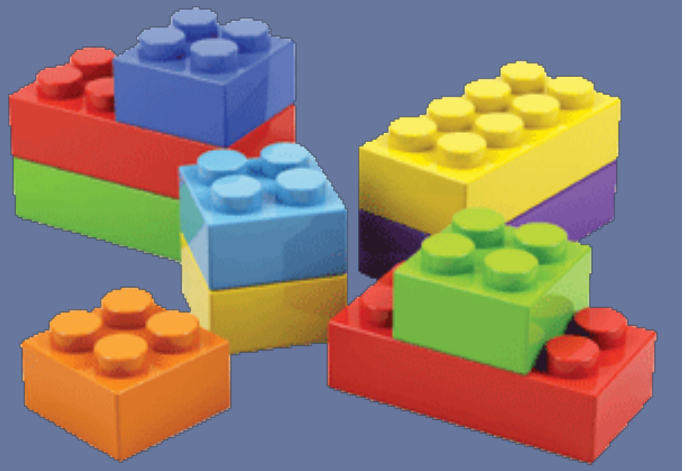
Synthetic Biology

Breaking it Down and Putting it Back Together



Megan Cotich
La Colina Junior High School
Santa Barbara, Ca

University of California, Santa Barbara
Materials Research Laboratory
Research Experiences for Teachers II

7th Grade Life Science Teacher ➔ Synthetic Biologist

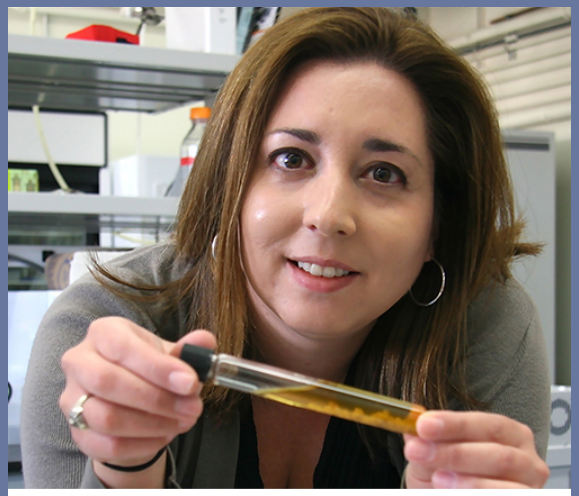
Next Generation Middle School Life Science and Engineering

Common Core Reading, Writing, Listening, Speaking

…with the help of Kevin Solomon, PhD

RET I: Expression of gut fungal cellulase in a bacterial host

* Current practice allows the creation of bio-fuels from agriculture (corn, etc.)
* The use of agricultural waste would present higher yields without the cost, acreage, and societal impacts of large grain production

