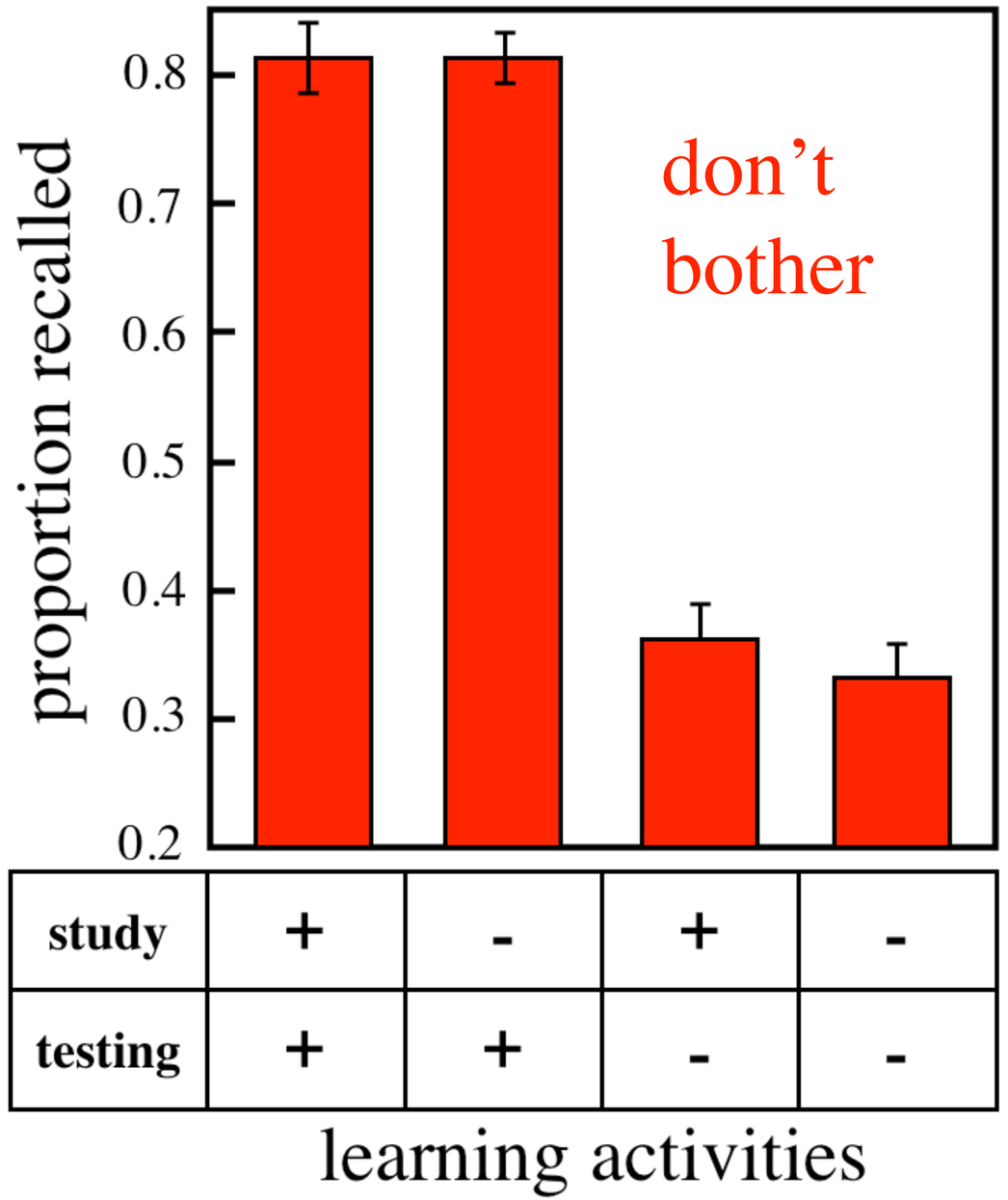


What would you predict with testing?

