Vision and Change Introductory Biology Lecture and Lab

A. Malcolm Campbell
Biology Department and GCAT

ASM Eastern PA
March 23, 2015
Outline of Presentation

Why change my intro bio course now?

How is ICB different?

Hands-on activity #1 - constructing your own knowledge

Did students meet learning objectives (content and attitude)?

Can intro labs be more authentic? Hands-on activity #2

pClone: real research by first year students

Closing remarks
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

Science
AAAS
AP Biology Redesign in Third year

AP® BIOLOGY

Curriculum Framework
2012–2013
**GRE General Test**

**Verbal Reasoning:** measures your ability to understand what you read and how you apply your reasoning skills.

**Quantitative Reasoning:** measures your ability to
- understand quantitative information
- interpret and analyze quantitative information
- solve problems using mathematical models
- apply basic mathematical skills and elementary mathematical concepts of arithmetic, algebra, geometry and data interpretation
- includes real-life scenarios

**Analytical Writing:** provide focused responses to prompts so you can demonstrate your ability to directly respond.
Critical Analysis and Reasoning Skills: analyze, evaluate, and apply information provided in passages

Natural Sciences: combine knowledge of natural science concepts with their scientific inquiry and reasoning skills to solve problems that demonstrate their readiness for medical school.

Psychological, Social, and Biological Foundations of Behavior
full disclosure

ICB is a commercial product
• 3 years to write, 4 years to publish
• traditional publishers rejected
• eBook hosted by Trunity
• David Botstein gift funded book
• Bruce Alberts wrote Foreword
• demonstrated learning gains
• adopt only chapters you use

• http://goo.gl/nRA0Od
Core Concepts = Big Ideas

Vision & Change
Evolution

Structure and Function
Information

Energy and Matter
Systems Biology

ICB
Evolution
Cells
Information
Homeostasis
Emergent Properties

AP Biology
Evolution
Information
Homeostasis
Emergent Properties
V&C Core Competencies

• Apply the process of science
• Use quantitative reasoning
• Use modeling and simulations
• Integrate different disciplines
• Communicate & collaborate
• Connect science & society
V&C Core Competencies (ICB)

- Apply the process of science (experimental design)
- Use quantitative reasoning (interpret raw data)
- Use modeling and simulations (work with models)
- Integrate different disciplines (chemistry, math, some physics)
- Communicate & collaborate (small group discussions, lab)
- Connect science & society (ELSI boxes)
What’s Wrong with Biology Education Now?

- Vocabulary is emphasized (800-1000 vs 1400)
- Experimental approaches are minimized
- Math is absent
- Memorization is rewarded
- Critical thinking is discouraged
- Information is irrelevant to students
Present information and data...
... in the context of the big picture.
Start with the literature…
Artificial Divide within Biology

Small Biology

Big Biology
Five Levels of Organization

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

- Molecular
- Ecological System
- Population
- Organismal
- Cellular

Information

Emergent properties

Evolution

Homeostasis

Cells

Biology
BioMath Exploration 4.2 (BME)

How fast is the vesicle size changing?

(A) non-stressed

(B) stressed
Ethical, Legal and Social Implications (ELSI)

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?
Hands-on Activity #1
Did my students “learn less” content?
Core Concepts Assessment

percent correct

Fall 2010

new

traditional

$p = 0.97$

$+/-$ SEM

83% response rate (new)

63% response rate (traditional)

$p = 0.06$
Core Concepts Assessment

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

\[ p = 0.06 \]

\[ p = 0.97 \]
Can my students analyze data better?
Core Competency Assessment

% Correct

Traditional  New

$p = 0.043$
Core Competency Assessment

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

- new, $p = 0.015$
- traditional, $p = 0.320$
Do *ICB* students see biology differently?  

