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

A. Malcolm Campbell
Biology Department and GCAT

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?
Guess what, I taught my dog to whistle!
Teaching vs Learning

Really?!
Teaching vs Learning

Whistle! C’mon boy, whistle!
Teaching vs Learning

???????????????
Teaching vs Learning

I thought you said you taught your dog to whistle.
I did, but I didn’t say that he learned to whistle.
“We have to remember that education is not about how we teach 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.officefurturepics.com/tag/used-office-cubicles/
Are they training for one job?


• 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
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.
List jobs that pay you to memorize information that you don’t use....

http://confessionsofahighbrow.com/tag/standardized-tests/
Who thinks they can remember more factoids than a computer?
Why try to compete with computers by memorizing?

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

Dr. Ben Carson

Edgar Degas

JK Rowling

Beyonce
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

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

Win #1: your design functions as expected.

Win #2: your design fails but you uncover basic biology
Real World Applications of Synthetic Biology
Land Mine Detection
Land Mine Detection
New weed may flag land mines

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

Building Bacterial Computers
Can we build a bacterial cryptographic hash function?
What is a hash function?
Can Bacteria Perform a Hash Function?
Use XOR Logic Gate for Hash Function

<table>
<thead>
<tr>
<th>Input 1</th>
<th>Input 2</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>
Use XOR Logic Gate for Hash Function

<table>
<thead>
<tr>
<th>Input 1</th>
<th>Input 2</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

![XOR Gate Diagram](image)
Use XOR Logic Gate for Hash Function

<table>
<thead>
<tr>
<th>Input 1</th>
<th>Input 2</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>
Design Linear Bacterial Hash Function

CAB = 010000001

HASH VALUE = 0
Time-Delayed Bacterial Growth

3 hours

15 hours

40 hours

AmpR

β-lactamase

β-lactamase

β-lactamase
Time-Delayed Bacterial Growth

0 hours

1mm
DNA-based XOR Logic Gate

RFP  RBS  pOmpC  pLux  GFP

RBS
DNA-based XOR Logic Gate

High Osmolarity (Input A)

3OC6 (Input B)

RFP → RBS → pOmpC

pLux → RBS → GFP
DNA-based XOR Logic Gate

High Osmolarity (Input A)  3OC6 (Input B)  Fluorescence (Output)

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>High Osmolarity</td>
<td>3OC6</td>
<td>Fluorescence</td>
</tr>
<tr>
<td>(Input A)</td>
<td>(Input B)</td>
<td>(Output)</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>1 (GFP)</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>1 (RFP)</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>
DNA-based XOR Logic Gate

<table>
<thead>
<tr>
<th>High Osmolarity (Input A)</th>
<th>3OC6 (Input B)</th>
<th>Fluorescence (Output)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>1 (GFP)</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>1 (RFP)</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>
DNA-based XOR Logic Gate

<table>
<thead>
<tr>
<th>High Osmolarity (Input A)</th>
<th>3OC6 (Input B)</th>
<th>Fluorescence (Output)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>1(GFP)</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>1(RFP)</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>
DNA-based XOR Logic Gate

<table>
<thead>
<tr>
<th>High Osmolarity (Input A)</th>
<th>3OC6 (Input B)</th>
<th>Fluorescence (Output)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>1(GFP)</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>1(RFP)</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>
DNA-based XOR Logic Gate

<table>
<thead>
<tr>
<th>High Osmolarity (Input A)</th>
<th>3OC6 (Input B)</th>
<th>Fluorescence (Output)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>1 (GFP)</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>1 (RFP)</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>
Testing Bacterial XOR Logic Gate

<table>
<thead>
<tr>
<th></th>
<th>LB</th>
<th>3OC6</th>
</tr>
</thead>
<tbody>
<tr>
<td>RFP</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>GFP</td>
<td>-</td>
<td>+</td>
</tr>
</tbody>
</table>
Testing Bacterial XOR Logic Gate

Relative Fluorescence

XOR +LuxR

RFP

GFP

<table>
<thead>
<tr>
<th>LB</th>
<th>-</th>
<th>-</th>
<th>+</th>
<th>+</th>
</tr>
</thead>
<tbody>
<tr>
<td>3OC6</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>+</td>
</tr>
</tbody>
</table>
Testing Bacterial XOR Logic Gate