What is the most effective way to study?

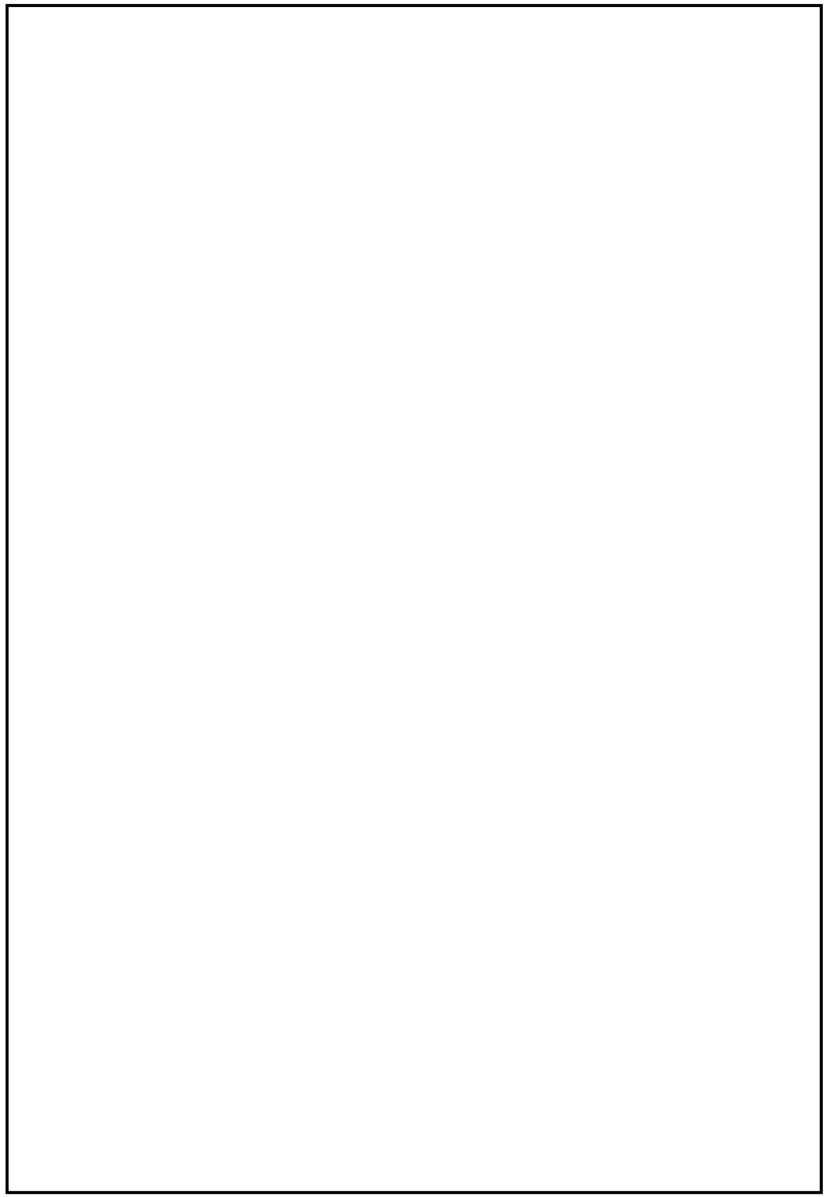


What is the most effective way to study?