<table>
<thead>
<tr>
<th>1-5 scale 5 = extremely accurate</th>
<th>Average at Start Fall</th>
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<tbody>
<tr>
<td>biology is definitions &amp; processes</td>
<td>2.86 2.61</td>
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<tr>
<td>big questions of biology already answered</td>
<td>1.71 1.50</td>
</tr>
<tr>
<td>big/small division of biology describes nature</td>
<td>3.15 3.02</td>
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* p<0.05, ** p<0.01, *** p<0.001, ^ p = 0.06

no
## Do ICB students see biology differently?

<table>
<thead>
<tr>
<th>1-5 scale 5 = extremely accurate</th>
<th>Average at Start Fall</th>
<th>( \Delta ) in Average End of Fall</th>
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<tr>
<td></td>
<td>ICB</td>
<td>Traditional</td>
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<tr>
<td>biology is definitions &amp; processes</td>
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<tr>
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<td>3.15</td>
<td>3.02</td>
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</table>

* p<0.05, ** p<0.01, *** p<0.001, ^ p= 0.06

*yes!*
### Do ICB students see biology differently?

<table>
<thead>
<tr>
<th></th>
<th>Average at Start Fall</th>
<th>Δ in Average End of Fall</th>
<th>Δ in Average End of Spring</th>
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<tr>
<td></td>
<td>ICB</td>
<td>Traditional</td>
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<tr>
<td>biology is definitions &amp; processes</td>
<td>2.86</td>
<td>2.61</td>
<td>-0.58***</td>
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<tr>
<td>big questions of biology already answered</td>
<td>1.71</td>
<td>1.50</td>
<td>-0.32*</td>
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<td>3.15</td>
<td>3.02</td>
<td>-1.08***</td>
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</tbody>
</table>

* p<0.05, ** p<0.01, *** p<0.001, ^ p = 0.06

Yes! Yes? Yes!
Hands-on Activity #2
Can introductory biology labs be more authentic?

A common criticism I had gotten for 16 years was the lecture and lab were “disconnected” or were “unrelated.”
When you do research in lab:

1. Has someone prepared data collection tables for you?
2. Does someone hand you all the controls you will need for the day?
3. Does someone else do all the creative thinking for you and you merely pipet?
4. Do you only work on one project until it is completed?
5. Is your research completed in 3 hours?
My educational goals for Intro Bio Lab

1. Employ a **scientific approach** to answering biological questions and test hypotheses.
2. **Design experiments** to test hypotheses, answer questions.
3. **Analyze experimental data** and reach logical conclusions.
4. Organize an **oral presentation** for sharing scientific information with peers.
5. Prepare a **written summary** of experiments designed, performed and analyzed personally.
6. Work on three overlapping labs: **discover new promoter**, **why mammals evolved bitter taste receptors**, and **evolution of antibiotic resistant bacteria**.
Major Changes I Made to Intro Bio Lab

1. Minimal lab manual

Before you come to lab
1) At 8:30 pm on the Wednesday before your lab, one person from each lab group MUST COME TO Dr. C’s research lab (Dana room 223). Make sure to bring your protocol from last week of how to prepare the oligonucleotide.

2) Answer each of these four questions in two sentences or less:
A) How will you ligate your new promoter into a plasmid for testing?
B) What will the plasmid need to contain if you want to determine if your promoter is working?
C) How is fluorescence of red fluorescent proteins (RFP) measured?
D) How is a spectrophotometer used to measure cell density in a population of E. coli?

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NOTE: At 5:30 pm on the Wednesday before your lab, one person from each lab group MUST COME TO Dr. C’s research lab (Dana room 223). Please be on time. We need to host the oligonucleotide so we can ligate them tomorrow. See page 2 for details.

