PLAN FOR TODAY

● What is a CURE?
● What does this look like in action?
● An example of an upper division CURE
● Developing a CURE for your class
What is the value of an undergraduate research experience?

 Courtesy of Dr. Cissy Balen, Auburn
Benefits of participating in Research Experiences

- Students who participate in research report many benefits:
  - Continuation to graduate education or careers in science
    - (Kardash, 2000; Laursen et al., 2010; Lopatto and Tobias, 2010)
  - How to ‘think like a scientist’, enthusiasm for science in general
    - (Laursen et al., 2010; Lopatto, 2010)
  - Women and underrepresented minorities (URMs) persistence in STEM
    - (Gregerman et al., 1998; Barlow and Villarejo, 2004; Eagan et al., 2011)
  - Technical, analytical, and science process skills
    - (Wilson et al., 2018, Bascom-Slack et al., 2012, Alkaher and Dolan, 2014, Jordan et al., 2014)
Demographically matched students who participated in NSF’s Research Experiences for Undergraduates (REU participants) with those who applied but did not participate (applicants) (N = 88 pairs)
However...

- Most research experiences fall under the *apprenticeship (faculty-mentored)* model
  - Only serves a proportion of interested students
  - Space and faculty constraints
  - Typically not available to non-science majors
  - Loss of diversity
    - Time constraints for students with jobs or families
    - Nuance of finding and obtaining a lab spot
- Students may be **excluded** from this experience regardless of scientific talent

Courtesy of Dr. Cissy Balen, Auburn
## Enter Course-based Undergraduate Research Experiences (CUREs)

- CUREs involve whole classes of students engaged in a research question.

<table>
<thead>
<tr>
<th></th>
<th>CUREs</th>
<th>Research Internships/Faculty-mentored</th>
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<tbody>
<tr>
<td>Scale</td>
<td>Many students</td>
<td>Few students</td>
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<tr>
<td>Mentorship Structure</td>
<td>One instructor to many students</td>
<td>One instructor to one student</td>
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<tr>
<td>Enrollment</td>
<td>Open to all students in a course</td>
<td>Open to a selected or self-selecting few</td>
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<tr>
<td>Time Commitment</td>
<td>Work done primarily in class</td>
<td>Work done primarily outside of class</td>
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<tr>
<td>Setting</td>
<td>Teaching lab</td>
<td>Faculty research lab</td>
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Table adapted from Auchincloss *et al.*, 2014

Courtesy of Dr. Cissy Balen, Auburn
What makes a research experience ‘authentic’?

Courtesy of Dr. Cissy Balen, Auburn
“Ingredients” of a Course-based Undergraduate Research Experience (CURE):

- From Auchincloss et al. 2014:
  - Use of scientific practices
  - Collaboration
  - Iteration

Courtesy of Dr. Cissy Balen, Auburn
“Ingredients” of a Course-based Undergraduate Research Experience (CURE):

○ Discovery-based
  ■ Outcome of research is unknown to students, instructors, and science as a whole

○ Broadly relevant and/or important work
  ■ Findings are of interest/use to some entity outside of the lab:
    ● researcher, community group, general public, other students
Novel findings that have potential for impact beyond the course
What does this look like in action?

Courtesy of Dr. Cissy Balen, Auburn
An Example of a National CURE

- Small World Initiative
  [http://www.smallworldinitiative.org/](http://www.smallworldinitiative.org/)
  - Students take environmental samples and isolate antibiotic producing bacteria
  - Two semesters
  - Non-majors to majors
  - National
  - Pre-developed
  - Products: database, potential new antibiotic

Courtesy of Dr. Cissy Balen, Auburn
Where can I find other ideas/examples?