<table>
<thead>
<tr>
<th></th>
<th>RFP</th>
<th>GFP</th>
</tr>
</thead>
<tbody>
<tr>
<td>LB</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3OC6</td>
<td>-</td>
<td>+</td>
</tr>
</tbody>
</table>

Relative Fluorescence

XOR +LuxR

RFP

GFP

0

High Osmolarity (Input A)

RBS

GFP

pOmpC

pLux

Thursday, September 20, 12
Testing Bacterial XOR Logic Gate

Relative Fluorescence

XOR +LuxR

<table>
<thead>
<tr>
<th></th>
<th>LB</th>
<th>-</th>
<th>-</th>
<th>+</th>
<th>+</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxy</td>
<td>3OC6</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>+</td>
</tr>
</tbody>
</table>
Testing Bacterial XOR Logic Gate

Relative Fluorescence

XOR +LuxR

<table>
<thead>
<tr>
<th></th>
<th>RFP</th>
<th>GFP</th>
</tr>
</thead>
<tbody>
<tr>
<td>LB</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>3OC6</td>
<td>-</td>
<td>+</td>
</tr>
</tbody>
</table>

Thursday, September 20, 12
Testing Bacterial XOR Logic Gate

<table>
<thead>
<tr>
<th></th>
<th>RFP</th>
<th>GFP</th>
<th>RFP</th>
<th>GFP</th>
</tr>
</thead>
<tbody>
<tr>
<td>LB</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>3OC6</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>+</td>
</tr>
</tbody>
</table>

Relative Fluorescence

XOR +LuxR

RFP

GFP
pLux + LuxR Promotes Backwards

<table>
<thead>
<tr>
<th>LuxR</th>
<th>-</th>
<th>-</th>
<th>+</th>
<th>+</th>
</tr>
</thead>
<tbody>
<tr>
<td>3OC6</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>+</td>
</tr>
</tbody>
</table>
pLux + LuxR Promotes Backwards

Relative Fluorescence

<table>
<thead>
<tr>
<th></th>
<th>LuxR</th>
<th>3OC6</th>
</tr>
</thead>
<tbody>
<tr>
<td>RFP</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>RBS</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>+</th>
<th>+</th>
</tr>
</thead>
</table>
pLux + LuxR Promotes Backwards

Relative Fluorescence

<table>
<thead>
<tr>
<th></th>
<th>0</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>LuxR</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3OC6</td>
<td>-</td>
<td>+</td>
</tr>
</tbody>
</table>
pLux + LuxR Promotes Backwards

![Diagram showing relative fluorescence with LuxR and 3OC6 conditions]
pLux + LuxR Promotes Backwards

Relative Fluorescence

<table>
<thead>
<tr>
<th></th>
<th>LuxR</th>
<th>3OC6</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>0</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>0</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>0</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>
pLux + LuxR Promotes Backwards

Relative Fluorescence

RFP

+LuxR

RBS

pLux

backwards promoter

<table>
<thead>
<tr>
<th></th>
<th>LuxR</th>
<th>3OC6</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>0</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>0</td>
<td></td>
<td>+</td>
</tr>
<tr>
<td>0</td>
<td></td>
<td>+</td>
</tr>
</tbody>
</table>
Why build bacterial computers?
Evolution of Computers