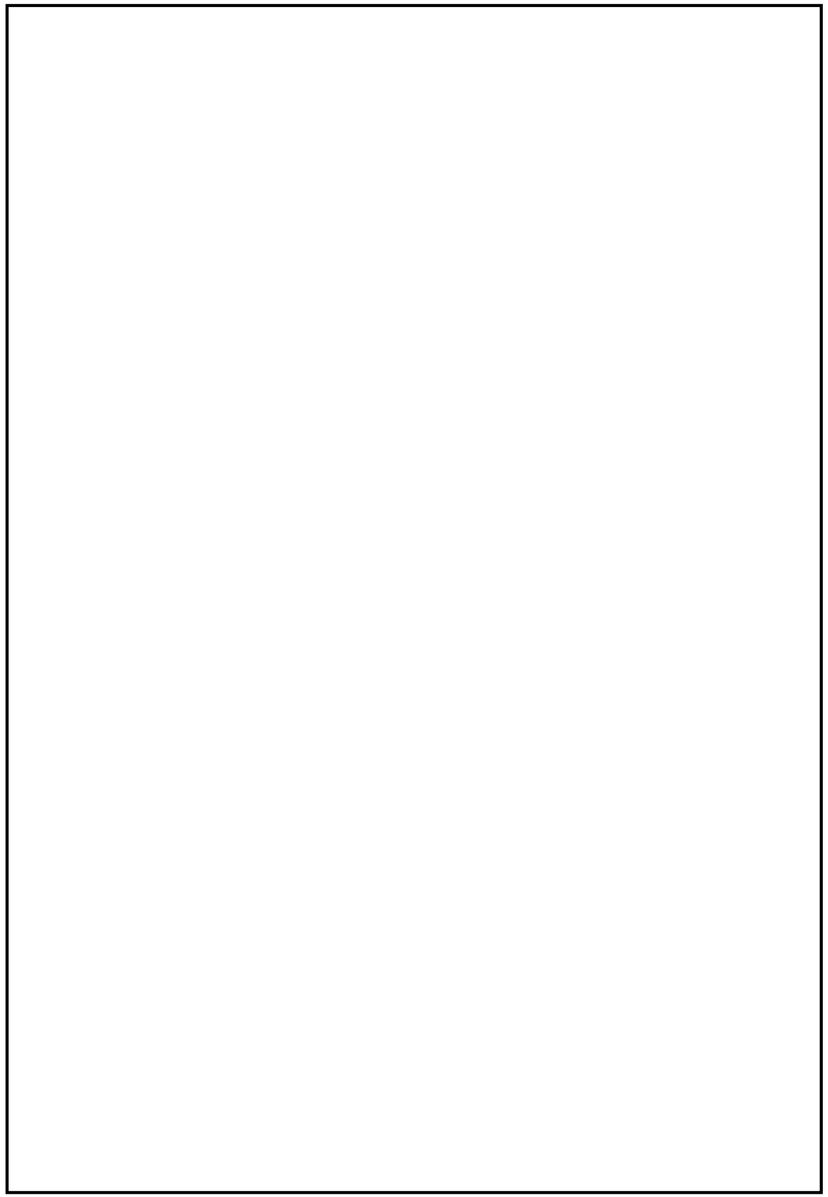
The Outline Method for Learning

The Outline Method for Learning



start with 1 blank piece of paper

The Outline Method for Learning



make an outline
of the chapter

The Outline Method for Learning