- UT Austin Freshman Research Initiative [https://cns.utexas.edu/fri/research-streams](https://cns.utexas.edu/fri/research-streams)
- CUNY Undergraduate Research Experience in Microbiology [http://www.cuny.edu/research/sr/undergrad-research/for-faculty/AREM.html](http://www.cuny.edu/research/sr/undergrad-research/for-faculty/AREM.html)
- Genome Consortium for Active Teaching (GCAT) [http://www.bio.davidson.edu/GCAT/](http://www.bio.davidson.edu/GCAT/)
- CourseSource [http://www.coursesource.org](http://www.coursesource.org)
- Discipline-based education research journals
  - Journal of Chemical Education [http://pubs.acs.org/journal/jceda8](http://pubs.acs.org/journal/jceda8)

Courtesy of Dr. Cissy Balen, Auburn
The *C. elegans* anchor cell - an in vivo model of invasion
Identifying genes that regulate cell invasion

*fos-1(RNAi)*

*wild-type*
BIO 327: Developmental Genetics Lab

- Capstone course in Developmental Genetics specialization in Biology Major (mostly 2nd semester seniors)
- 14 weeks, 2 3-hour labs / week, 53-minute lecture on Fridays
- ~70 students in 4 sections led by 4 graduate student TAs (1st or 2nd year PhD students)
- Pre-req’s include upper division Genetics and Developmental Biology lecture-based courses
The evolution of an upper division CURE for Biology majors

BIO 327 is born!

2002

NSF funded through CCLI and RAIRE awards

2002

J. Peter Gergen: Drosophila screens to understand pattern formation and gene regulation

2014

D. Matus guest lecture

2015 2016 2017 2018

Switch to CURE

D. Matus course Coordinator:
The evolution of an upper division CURE for Biology majors

2015
RNAi screen for pro-invasive transcription factors (based on Matus lab research)

2016
RNAi any target gene (~15,000 RNAi clones) in any available C. elegans strain (1000s available @ $7/strain)

2017-2019
1 or 2 genetic backgrounds:
RNAi any target gene
Questions causally related to Matus lab research (2017) and directly related (2018-19)

CURE ITERATION #1

CURE ITERATION #2-4

Too cookbook!

mass chaos!

organized chaos!
BOOTCAMPS WITH EACH MODEL ORGANISM TO LEARN BASIC SKILLS

**Week**

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<thead>
<tr>
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<th>1-2</th>
<th>3-4</th>
<th>5</th>
<th>6-14</th>
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independent group projects

* Lab Reports
WEEKS 1-5

SKILL BUILDING

Worms
- RNAi feeding
- Strain maintenance
- DIC/GFP microscopy
- Bioinformatics
- Statistics

Flies
- Fly flipping
- Cuticle Preps
- Genetic manipulation
- Darkfield microscopy
- Bioinformatics
- Statistics

Sea anemones
- Spawning
- Embryo manipulation
- Surgical manipulation
- Regeneration staging
- Drug treatment (LiCl)
- Microscopy
- Bioinformatics
- Statistics
WEEKS 1-5

SKILL BUILDING
- RNAi feeding
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- Statistics

Worms

6-7

PROJECT PLANNING

Team Building
Primary Literature Review
Genome Browsers
Hypothesis Construction
**WEEKS 1-5**

**SKILL BUILDING**
- RNAi feeding
- Strain maintenance
- DIC/GFP microscopy
- Bioinformatics
- Statistics

**WEEKS 6-7**

**PROJECT PLANNING**

**WEEKS 8-12**

**DATA COLLECTION**

**Team Building**
- Primary Literature Review
- Genome Browsers
- Hypothesis Construction

**Worms**
- Fly flipping
- Cuticle Preps
- Genetic manipulation
- Darkfield microscopy
- Bioinformatics
- Statistics

**Flies**
- Spawning
- Embryo manipulation
- Surgical manipulation
- Regeneration staging
- Drug treatment (LiCl)
- Microscopy
- Bioinformatics
- Statistics

**Sea anemones**
- Quantitative GFP Imaging
- Phenotype scoring
- Progeny counting
- Immunohistochemistry
- Dose-dependence drug responses
- Regeneration staging
13
DATA
ANALYSIS

Quantitative Image Analyses
Statistical tests for significance
Evaluation of Hypotheses
Quantitative Image Analyses
Statistical tests for significance
Evaluation of Hypotheses

Science
communication
Science
writing
Dissemination
Collaboration
Reverse genetics (RNAi) and cell invasion

So what do the students do?