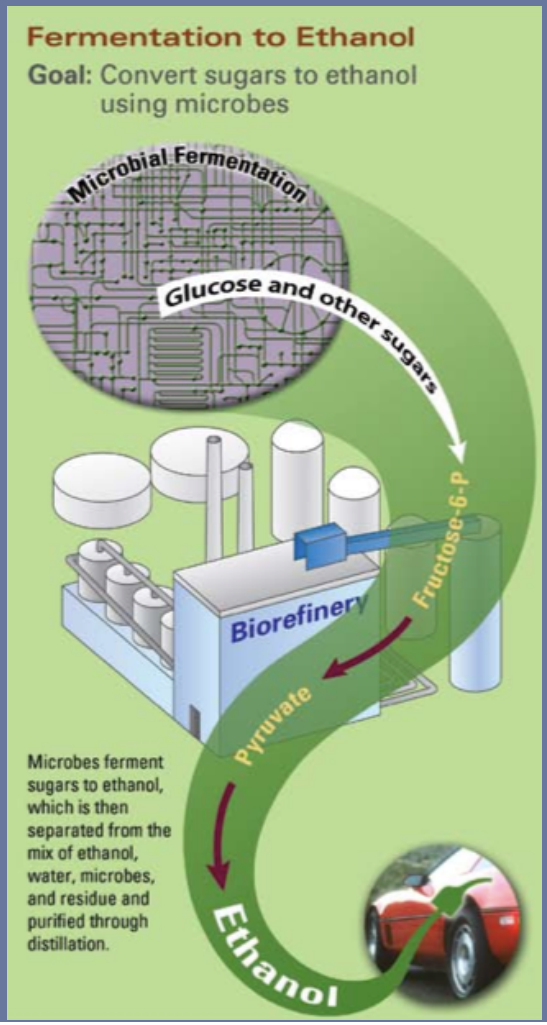


U.S. DEPARTMENT OF ENERGY

Principal Investigator, Michelle O'Malley, with *P. finn* fungus used in the lab

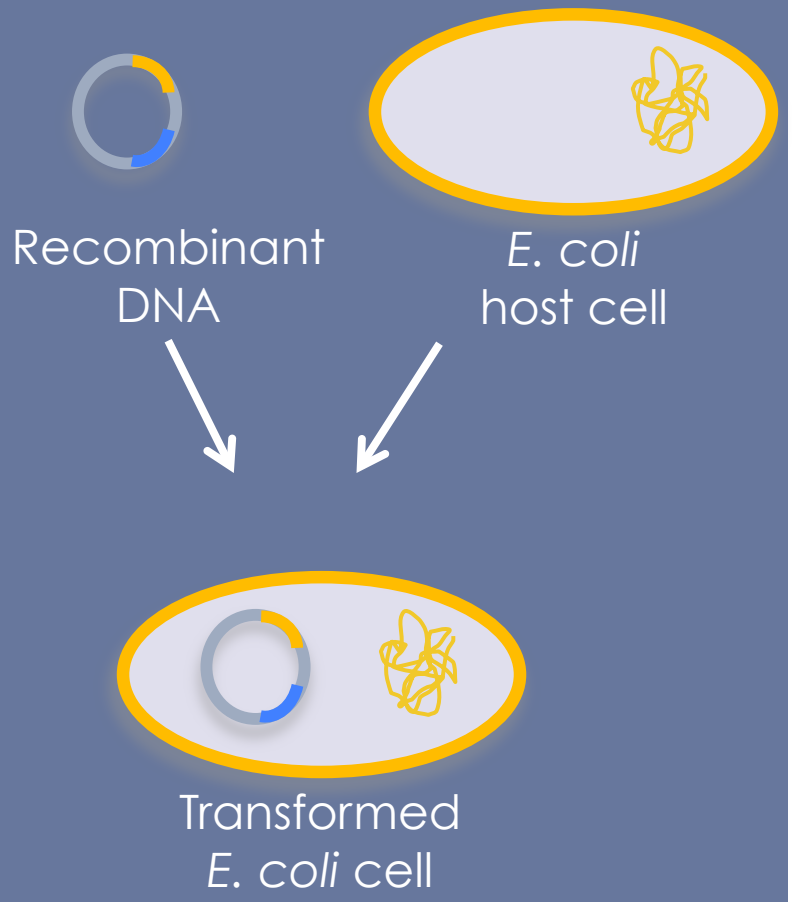
RET I: Expression of gut fungal cellulase in a bacterial host

- The purpose of this research is to use bacterial plasmids to create chemicals on a large scale
- Uses and applications include:
  - Pharmaceuticals
  - Bio-fuels



RET I Project Goals

- Clone cellulase, an enzyme from *P. finn* fungus
- Transform into *E. coli* bacteria
- Ultimately it will be able to break down biomass in order to make chemical products