Why I love Biology

1. it is fun
   I understand me
   I know my dog better

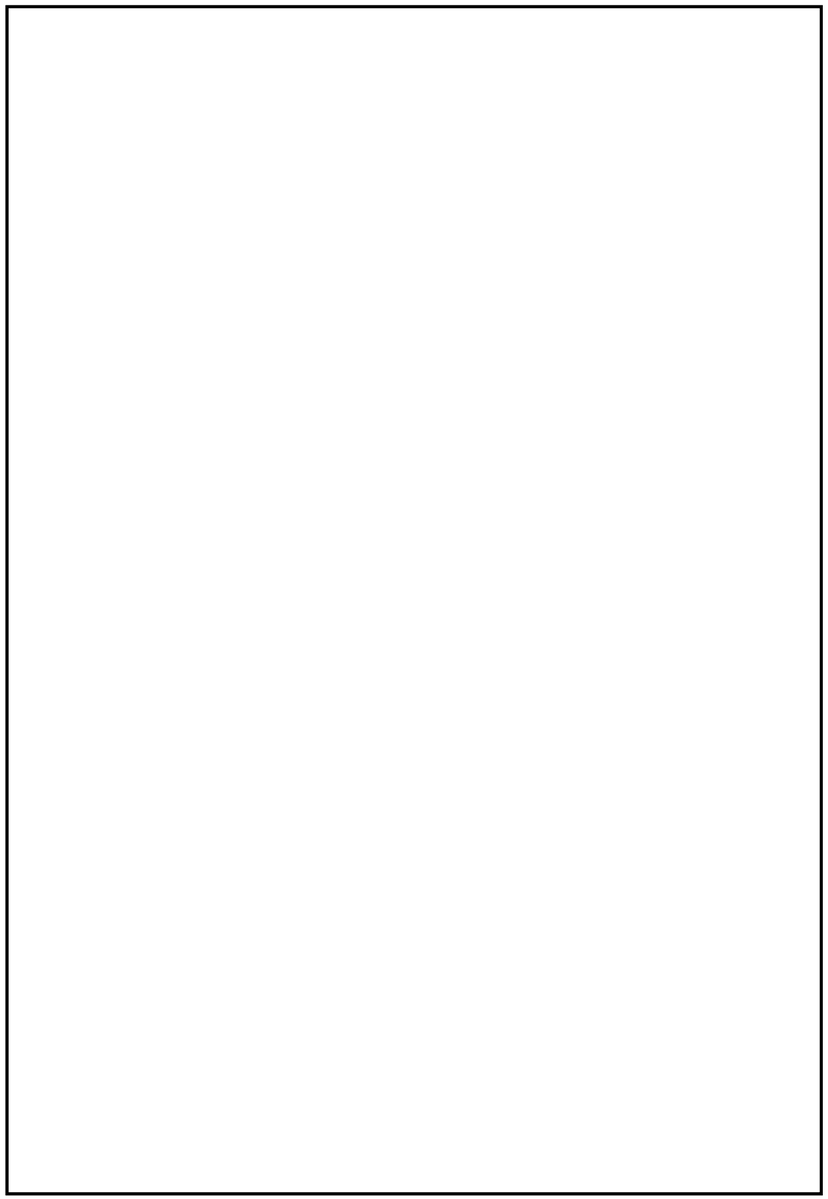
2. I can get any job I want
   I can do research
   I can work in a zoo
   I can become a superhero