1943
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

TT + RBS + RFP

TT
RBS
RFP

origin
antibiotic resistance

plasmid backbone
Golden Gate Assembly Method

promoter + RBS + RFP

RBS

RFP

origin

antibiotic resistance

plasmid backbone
Eco RI

GAATTCC
CTTAAG

type II

coeleotide palindrome
Eco RI

GAATTTC
CTTAAG

palindrome

type II
Eco RI

GAATTC
CTTAAG

type II
Eco RI

G
CTTAA

AATTC
G

type II
Bsa I

GAGACC

CTCTGG

not a palindrome

type IIIs
Bsa I

1234nGAGACC

-----nCTCTGG

type IIIs
Bsa I

----

1234nGAGACC
nCTCTGG

type IIIs
Bsa I

GGTCTC

CCAGAG

n1234

type IIIs
Bsa I

GGTCTCn
CCAGAGn1234

type IIIs
Bsa I

1234 nGAGACC

---- nCTCTGG

GGTCTCn ----

CCAGAGn 1234
Insert J100091
Bsa I

CGAC\text{tGAGACC}(TT)\text{GGTCTCaGCGG}

GCTGaCTCTGG\text{(TT)CCAGAGtCGCC}

Bsa I
CGAC^tGAGACC(TT)GGTCTCa
aCTCTTG(TT)CCAGAG^tCGCC

CGAC^tGAGACC(TT)GGTCTCa
aCTCTTG(TT)CCAGAG^tCGCC

CGAC(promoter)
(promoter)CGCC

RBS + RFP
RBS
RFP
GGA Ligation Method

TT + RBS + RFP

TT

RBS

RFP

BsaI + Ligase

origin

antibiotic resistance

plasmid backbone
GGA Ligation Method

promoter + RBS + RFP

BsaI + Ligase

plasmid backbone
GGA Ligation Method

promoter + RBS + RFP

no gel purifications!

origin → antibiotic resistance

plasmid backbone
GGA Ligation Method

promoter + RBS + RFP

RBS

RFP

no gel purifications!