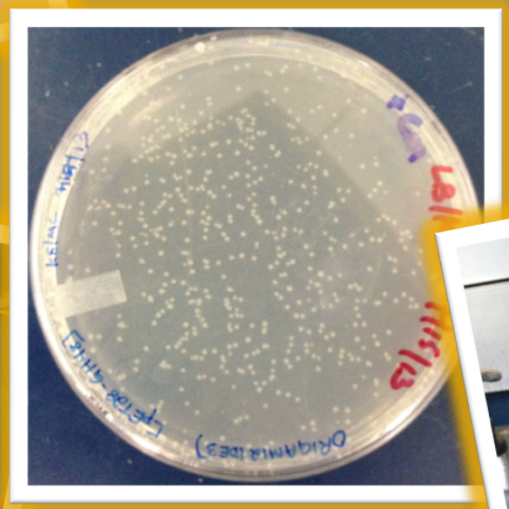


Lab Process

Source DNA P. finn

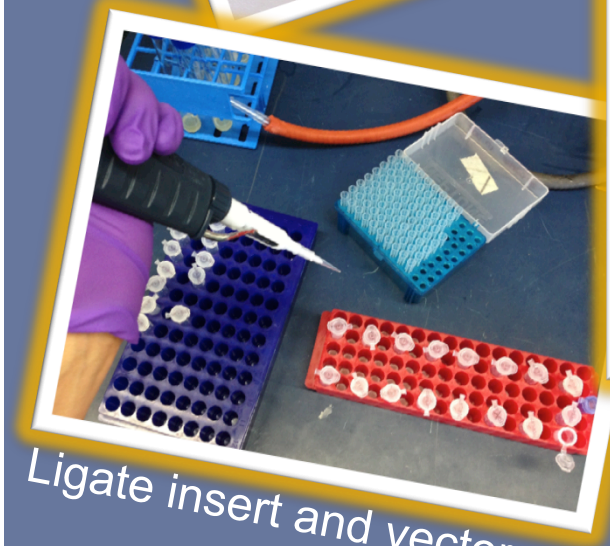
Confirm source DNA

Digest insert and vector



Make index plates

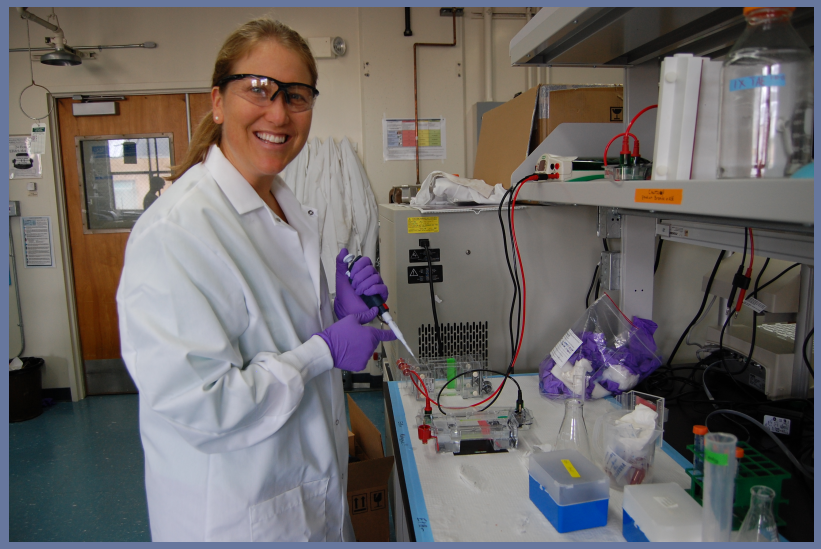
Check growth of colonies and screen overnight