Chemical genetics and regeneration

Forward genetics (transposable elements) and pattern formation
SKILLS ACQUIRED

- Basic *C. elegans* handling/maintenance
- Compound microscopy (DIC and epifluorescence imaging)
- Visualizing a developmental process (anchor cell invasion)
- Bacterial culture & RNAi plate making
- RNAi experiments
Reverse genetics (RNAi) and cell invasion

**ACTUAL SKILLS ACQUIRED**

- Lab skills
- Microscopy / Image analysis
- Time management (planning and executing experiments)
- How to browse a model organism website (wormbase.org)
Example C. elegans "Bootcamp" exercise: Depletion of GFP by RNAi

~2 days at 15°C

Empty vector control

RNAi targeting GFP
Quantification of results using FIJI and PRISM

Click here to generate the graph

Adjust the titles / label your axes
ASSESSMENTS

Lab report #1: Figure generation and how to write the RESULTS section

Lab report #2: How to write an ABSTRACT

Lab report #3: How to write an INTRODUCTION

SKILL BUILDING

Worms
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- Bioinformatics
- Statistics
ASSESSMENTS

In class midterm:

Tests critical thinking and lab knowledge and background material for three model systems
ASSESSMENTS

Project Update:

Intro
Methods
Hypothesis
Preliminary Results
C. elegans strain with basement membrane GFP marker:
Examine GFP marker in wild-type vs. RNAi knockdown:
1. Class RNAi screen to identify change in reproduction (Egl/Pvl/other vulval defects?) at plate level
2. Pick a hit and visualize AC invasion (laminin::GFP)
3. Examine DIC for change in morphology

You pick the RNAi targets (we have a library of ~15,000 different RNAi clones)
Example plate-level phenotypes

mom-4

Pvl (Protruded vulva)

BIO 327 2017 class data
Team C. elegans class RNAi screen results
Control (empty vector)

egl-18(RNAi)

BIO 327 2018 class data
Team Oral Presentations

Final Project Reports:
- Intro
- Methods
- Hypothesis
- Results
- Discussion

In class final exam:
Based on research talks from faculty & inquiry based projects
ASSESSMENTS

Grinnell College

Participation in D. Lopatto’s pre- and post-course CURE survey (2017-18)
- Reported strong learning gains in scientific writing above both CURE and SURE survey national averages

Stony Brook University

2018: P. Khost (English department) survey to understand student gains in self-efficacy in writing

2018: pilot program for the Stony Brook Curriculum Assessment Project assessing gains in General Education goals by the University
Students reported gains (Lopatto CURE survey 2018)

Figure 1. The figure illustrates the mean ratings by students of gains in 25 areas corresponding to the course elements above.
BOOTCAMPs:
1. Microscopy
2. *C. elegans*
3. Nematostella

LAB SCHEDULE

Week: 1 2-3 4-5 6-14

* independent group projects

* *Lab Reports Due*
GUIDED INQUIRY BASED LEARNING!

1. Novel genetic screen for cell migration
2. RNAi screen
3. Quantitative assessment of cell migration defects
   
4. Pharmacological genetic approach to studying regeneration
5. Dose response of pathway inhibition
6. Assessment of regeneration defect phenotypes
# LAB SCHEDULE

<table>
<thead>
<tr>
<th>Week 6</th>
<th>PROJECT PLANNING</th>
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</thead>
<tbody>
<tr>
<td>Week 7</td>
<td>PROJECT PLANNING (list of reagents needed by Friday 3/15 9 AM (day of mid-term))</td>
</tr>
<tr>
<td></td>
<td><strong>spring break</strong></td>
</tr>
<tr>
<td>Week 8</td>
<td>Hypothesis? Collect reagents, set up experiments?</td>
</tr>
<tr>
<td>Week 9</td>
<td>Experiments</td>
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<tr>
<td>Week 10</td>
<td>Experiments</td>
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<table>
<thead>
<tr>
<th>ORAL PRESENTATION I</th>
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<tr>
<td>ORAL PRESENTATION I</td>
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<td>ORAL PRESENTATION II</td>
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<td>Week 11</td>
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<td>Week 12</td>
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<td>Week 13</td>
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<tr>
<td>Week 14</td>
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</tbody>
</table>
J. Peter Gergen: Drosophila screens to understand pattern formation