plasmid backbone

origin

antibiotic resistance

20 Bsa

10.29
Registry of Functional Promoters

Campbell M Lab Parts

<table>
<thead>
<tr>
<th>ID</th>
<th>Name</th>
<th>Type</th>
<th>Description</th>
<th>Designer</th>
<th>Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blu_11001</td>
<td>Coding</td>
<td></td>
<td>Cris with hsp octamer sites and 1-CAT 2-BAT Promoter Inserted</td>
<td>Eric Savary</td>
<td>1987</td>
</tr>
<tr>
<td>Blu_11002</td>
<td>Composite</td>
<td></td>
<td>p52R5R5-SAT-Ch2-R13-CAT-Cl9 promoter RNA COACU</td>
<td>Eric Savary</td>
<td>1137</td>
</tr>
<tr>
<td>Blu_11003</td>
<td>Generator</td>
<td></td>
<td>p52R5R5-SAT-Ch2-R13-CAT-Cl9 promoter RNA COACU</td>
<td>Eric Savary</td>
<td>1137</td>
</tr>
<tr>
<td>Blu_11004</td>
<td>Reporter</td>
<td></td>
<td>p52R5R5-SAT-Ch2-R13-CAT-Cl9 promoter RNA COACU</td>
<td>Eric Savary</td>
<td>1137</td>
</tr>
<tr>
<td>Blu_11005</td>
<td>Other</td>
<td></td>
<td>Paleodiplo Stop Sequence</td>
<td>Eric Savary</td>
<td>2211</td>
</tr>
<tr>
<td>Blu_11006</td>
<td>Intermediate</td>
<td></td>
<td>LoxP-Stp Sequence-LoxP</td>
<td>Eric Savary</td>
<td>3323</td>
</tr>
<tr>
<td>Blu_11007</td>
<td>Intermediate</td>
<td></td>
<td>pLex-RBS-LexP-LoxP-Stp Sequence-LoxP</td>
<td>Eric Savary</td>
<td>3323</td>
</tr>
<tr>
<td>Blu_11008</td>
<td>Composite</td>
<td></td>
<td>pLex-RNA COACU plex-RNA COACU</td>
<td>Eric Savary</td>
<td>4086</td>
</tr>
<tr>
<td>Blu_11009</td>
<td>Composite</td>
<td></td>
<td>pLex-RNA COACU plex-RNA COACU</td>
<td>Eric Savary</td>
<td>4086</td>
</tr>
<tr>
<td>Blu_11010</td>
<td>Composite</td>
<td></td>
<td>pLex-RNA COACU plex-RNA COACU</td>
<td>Eric Savary</td>
<td>4086</td>
</tr>
<tr>
<td>Blu_11011</td>
<td>Composite</td>
<td></td>
<td>pLex-RNA COACU plex-RNA COACU</td>
<td>Eric Savary</td>
<td>4086</td>
</tr>
<tr>
<td>Blu_11012</td>
<td>Intermediate</td>
<td></td>
<td>RSC-REP-RBS</td>
<td>Eric Savary</td>
<td>7471</td>
</tr>
<tr>
<td>Blu_11013</td>
<td>Coding</td>
<td></td>
<td>Lax with 1-Deoxy-2-BAT Promoter</td>
<td>Eric Savary</td>
<td>6353</td>
</tr>
<tr>
<td>Blu_11014</td>
<td>Coding</td>
<td></td>
<td>Lax with 2-Deoxy-2-BAT Promoter</td>
<td>Eric Savary</td>
<td>8552</td>
</tr>
<tr>
<td>Blu_11015</td>
<td>Composite</td>
<td></td>
<td>2-Deoxy-2-BAT Promoter</td>
<td>Eric Savary</td>
<td>2373</td>
</tr>
<tr>
<td>Blu_11016</td>
<td>Composite</td>
<td></td>
<td>2-Deoxy-2-BAT Promoter</td>
<td>Eric Savary</td>
<td>2477</td>
</tr>
<tr>
<td>Blu_11017</td>
<td>Composite</td>
<td></td>
<td>TTS-copt-RBS-DG/3×3×3×2×CAT 2-Deoxy-2-BAT Promoter</td>
<td>Eric Savary</td>
<td>3355</td>
</tr>
<tr>
<td>Blu_11018</td>
<td>Protein-Domains</td>
<td></td>
<td>First half of XPG-gene</td>
<td>Jada Farnham</td>
<td>444</td>
</tr>
<tr>
<td>Blu_11019</td>
<td>Protein-Domains</td>
<td></td>
<td>First half of XPG-gene</td>
<td>Jada Farnham</td>
<td>444</td>
</tr>
<tr>
<td>Blu_11020</td>
<td>Protein-Domains</td>
<td></td>
<td>Second half of XPG</td>
<td>Catherine Boyle</td>
<td>8039</td>
</tr>
<tr>
<td>Blu_11021</td>
<td>Protein-Domains</td>
<td></td>
<td>First half of XPG</td>
<td>Catherine Boyle</td>
<td>8039</td>
</tr>
<tr>
<td>Blu_11022</td>
<td>Protein-Domains</td>
<td></td>
<td>Second half of XPG</td>
<td>Catherine Boyle</td>
<td>8039</td>
</tr>
<tr>
<td>Blu_11023</td>
<td>Protein-Domains</td>
<td></td>
<td>First half of CAT-gene</td>
<td>James Harden</td>
<td>434</td>
</tr>
<tr>
<td>Blu_11024</td>
<td>Protein-Domains</td>
<td></td>