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Major Changes I Made to Intro Bio Lab

1. Minimal lab manual
2. Overlapping lab modules

9 weeks on promoters
8 weeks on taste receptor
7 weeks on antibiotic\(^R\)
Major Changes I Made to Intro Bio Lab

1. Minimal lab manual
2. Overlapping lab modules
3. CATME tool (CATME.org)
Promoter Research Using Golden Gate Assembly

Todd Eckdahl
MWSU
Eco RI

GAATTC
CTTAAG

palindrome

type II
Bsa I

GAGACC
CTCTTG

not a palindrome

type IIIs
Bsa I

1234nGAGACC

----nCTCTGG

type IIIs
Bsa I

1234nGAGACC
nCTCTCTGG

type IIIs
Bsa I

GGTCTCn−−−−
CCAGAGn1234

type IIIs
Bsa I

GGTCTCn
CCAGAGn1234

---

type IIIs
Bsa I

cuts left

1234 nGAGACC

---- nCTCTCTG

GGTCTCTCn----

CCAGAGAgn1234
cuts right
GGA Ligation Method - one step, one tube

TT + RBS + RFP

TT

RBS

RFP

BsaI + Ligase

origin

antibiotic resistance

plasmid backbone
GGA Ligation Method - one step, one tube

TT + RBS + RFP

TT

RBS

RFP

BsaI + Ligase

origin

antibiotic resistance

plasmid backbone
GGA Ligation Method - one step, one tube
GGA Ligation Method - one step, one tube

Bsa I

CGAC\textcolor{red}{tGAGACC}(TT)GGTCTCaGCGG

GCTGaCTCTGG(\textcolor{red}{TT})\textcolor{blue}{CCAGAG}t\textcolor{blue}{CGCC}

Bsa I

ligase

TT \textcolor{green}{RBS} \textcolor{red}{RFP}
CGAC\textbf{tGAGACC (TT) GGTCTCa}
\textbf{aCTCTGG (TT) CCAGAGtCGCC}

\begin{align*}
\text{ligase} & \quad \text{ligase}
\end{align*}
GGA Ligation Method - one step, one tube

promoter + RBS + RFP

no gel purifications!

plasmid backbone
50% ligation success rate
### Registry of Standard Biological Parts