3. In movies, knowledge is key
   Bourne Legacy - blue pill
   Hunger Games - find water
   Harry Potter - spells win

make an outline of the chapter

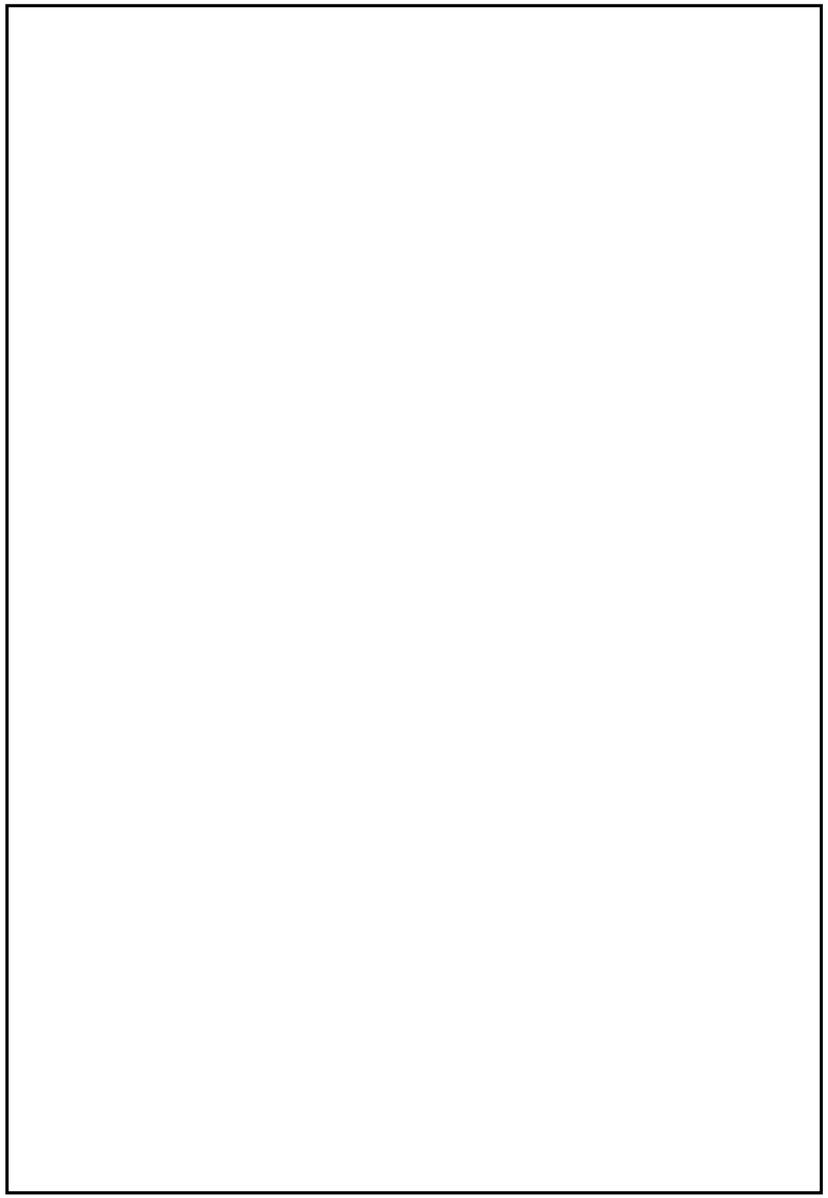