<td>Second half of CAT-gene</td>
<td>Jada Farnham</td>
<td>347</td>
</tr>
<tr>
<td>Blu_11025</td>
<td>Protein-Domains</td>
<td></td>
<td>Second half of CAT-gene</td>
<td>Jada Farnham</td>
<td>347</td>
</tr>
<tr>
<td>Blu_11026</td>
<td>Protein-Domains</td>
<td></td>
<td>Second half of TyR</td>
<td>James Harden</td>
<td>298</td>
</tr>
<tr>
<td>Blu_11027</td>
<td>Protein-Domains</td>
<td></td>
<td>Second half of TyR</td>
<td>James Harden</td>
<td>298</td>
</tr>
<tr>
<td>Blu_11028</td>
<td>Other</td>
<td></td>
<td>plasmid insert for Bsl Golden Gate Assembly of promoter</td>
<td>Malcolm Campbell</td>
<td>877</td>
</tr>
<tr>
<td>Blu_11029</td>
<td>Regulatory</td>
<td></td>
<td>The promoter of gndP3-PS</td>
<td>Maggie Sinsky</td>
<td>76</td>
</tr>
<tr>
<td>Blu_11030</td>
<td>Regulatory</td>
<td></td>
<td>phn/promoter induced by phosphate starvation</td>
<td>Scott Hall</td>
<td>76</td>
</tr>
<tr>
<td>Blu_11031</td>
<td>Regulatory</td>
<td></td>
<td>C-terminal promoter of Gene 1 of TT transcript RNA P2</td>
<td>Caroline Umas</td>
<td>110</td>
</tr>
<tr>
<td>Blu_11032</td>
<td>Regulatory</td>
<td></td>
<td>pyrP3 promoter</td>
<td>Mike Merrish</td>
<td>90</td>
</tr>
<tr>
<td>Blu_11033</td>
<td>Regulatory</td>
<td></td>
<td>pyrP3 promoter</td>
<td>Chas Pape</td>
<td>121</td>
</tr>
<tr>
<td>Blu_11034</td>
<td>Regulatory</td>
<td></td>
<td>gndP promoter</td>
<td>Joseph Strain</td>
<td>44</td>
</tr>
<tr>
<td>Blu_11035</td>
<td>Regulatory</td>
<td></td>
<td>Protease induced by RNA damage</td>
<td>Eric Satch</td>
<td>52</td>
</tr>
<tr>
<td>Blu_11036</td>
<td>Regulatory</td>
<td></td>
<td>GndP Promoter induced by GDN2</td>
<td>Eric Satch</td>
<td>52</td>
</tr>
<tr>
<td>Blu_11037</td>
<td>Regulatory</td>
<td></td>
<td>GndP Promoter induced by GDN2</td>
<td>Eric Satch</td>
<td>52</td>
</tr>
<tr>
<td>Blu_11038</td>
<td>Coding</td>
<td></td>
<td>Lax with 3-Deoxy-2-BAT promoter</td>
<td>Eric Savary</td>
<td>8546</td>
</tr>
<tr>
<td>Blu_11039</td>
<td>Composite</td>
<td></td>
<td>LaxR5P5-GFP with 3-Deoxy-2-BAT promoter</td>
<td>Eric Savary</td>
<td>2653</td>
</tr>
<tr>
<td>Blu_11040</td>
<td>Coding</td>
<td></td>
<td>Lax with 3-Deoxy-2-BAT promoter</td>
<td>Eric Savary</td>
<td>2653</td>
</tr>
<tr>
<td>Blu_11041</td>
<td>Composite</td>
<td></td>
<td>LaxR5P5-GFP with 3-Deoxy-2-BAT promoter</td>
<td>Eric Savary</td>
<td>2653</td>
</tr>
<tr>
<td>Blu_11042</td>
<td>Coding</td>
<td></td>
<td>Lax with 4-Deoxy-2-BAT promoter</td>
<td>Eric Savary</td>
<td>704</td>
</tr>
<tr>
<td>Blu_11043</td>
<td>Composite</td>
<td></td>
<td>LaxR5P5-GFP with 4-Deoxy-2-BAT promoter</td>
<td>Eric Savary</td>
<td>704</td>
</tr>
<tr>
<td>Blu_11044</td>
<td>Composite</td>
<td></td>
<td>LaxR5P5-GFP with 4-Deoxy-2-BAT promoter</td>
<td>Eric Savary</td>
<td>704</td>
</tr>
<tr>
<td>Blu_11045</td>
<td>RNA</td>
<td></td>
<td>pPrRNA COACU 10 bp antisense repeat loop</td>
<td>Eric Savary</td>
<td>201</td>
</tr>
<tr>
<td>Blu_11046</td>
<td>Protein-Domains</td>
<td></td>
<td>TyR2</td>
<td>Jada Farnham</td>
<td>900</td>
</tr>
<tr>
<td>Blu_11047</td>
<td>Protein-Domains</td>
<td></td>
<td>TyR2</td>
<td>Jada Farnham</td>
<td>900</td>
</tr>
<tr>
<td>Blu_11048</td>
<td>Composite</td>
<td></td>
<td>LaxR5P5 promoter and ORF gate</td>
<td>Malcolm Campbell</td>
<td>2775</td>
</tr>
<tr>
<td>Blu_11049</td>
<td>Composite</td>
<td></td>
<td>LaxR5P5 promoter and ORF gate</td>
<td>Malcolm Campbell</td>
<td>2775</td>
</tr>
</tbody>
</table>
Student Sample