<table>
<thead>
<tr>
<th>Part ID</th>
<th>Description</th>
<th>Authors</th>
<th>ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>BBa_J100007</td>
<td>Regulatory fedB promoter (long sequence)</td>
<td>Meredith Nakano</td>
<td>85</td>
</tr>
<tr>
<td>BBa_J100066</td>
<td>Regulatory fedB promoter (short sequence)</td>
<td>Meredith Nakano</td>
<td>81</td>
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<tr>
<td>BBa_J100069</td>
<td>Reporter Superfolder GFP</td>
<td>Rebecca Evans</td>
<td>712</td>
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<tr>
<td>BBa_J100070</td>
<td>Coding Superfolder GFP</td>
<td>Rebecca Evans</td>
<td>720</td>
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<tr>
<td>BBa_J100071</td>
<td>Regulatory cdtA promoter</td>
<td>Ben Clarkson</td>
<td>334</td>
</tr>
<tr>
<td>BBa_J100072</td>
<td>Regulatory LexP promoter—Long cpxP promoter</td>
<td>Ben Clarkson</td>
<td>392</td>
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<tr>
<td>BBa_J100075</td>
<td>Regulatory Spo0F Short cpxP promoter</td>
<td>Ben Clarkson</td>
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<td>BBa_J100074</td>
<td>Regulatory Long pLux Promoter</td>
<td>Betsy Gammon</td>
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<tr>
<td>BBa_J100075</td>
<td>Regulatory CydAP1 Long Promoter</td>
<td>Betsy Gammon</td>
<td>158</td>
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<tr>
<td>BBa_J100076</td>
<td>Regulatory CydAP1 Short Promoter</td>
<td>Betsy Gammon</td>
<td>151</td>
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<tr>
<td>BBa_J100077</td>
<td>Composite J100058 K000000</td>
<td>Meredith Nakano</td>
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<td>BBa_J100076</td>
<td>Composite J100057 K000005</td>
<td>Meredith Nakano</td>
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<tr>
<td>BBa_J100079</td>
<td>Device Riboswitch and GFP</td>
<td>Rebecca Evans</td>
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<td>BBa_J100080</td>
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<td>882</td>
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<tr>
<td>BBa_J100081</td>
<td>Reporter J100071=E0240</td>
<td>Ben Clarkson</td>
<td>334</td>
</tr>
<tr>
<td>BBa_J100062</td>
<td>Reporter J100072=E0240</td>
<td>Ben Clarkson</td>
<td>1276</td>
</tr>
<tr>
<td>BBa_J100063</td>
<td>Composite LuxI Long + RBS + GFP</td>
<td>Betsy Gammon</td>
<td>1081</td>
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<tr>
<td>BBa_J100064</td>
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<td>Betsy Gammon</td>
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<tr>
<td>BBa_J100085</td>
<td>RNA short CRISPR sequence with GFP target spacer</td>
<td>Caroline Yanes</td>
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<tr>
<td>BBa_J100066</td>
<td>Composite CydAP Short Promoter + RBS + GFP</td>
<td>Betsy Gammon</td>
<td>1035</td>
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<td>BBa_J100078</td>
<td>Reporter J100073=E0240</td>
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<td>BBa_J100088</td>
<td>Generator J100071+J100063 (LexP+LRE, Luciferase)</td>
<td>Ben Clarkson</td>
<td>2965</td>
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<td>BBa_J100089</td>
<td>Generator J100072+J100063 (LexP+LRE, Luciferase)</td>
<td>Ben Clarkson</td>
<td>3023</td>
</tr>
<tr>
<td>BBa_J100090</td>
<td>Regulatory CRISPR sequence with GFP and AmpR targets</td>
<td>Caroline Yanes</td>
<td>412</td>
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<td>BBa_J100092</td>
<td>Regulatory Constitutive promoter for M1-152</td>
<td>Natalie Specht</td>
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<tr>
<td>BBa_J100053</td>
<td>Regulatory ribE Pi promoter</td>
<td>Kayta McAvoy</td>
<td>60</td>
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<tr>
<td>BBa_J100094</td>
<td>Regulatory lac promoter E. coli</td>
<td>Cameron Bard</td>
<td>44</td>
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<td>BBa_J100095</td>
<td>Regulatory malleE1 Malose induced promoter</td>
<td>Pooja Potharaju</td>
<td>65</td>
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<tr>
<td>BBa_J100096</td>
<td>Regulatory PRAD Promoter from araE Gene</td>
<td>Elizabeth Brunner</td>
<td>27</td>
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<tr>
<td>BBa_J100097</td>
<td>Regulatory Purine operon inducible promoter with Bsal sticky ends</td>
<td>Sarah Kim</td>
<td>55</td>
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<tr>
<td>BBa_J100098</td>
<td>DNA Promoter for the argF gene</td>
<td>Erich Neumann</td>
<td>44</td>
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<tr>
<td>BBa_J100099</td>
<td>Regulatory A promoter (CydAB) activated by the FNR enzyme</td>
<td>Phoebe Parrish</td>
<td>64</td>
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</tbody>
</table>
A promoter (CydAB) activated by the FNR enzyme

The promoter, CydAB, was found to be activated by the FNR enzyme, which is induced by the presence of (NH4)2Fe(SO4)2 and ascorbate. The oligo includes both CydAB, the FNR binding site, and the sticky ends needed for the Golden Gate Assembly method.

Assembly Compatibility: 10 12 21 23 25

Applications of BBa_J100099

We pipetted 200 microliters of one solution containing E. coli cells from a small colony and the activators, one with cells from a small colony and no activators, one containing cells from a large colony and the activators, and one containing cells from a large colony and no activators. We also did a positive control with E. coli cells containing a known promoter that causes red fluorescence (J04450) and a negative control with cells containing a the transcriptional terminator that does not cause red fluorescence (J100091). We tested both fluorescence of our samples using a fluorometer and the light absorbance using a spectrophotometer. We measured the fluorescence and absorbance of five samples of each solution, including a control solution that just contained the growth medium. We averaged the values for each solution and subtracted the average fluorescence/absorbance of the control. We then divided the average fluorescence by the average absorbance for each solution. These values are displayed on the accompanying graph.
Registry of Functional Promoters (RFP)

Welcome to the Registry of Functional Promoters

This Registry of Functional Promoters was developed by Bill Hatfield, Laurie J. Heyer, A. Malcolm Campbell at Davidson College and Todd Eckdahl of Missouri Western State University, through the support of HHMI grant 52006292 (GCA T main page) and is freely available for others to use though no support other than the user manual is available.