Ligate insert and vector

RET I – RET II

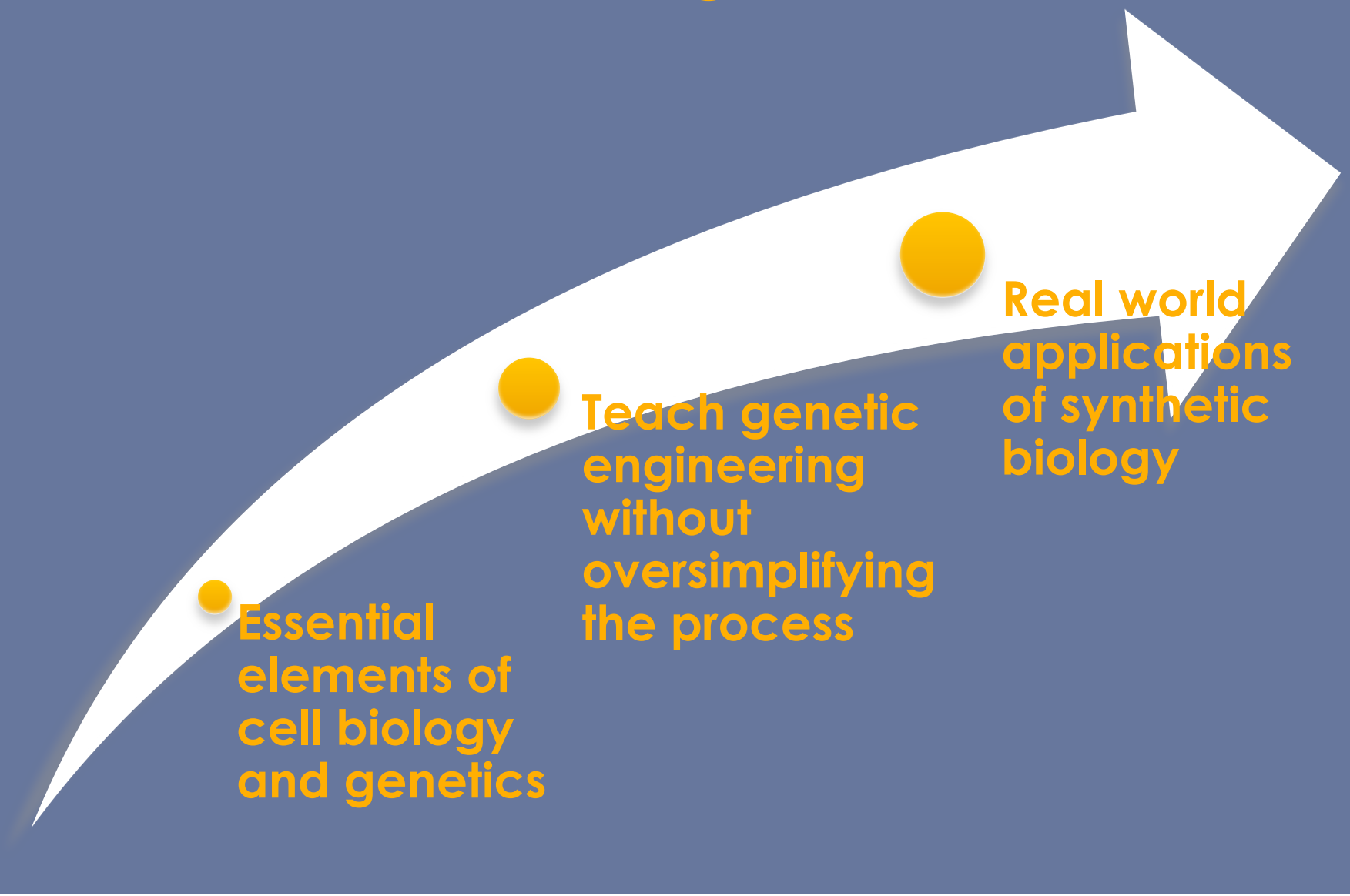
How does this translate to 7th grade life science?