The Outline Method for Learning

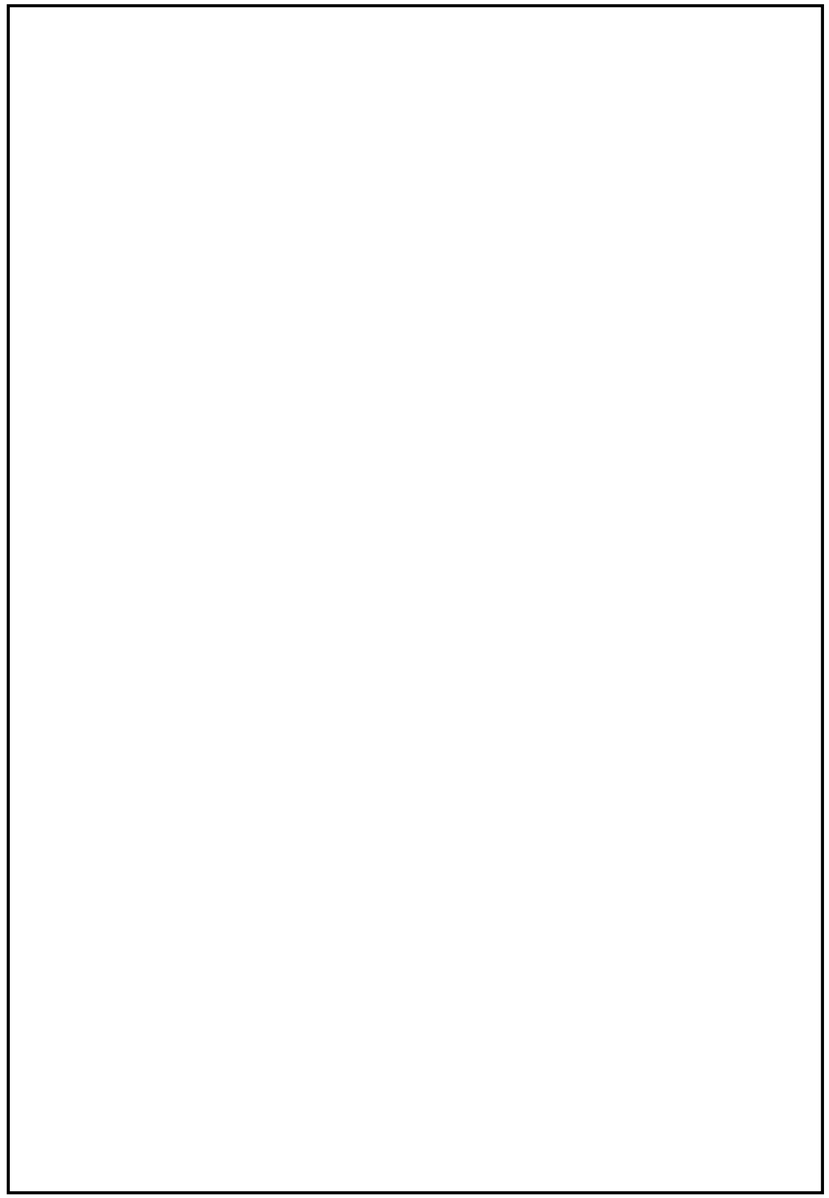
turn the paper over



The Outline Method for Learning

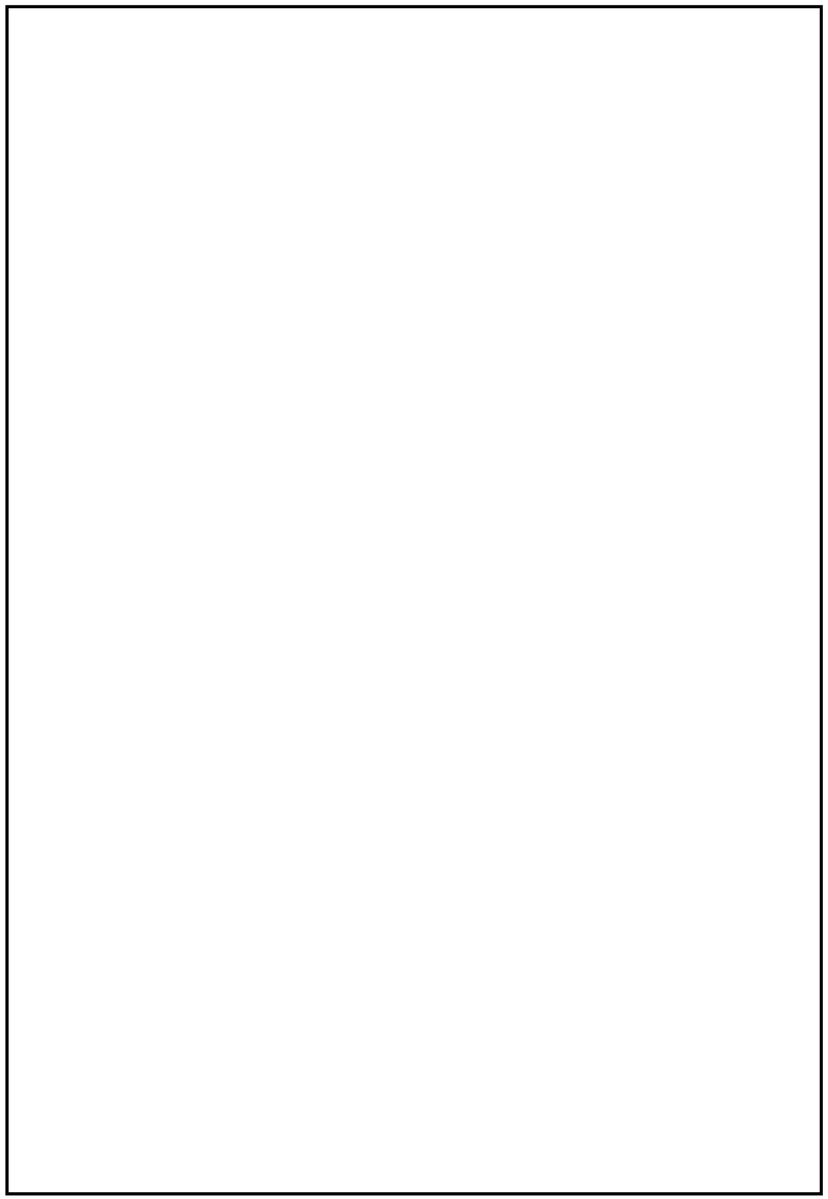
get a clean sheet of paper