If you are already a Registered User of GCAT-alog, you do not need to Reregister

LOGIN  REGISTER AS NEW USER

For comments or questions about this website contact, Malcolm Campbell

gcat.davidson.edu/RFP/
Registry of Functional Promoters (RFP)

gcat.davidson.edu/RFP/
Registry of Functional Promoters (RFP)

SEARCH PROMOTER RESULTS

<table>
<thead>
<tr>
<th>Entry No.</th>
<th>Promoter Name</th>
<th>Part Number</th>
<th>Sequence</th>
<th>Length</th>
<th>Citation</th>
<th>Species of Interest</th>
<th>Constitutive/Regulated</th>
<th>Inducible/Repressible</th>
<th>Regulator</th>
<th>RBS Used for Testing</th>
<th>ORF Used for Testing</th>
<th>Plasmid Use</th>
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<tbody>
<tr>
<td>1</td>
<td>TetR Repressible Promoter</td>
<td>B0040</td>
<td>acctatcgagagagacatcacgctgagagatgacgcac</td>
<td>54</td>
<td></td>
<td>Regulated</td>
<td>Repressible</td>
<td>TetR</td>
<td></td>
<td>p35</td>
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<td></td>
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<td>2</td>
<td>56 bp Lac Promoter</td>
<td>B001111</td>
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<td>200 bp Lac Promoter</td>
<td>B0010</td>
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<td></td>
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<td>4</td>
<td>LuxR &amp; HSL Regulated Lux</td>
<td>B0062</td>
<td>acctcgagagctgagagacatcacgctgagagatgaanagagatgacgcac</td>
<td>55</td>
<td></td>
<td>Regulated</td>
<td>Repressible</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<td>5</td>
<td>Backwards 200 bp Lac Promoter (right to left)</td>
<td>F11913</td>
<td>acctgagagatgacgcacagagagacatcacgctgagagatgagccgg</td>
<td>200</td>
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<td>7</td>
<td>23K series very strong</td>
<td>F22107</td>
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To Edit an Entry, Enter the Entry # and press "Edit Entry".

To Delete an Entry, Enter the Entry # and press "Delete Entry".

gcat.davidson.edu/RFP/
Testing Known Promoters: Ptac

5’ CGACGAGCTGTTGACAATTAATCATCGGCTCGTATAATGTGTGGA 3’
3’ CTCGACAACTGTTAATTAGTAGCCGAGCATATTACACACCTCGCC 5’
5’ CGACGAGCTGTTTtACAATTAATCATCGGCTCGTATAATGTGTGGA 3’
3’ CTCGACAAaTGTTAATTAGTAGGGCCGAGCATATTACACACCTCGCC 5’

Student Sample, November 2012
-35 ATAA (deleted) -10

5' CGACGAGCTGTGGACA----ATCATCGGCTCGTATAATGTGTGGA 3'
3' CTCGACAAGCTGT----TAGTAGCCGAGCATATTACACACCTCGCC 5'

Student Sample, November 2012
pClone Red
J119137
Remove Initial Promoter
J119137
Insert Non-functional Promoter

J119137
Insert Forward Promoter
J119137
Insert Bi-directional Promoter

J119137
pClone Red

J119137

Quantify with Phone and ImageJ
J119137

<table>
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<th>Mutant</th>
<th>J119319</th>
<th>J119320</th>
<th>J119321</th>
<th>J119322</th>
<th>J119323</th>
<th>J119324</th>
<th>J119325</th>
<th>J119326</th>
</tr>
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<tbody>
<tr>
<td>Expression Ratio</td>
<td>4.09</td>
<td>3.94</td>
<td>3.84</td>
<td>2.04</td>
<td>1.54</td>
<td>1.34</td>
<td>3.52</td>
<td>1.00</td>
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</table>

pClone Blue

Measure Promoter Qualitatively

J119313

A

0% Blue  40% Blue  70% Blue  90% Blue  100% Blue
### Assessment Davidson Intro Bio