University Research

50 min Junior High Period

Synthetic Biology in 7th Grade



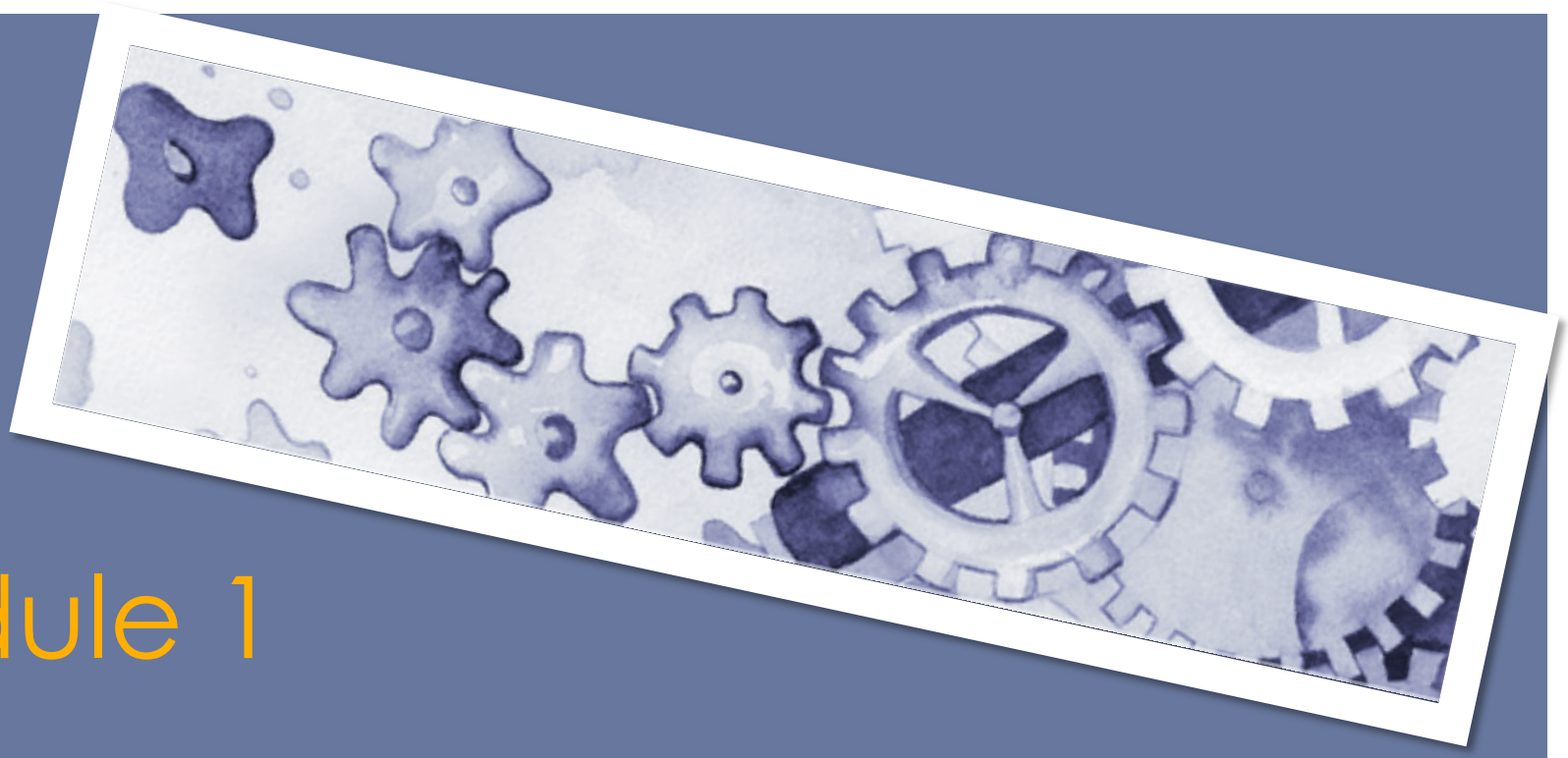
Module	Big Idea	Activities
1. *Synthetic Biology*	Use of Microbes	Introduction PowerPoint
2. *Breaking it Down*	Metrics, Prokaryotes, DNA	Size and Scale, Enzymes, Microbes, DNA Extraction
3. *Putting it Back Together*	Prokaryotes, Genetics, DNA, Engineering	Bacterial Growth, Recombinant DNA Lab, Bacterial Transformation
4. *Ethics Debate*	Influence of Sci., Engr. & Tech. on Society	Syn. Bio. Ethics Debate

Next Generation Sci. Standards

- **LS1.A: Structure and Function:** special structures are responsible for particular functions
- **LS1.B: Growth and Development of Organisms:**
- **LS1.C: Organization for Matter and Energy Flow in Organisms**
- **LS2.A: Interdependent Relationships in Ecosystems**
- **LS3.A: Inheritance of Traits**
- **LS3.B: Variation of Traits**
- **LS3.2** Using models to show asexual vs. sexual reproduction and resulting variation
- **LS4.D: Biodiversity and Humans**
- **Developing and Using Models** to describe, test, and predict more abstract phenomena and design systems
- **Influence of Science, Engineering, and Technology on Society and the Natural World**
- **PS1.B: Chemical Reactions**
- **ETS1.B: Developing Possible Solutions**
- **ETS1.C: Optimizing the Design Solution**

Common Core State Standards

- Reading:
  - Cite specific textual evidence
  - Follow precisely a multistep procedure when carrying out experiments
  - Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).
- Writing
  - Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes.
  - Write arguments focused on *discipline-specific content*
- Writing Continued:
  - Support claim with evidence and reasoning
  - Conduct short research projects
  - Gather relevant information from print and digital sources
  - Draw information from informational texts to support research and reflection
- Speaking and Listening
  - Engage in a range of collaborative discussions, building on others' ideas and expressing their own clearly



Module 1

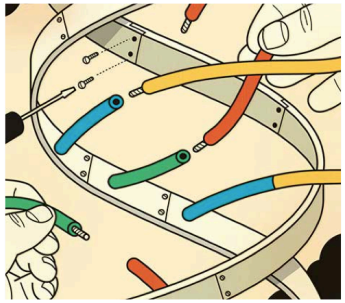
Synthetic Biology Intro

1.1 Synthetic Biology Intro

- Introduction to the unit through PowerPoint presentation and dialogue
- Presentation of current synthetic biology research and methods
- Vocabulary development
- Preliminary reflection
- Standards: LS1A, influence of science on society