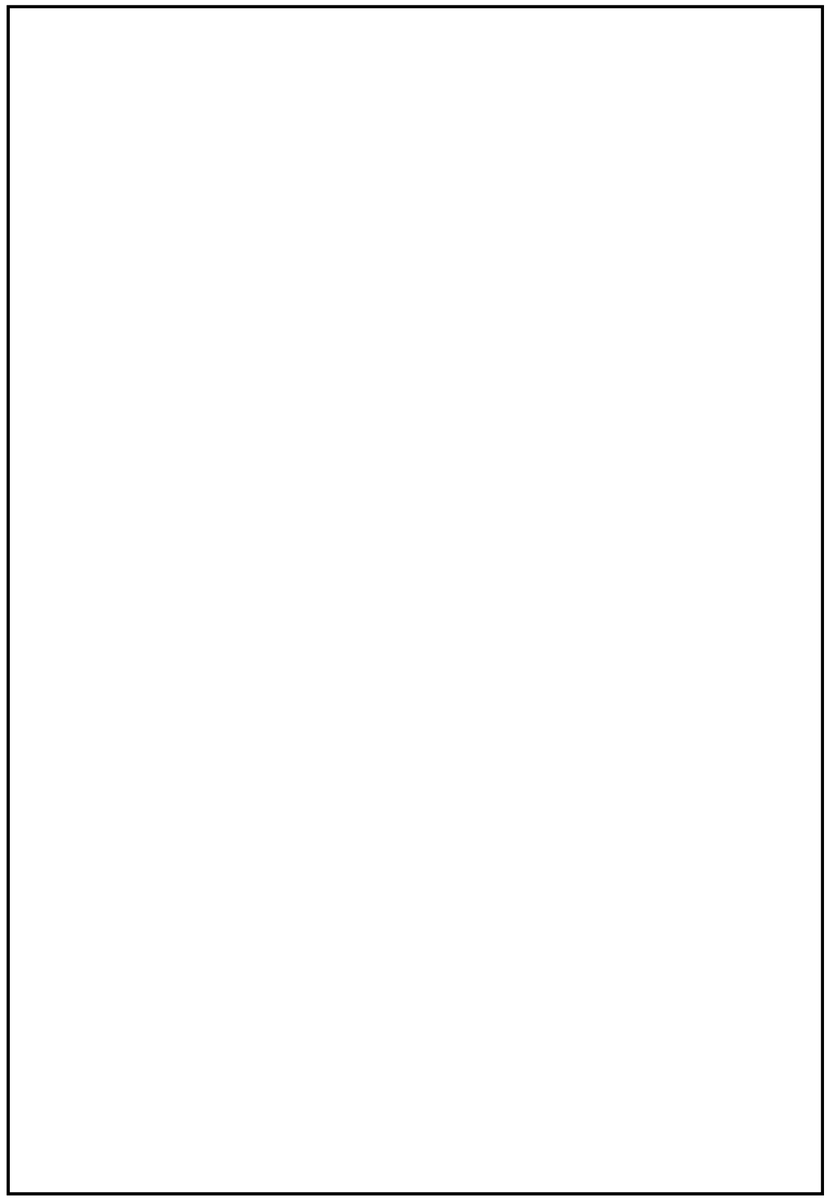




The Outline Method for Learning

try to recreate the outline





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The Outline Method for Learning