Part: BBa_J100033
Designed by Chris Peek  Group: Campbell_M_Lab  (2011-09-01)

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

<table>
<thead>
<tr>
<th>Format:</th>
<th>Subparts</th>
<th>Ruler</th>
<th>SS</th>
<th>DS</th>
<th>Search:</th>
<th>Length: 101 bp</th>
<th>Context: Part only</th>
<th>Get selected sequence</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>11</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>21</td>
<td>41</td>
<td>51</td>
<td></td>
<td></td>
<td>61</td>
<td>71</td>
<td>81</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>81</td>
<td>91</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>a</td>
<td>t</td>
<td></td>
</tr>
</tbody>
</table>

Assembly Compatibility: 10 12 21 23 25
Part:BBa_J100033:Experience
Designed by Chris Peck Group: Campbell_M_Lab (2011-09-01)

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

![Mean Fluorescence per Cell Density](chart.png)

- **Condition**
  - kPA1 (-)
  - kPA1 (+)
  - J10028 (-)
  - pTet (+)
  - pLac + IPTG
  - pLac - IPTG

- **Mean Fluorescent Intensity (RFU) per Cell Density**

- **A**: Experimental:

  - *p < 0.01

- **Cells**
  - containing dnaKP1 without heat shock (incubated at 37°C)
  - Experimental: cells containing dnaKP1 with heat shock (incubated at 40°C)
  - Negative control: part :100036 without nTet repressor
  - Positive control: part :100036 with nTet repressor (always on)
  - pLac promoter (always on)
  - pLac promoter (heat 41°C) with inducer (IPTG)
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
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
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

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

http://www.quintcareers.com/job_skills_values.html
Your College Education Put Into Focus
Would you rather settle for a blue collar B
or try for an A and risk failure?
“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

- Homeostasis
- Emergent Properties
- Information
- Evolution
- Cells
Five by Five Matrix of Biology

- **Information**
  - Cellular
  - Organismal
  - Population
  - Ecological System

- **Homeostasis**
  - Molecular
  - Organismal
  - Population
  - Ecological System

- **Emergent Properties**
  - Molecular
  - Organismal
  - Population
  - Ecological System

- **Cells**
  - Molecular
  - Organismal
  - Population
  - Ecological System

- **Evolution**
  - Molecular
  - Organismal
  - Population
  - Ecological System

Biology

- **Ecological System**
- **Population**
- **Cellular**
- **Organismal**
- **Molecular**
Five by Five Matrix of Biology

Molecular Ecological System
Population Organismal Cellular Molecular Ecological System
Evolution Population Organismal Cellular Molecular Ecological System
Emergent Properties Population Organismal Cellular Molecular Ecological System
Information Population Organismal Cellular Molecular Ecological System
Biology
Five by Five Matrix of Biology
Five by Five Matrix of Biology
Five by Five Matrix of Biology

- Information
- Population
- Evolution
- Cells
- Emergent Properties
- Homeostasis
- Ecological System
- Molecular
- Organismic
- Cellular
- Organismal

Biology
Five by Five Matrix of Biology

- Information
- Ecological System
- Biology
- Emergent Properties
- Cells
- Evolution
- Homeostasis

- Population
- Organismal
- Cellular
- Molecular
- Ecological System
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

- 83% response rate (new)
- 63% response rate (traditional)

- $p = 0.06$

- $p = 0.97$

- Fall 2010

+/- SEM
Student Content Assessment

83% response rate (new)  
63% response rate (traditional)

$\text{percent correct} \quad p = 0.97 \quad p = 0.06$

Fall 2010  
Spring 2011

$\pm$ SEM
Can my students analyze data better?
Student Skills Assessment

\[ p = 0.043 \]
Student Skills Assessment

- Traditional (quiz averages)
- New (quiz averages)

Percent Correct

- First
- Second
- Third
- Fourth

New, p = 0.015

Traditional, p = 0.320
Why bother changing?
National Recognition of Need to Change

VISION AND CHANGE
A CALL TO ACTION

A SUMMARY OF RECOMMENDATIONS
MADE AT A NATIONAL CONFERENCE ORGANIZED BY THE
AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE
AP Biology is Changing to Match Our Design

AP® BIOLOGY
Curriculum Framework
2012–2013
Lab on Information and Evolution
Evolution of Antibiotic Resistance
Emergent Properties in Slime Mold
Computer Simulation to Deduce Timing

Legend:
- receptive to cAMP
- emitting cAMP
- moving
- refractory

Cells

Step: 0
Refractory: 3
Center Cell: 0
Density: 189

Step: 0
Refractory: 3
Time between cAMP waves: 7
Reduce Lab Manual, Increase Student Input