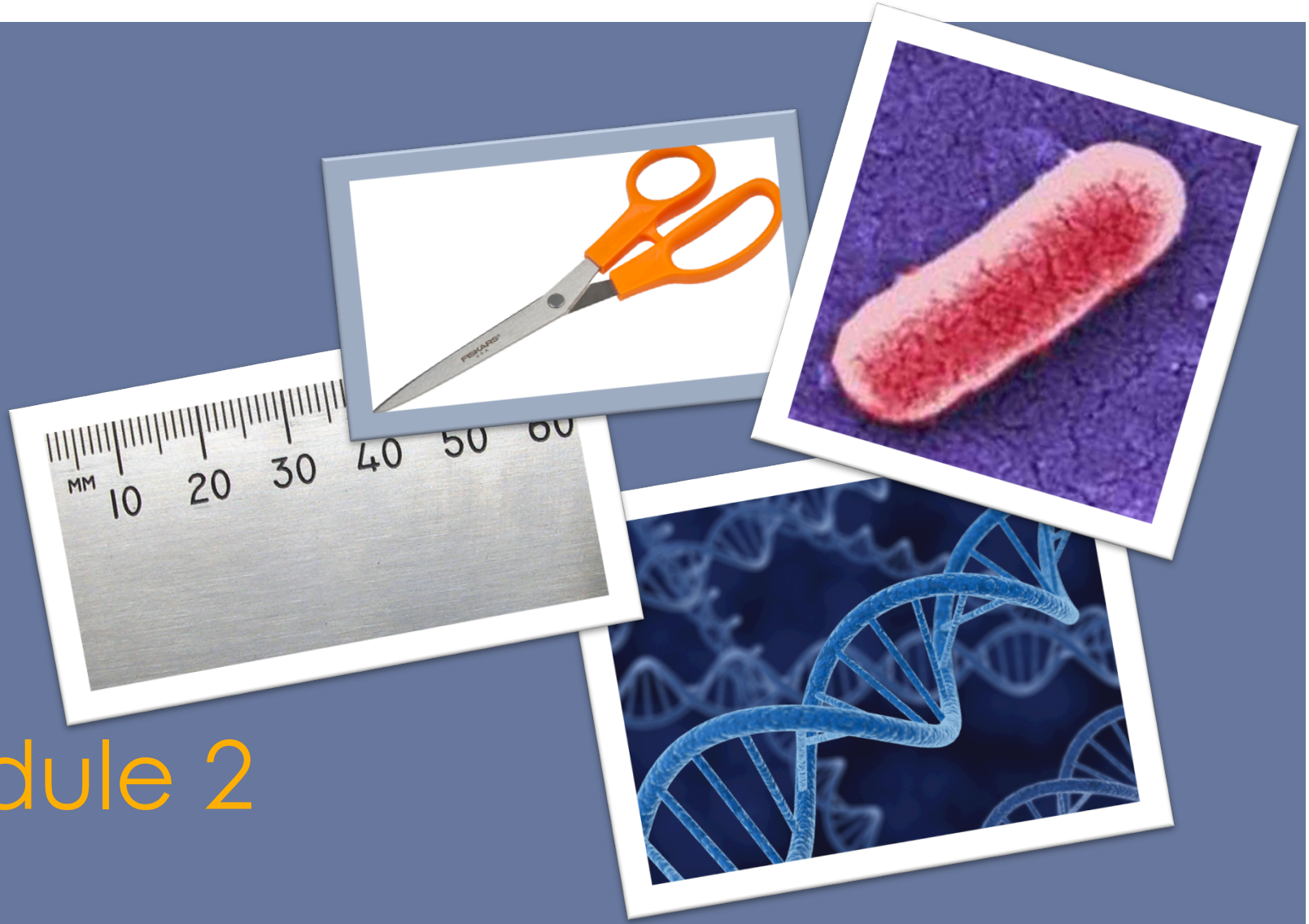
Definition

- Synthetic Biology is the design and construction of new biological components
  - Enzymes
  - Genetic circuits
  - Cells
- Combines biology and engineering
- Understanding how life works and how to use it to benefit society



Key Vocabulary

Plasmid	Enzyme	PCR (polymerase chain reaction)	Ligate
Bacterial in origin, extra-chromosomal, circular, double-stranded DNA, much smaller than the genome	A substance produced by a living organism that acts as a catalyst to bring about a specific biochemical reaction.	To amplify a piece of DNA, generating thousands to millions of copies of the sequence	To link two ends of DNA or RNA