this is what you DO know

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The Outline Method for Learning

this is what you don't know

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The Outline Method for Learning

flip back over

look up the missing info

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The Outline Method for Learning

fill in these parts

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The Outline Method for Learning

make sure you understand

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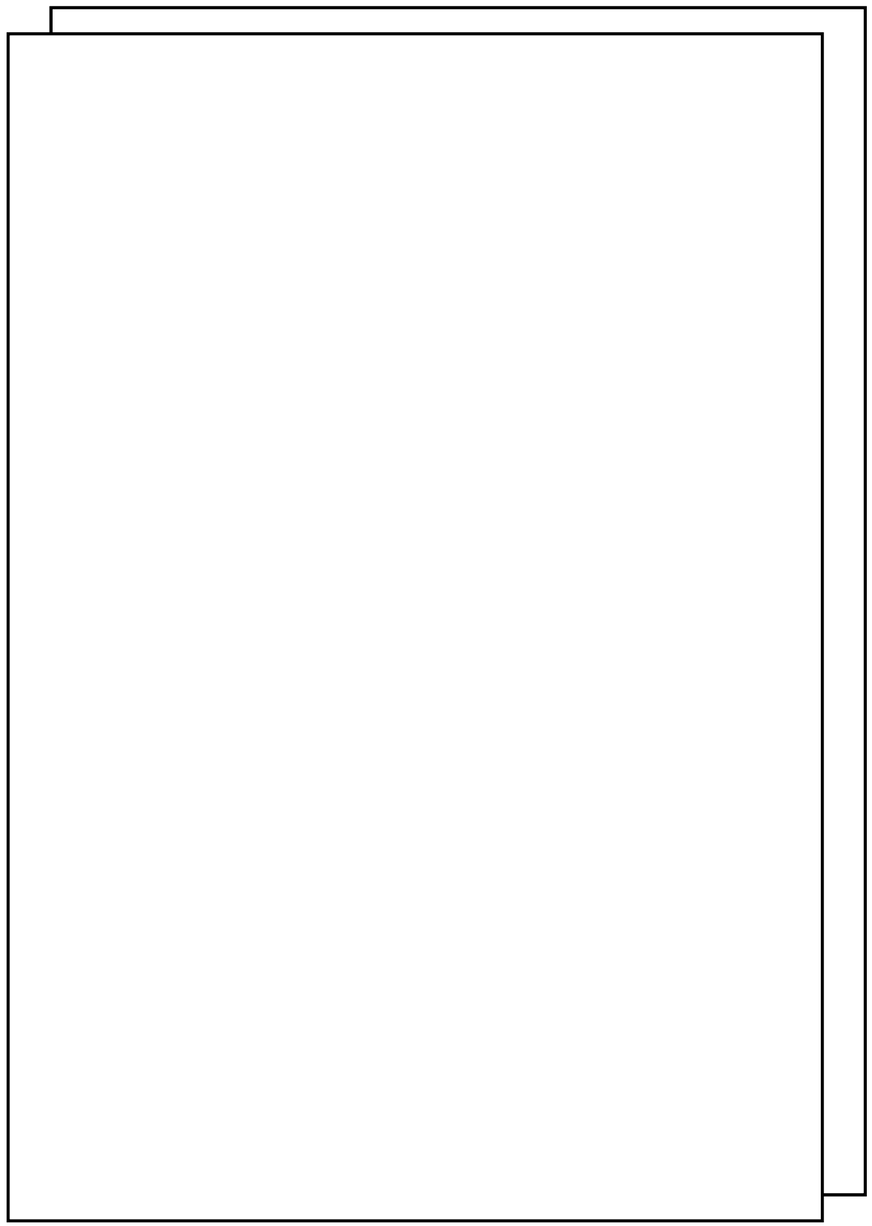
turn the paper over



try again to reproduce outline