Discovery-based Inquiry

Science Process Skills
Iteration
Collaboration

results unknown to students, instructors, and science as a whole

CURE

Broadly Relevant

Switch to CURE
Final Thoughts

- This is an iterative process
- Working in teams is great for feedback
- Don’t forget evaluation of the CURE itself

  - Some tools already exist
    - (CURE survey, affective measures), especially for measuring short-term outcomes
PLAN FOR TODAY

● What is a CURE?
● What does this look like in action?
● An example of an upper division CURE
● Developing a CURE for your class
What are the learning goals for your lab?

- Take a few minutes to think about what you hope your students will learn and take away from your lab course.
What are the learning goals for your lab?

- Take a few minutes to think about what you hope your students will learn and take away from your lab course.
- Discuss your goal(s) with another person.
What makes a “good” research question for undergraduate research?

- Brainstorm a list of criteria which define a “good” research question in this context
EXAMPLE 1: Table 3. Seven Helpful Attributes for High School and Undergraduate Research Projects

1. Technical simplicity, especially at the initial stages
2. Conceptual simplicity, and minimal background requirements
3. Compatibility with flexible scheduling
4. Multiple achievement milestones
5. Real research that is publishable and interesting to others
6. Project ownership provides strong motivation

**EXAMPLE 2:** Box 1. Suggestions for Creating a Research-Based Course Using a Faculty Research Program

1. Low barrier of technical expertise for students to collect data
2. Established checks and balances for student-collected data
3. Diverse, but constrained set of variables for developing hypotheses
4. Central database accessible to all students
5. Course assessments reflect authentic scientific communication
6. Research-specific expertise of faculty member

Potential Limitations and Constraints

- What are some limitations or constraints that you will need to consider?
- Brainstorm with your working group
- Write down your thoughts

Research Questions
Potential Limitations and Constraints

- What are some limitations or constraints that you will need to consider?
- Brainstorm with your working group
- Write down your thoughts

- Now, what are some potential solutions?
Design your Research Questions

● Define your ‘big picture’ research question(s) for your CURE

● Does it align with your learning goals and objectives defined earlier?
Design your Research Questions

- Define your ‘big picture’ research question(s) for your CURE.
- Does it align with your learning goals and objectives defined earlier?
- What may result?
  - Brainstorm and discuss with your working group
  - Any potential collaboration?
Modules

- Modules are the major steps or experiments of your research question
- Most CUREs will consist of several Modules

• What are the **research and learning tasks (modules)** necessary for making progress towards the research question?
• How will students know when they’ve accomplished tasks? (**assessment**)?
• How will you use **inclusive practices** in your task and assessment design?
Module Example: Developing Hypotheses

Task 1: Find and Read Literature
Skills - literature search, quality assessment

Task 2: Formulate Hypotheses
Skills - hypothesis design

Task 3: Work with research group to choose one hypothesis
Skills - collaboration, communication

Assessments

WEEKS 1-5
SKILL BUILDING
RNAi feeding
Strain maintenance
DIC/GFP microscopy
Bioinformatics
Statistics

WEEKS 6-7
PROJECT PLANNING

8-12
DATA COLLECTION

13
DATA ANALYSIS

14
PRESENTATION
Module Example: Developing Hypotheses

Task 1: Find and Read Literature
Skills: literature search, quality assessment

Task 2: Formulate Hypotheses
Skills: hypothesis design

Task 3: Work with research group to choose one hypothesis
Skills: collaboration, communication

Assessments
- Reference list
- Peer-review of hypotheses
- Participation in group work

Inclusive Practices
- Show examples of primary literature/scientists from a variety of labs and backgrounds
- Independent work to create own hypothesis
- Group work, variety of tasks within group
THANKS!

Cissy Ballen
Auburn University

Peter Gergen
Stony Brook University

Rebecca Adikes
Stony Brook University

Jerry Thomsen
Stony Brook University