Module 2

Breaking it Down

2.1 How Small is *Really* Small?

- Conceptualize the size and scale of the individual components used in synthetic biology
- Card sort

Name: _____ Per: ____

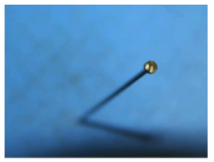
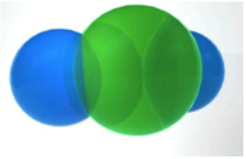
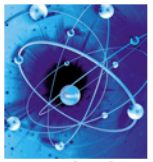
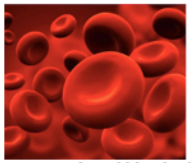
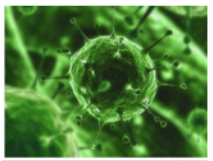
How Small is *Really* Small?

Arrange the items (on the Popsicle sticks) from **LARGEST** → smallest		
#	Name	Size
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

Synthesis:

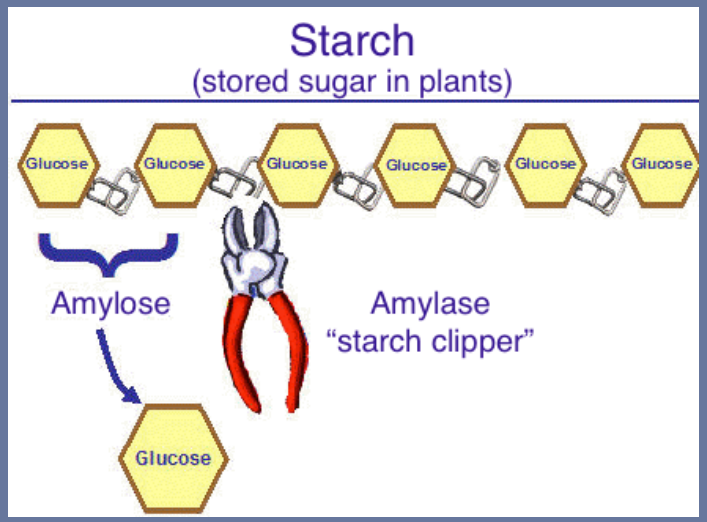
1. What size surprised you the most and why?

2. In this unit, we will learn about a range of items from a cell, to a gene and enzymes. What do you estimate this size range to be in nanometers (nm)? What did you base your estimate on?

 The head of a pin	 Length of an *E. coli* bacterium
 Diameter of a DNA double helix	 Water molecule
 Diameter of an electron	 Diameter of an average human hair
 Length of a lysosome	 Diameter of a red blood cell
 Length of a mitochondrion	 Diameter of a virus

2.2 Enzymes Break it Down

- Demonstrate how enzymes change the chemical properties of substances
- Vital for life functions (ex. digestion), and for synthetic biology
- Iodine on chewed up saltine crackers will present a color change to show presence of enzymes



2.3 Microbiology + Presentations

- Introduction to microbes and their role in synthetic bio
- Small group research and presentations on subfields of microbiology

Project Description

- In groups of 4-5, research one of the seven subfields of microbiology on iPad's and make a Google Presentation
- Include a general description of this field of microbiology
- Explain the role of microbes in research and development
- Highlight 2 careers in this field including average salary
- Explain at least one current area of research (the latest breakthroughs)