<table>
<thead>
<tr>
<th>Learning objective</th>
<th>Pretest experimental</th>
<th>Posttest experimental</th>
<th>Comparison course</th>
<th>$F(2,88)$</th>
<th>Effect size ($\eta^2$)</th>
<th>Conclusion</th>
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<tbody>
<tr>
<td>1</td>
<td>Function of promoter</td>
<td>43%</td>
<td>87%$^a$</td>
<td>48%</td>
<td>8.008, $p = 0.001$</td>
<td>0.154</td>
</tr>
<tr>
<td>2</td>
<td>Repressor diagram</td>
<td>23%</td>
<td>53%$^a$</td>
<td>13%</td>
<td>7.206, $p = 0.001$</td>
<td>0.141</td>
</tr>
<tr>
<td>3</td>
<td>Activator diagram</td>
<td>0%</td>
<td>41%$^a$</td>
<td>0%</td>
<td>7.250, $p = 0.001$</td>
<td>0.167</td>
</tr>
<tr>
<td>4</td>
<td>Experiment overview</td>
<td>0%</td>
<td>13%$^a$</td>
<td>0%</td>
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$^a$Significant improvement between pre- and posttest.

### Assessment MWSU Genetics (soph)

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<th>$F(2252)$</th>
<th>Effect size ($\eta^2$)</th>
<th>Conclusion</th>
</tr>
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<tr>
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<td>36%</td>
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<td>20%</td>
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<tr>
<td>2</td>
<td>−10 and −35 sites</td>
<td>3%</td>
<td>70%$^a$</td>
<td>0%</td>
<td>145.374, $p &lt; 0.001$</td>
<td>0.536</td>
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<tr>
<td>3</td>
<td>Mutational analysis</td>
<td>30%</td>
<td>75%$^a$</td>
<td>33%</td>
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<td>0.186</td>
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<td>Student-designed mutation</td>
<td>0%</td>
<td>0%</td>
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Assessment Davidson Intro Bio

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<th>$F(2,88)$</th>
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<tr>
<td>1 Function of promoter</td>
<td>43%</td>
<td>87%^a</td>
<td>48%</td>
<td>8.008, $p = 0.001$</td>
<td>0.154</td>
<td>Large effect</td>
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<tr>
<td>2 Repressor diagram</td>
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<td>53%^a</td>
<td>13%</td>
<td>7.206, $p = 0.001$</td>
<td>0.141</td>
<td>Large effect</td>
</tr>
<tr>
<td>3 Activator diagram</td>
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<td>41%^a</td>
<td>0%</td>
<td>7.250, $p = 0.001$</td>
<td>0.167</td>
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<td>4 Experiment overview</td>
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rClone Red

J119###
rClone Red

J119###

12 - 60 bp

RBS

Bsa I

RFP
tClone Red

J119361
tClone Red

J119361

60 - 230 bp

+/−

Bsa I

RBS

RFP

OR

+
actClone Red

J100204
actClone Red

J100204

OmpR

C1  C2  C3
60 bp

GFP  RBS

Bsa I

RBS  RFP

3’ PompR

Red
repClone Red

J100205
repClone Red

Ptet

54 bp

Bsa I

TetR RBS

OR

Bsa I

RBS RFP

OR
Teaching vs Learning

Guess what, I taught my dog to whistle!

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

Teaching vs Learning
Acknowledgements

**Lecture:** A. Malcolm Campbell Laurie Heyer, Chris Paradise

**Lab:** Jeff Poet, Todd Eckdahl


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Davidson College James G. Martin Genomics Program
MWSU SGA, Foundation & Summer Research Institute
Remember, teaching is supposed to be fun!