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

### 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**

<table>
<thead>
<tr>
<th>Information</th>
<th>Learning Objectives</th>
<th>Before Lab...</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1) 4 pm day before lab, boil oligos</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2) Answer 4 Questions</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3) View the <a href="#">receiving plasmid J100091</a></td>
</tr>
<tr>
<td></td>
<td></td>
<td>During Lab...</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4) <a href="#">use the L oligator</a> to get oligos ready for ligation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5) do <a href="#">GGA ligation</a> for oligos</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6) <a href="#">transform E. coli cells</a></td>
</tr>
<tr>
<td></td>
<td></td>
<td>7) design promoter experiment (with controls)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8) <a href="#">CATME peer review</a></td>
</tr>
</tbody>
</table>

**Lab Manual Week #4**

www.bio.davidson.edu/113/113labschedule2012.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


The Duke Endowment, NSF, HHMI
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.

25 undergraduate co-authors

Paper of the year, 2008 & 2009
What is the most effective way to study?

![Graph showing the proportion recalled for different learning activities: study and testing.](image-url)
What is the most effective way to study?

<table>
<thead>
<tr>
<th>study</th>
<th>testing</th>
</tr>
</thead>
<tbody>
<tr>
<td>reread text and notes</td>
<td></td>
</tr>
</tbody>
</table>

learning activities
What is the most effective way to study?

<table>
<thead>
<tr>
<th>activity</th>
<th>proportion recalled</th>
</tr>
</thead>
<tbody>
<tr>
<td>study</td>
<td>reread text and notes</td>
</tr>
<tr>
<td>testing</td>
<td>self-quizzing, recall</td>
</tr>
</tbody>
</table>

Learning activities
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?

<table>
<thead>
<tr>
<th>learning activities</th>
<th>study</th>
<th>testing</th>
</tr>
</thead>
<tbody>
<tr>
<td>proportion recalled</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>0.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

What would you predict with study?
What is the most effective way to study?

Surprised?

<table>
<thead>
<tr>
<th>learning activities</th>
<th>study</th>
<th>testing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
What is the most effective way to study?

Are these different?

<table>
<thead>
<tr>
<th>learning activities</th>
<th>study</th>
<th>testing</th>
</tr>
</thead>
<tbody>
<tr>
<td>proportion recalled</td>
<td>+</td>
<td>-</td>
</tr>
</tbody>
</table>

Thursday, September 20, 12
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?

<table>
<thead>
<tr>
<th>learning activities</th>
<th>study</th>
<th>testing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>+</td>
<td>-</td>
</tr>
</tbody>
</table>

What would you predict with testing?
What is the most effective way to study?

![Bar chart showing the effectiveness of different study methods.](chart.png)

<table>
<thead>
<tr>
<th>Learning Activities</th>
<th>Study</th>
<th>Testing</th>
</tr>
</thead>
<tbody>
<tr>
<td>-</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>+</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

OMG!
What is the most effective way to study?

<table>
<thead>
<tr>
<th>learning activities</th>
<th>study</th>
<th>testing</th>
</tr>
</thead>
<tbody>
<tr>
<td>proportion recalled</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

don’t bother
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
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
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

The Outline Method for Learning

turn the paper over
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

The Outline Method for Learning

get a clean sheet of paper
The Outline Method for Learning

try to recreate the outline
Why I love Biology

1. it is fun
   I know my dog better

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

3. In movies, knowledge is key
   Bourne Legacy - blue pill
   Hunger Games -
   Harry Potter - spells win
Why I love Biology

1. it is fun
   I know my dog better

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

3. In movies, knowledge is key
   Bourne Legacy - blue pill
   Hunger Games -
   Harry Potter - spells win
Why I love Biology

1. it is fun
   I know my dog better

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

3. In movies, knowledge is key
   Bourne Legacy - blue pill
   Hunger Games - find water
   Harry Potter - spells win
Why I love Biology
1. it is fun
   I know my dog better
2. I can get any job I want
   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
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

The Outline Method for Learning

flip back over

look up the missing info
The Outline Method for Learning

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

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
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
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