2.3 Presentation Rubric

Field of Microbiology: _____

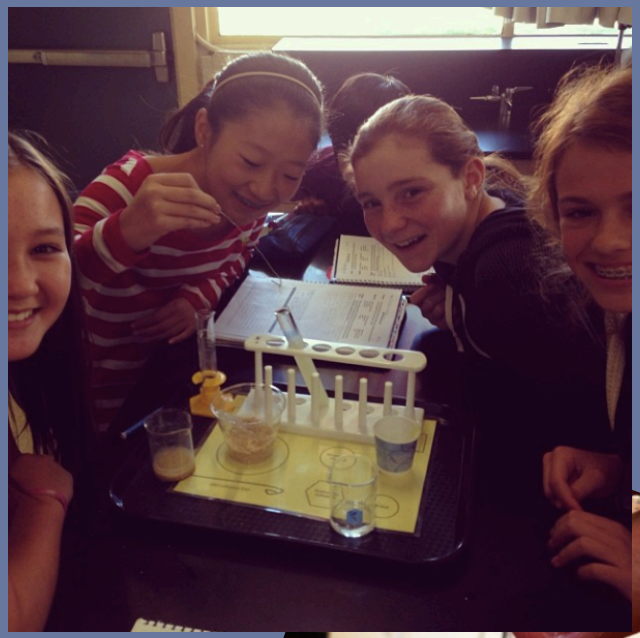
Microbiology Presentation

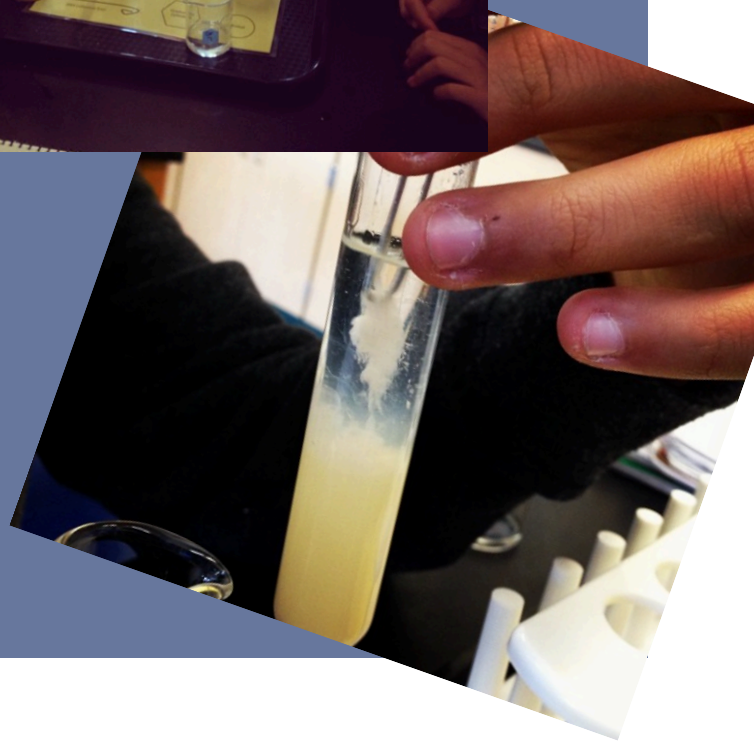
	Poor	Satisfactory	Excellent
Slide 1: Title Page Initials _____	Names Only (0 pts)	Names and Field of Microbiology (1 pts)	Names, Field of Microbiology, Graphic (2 pts)
Slide 2: General Description Initials _____	Not bulleted, too brief, graphic doesn't relate (1 pt)	Bulleted, too brief, graphic is not relevant to field (2 pts)	Bulleted, thorough, graphic is relevant to field (3 pts)
Slide 3: Role of Microbes Initials _____	Not bulleted, too brief, graphic doesn't relate (1 pt)	Bulleted, too brief, graphic does not show microbe in action (2 pts)	Bulleted, thorough, graphic shows microbe in action (3 pts)
Side 4: Careers in Microbiology Initials _____	Not bulleted, too brief, graphic doesn't relate (1 pt)	Bulleted, too brief, graphic does not show career choices (2 pts)	Bulleted, thorough, graphic shows career choices (3 pts)
Slide 5: Current Research Initials _____	Not bulleted, too brief, graphic doesn't relate (1 pt)	Bulleted, too brief, graphic does not relate to current research (2 pts)	Bulleted, thorough, graphic relates to current research (3 pts)
Aesthetics	Fonts are hard to read on background color, distracting, no pictures (1 pt)	Readable, but text is not organized, background is distracting, some pictures (2 pts)	Organized, clear images, background complements images and font color (3 pts)
Oral Presentation	Not prepared, group was lost. Failed to answer the audience's questions (1 pt)	Not all of the members spoke on the topic, at least 1 person seemed unknowledgeable (2 pts)	All members spoke and understood the topic. Questions were answered accurately (3 pts)
Saving and Sharing	Presentation is saved on another format and not loaded on presenting computer (0 pts)	Presentation is saved on Google Drive but not shared with group members or teacher (2 pts)	Presentation is saved on Google Drive and shared with all members and teacher (2 pts)

Total Points Earned: /22

2.4 DNA Extraction Lab

- Inquiry based DNA extraction
- Reading of informational text to write procedures
- Multiple trials encouraged to improve procedures
- More authentic lab experience…failure is inevitable



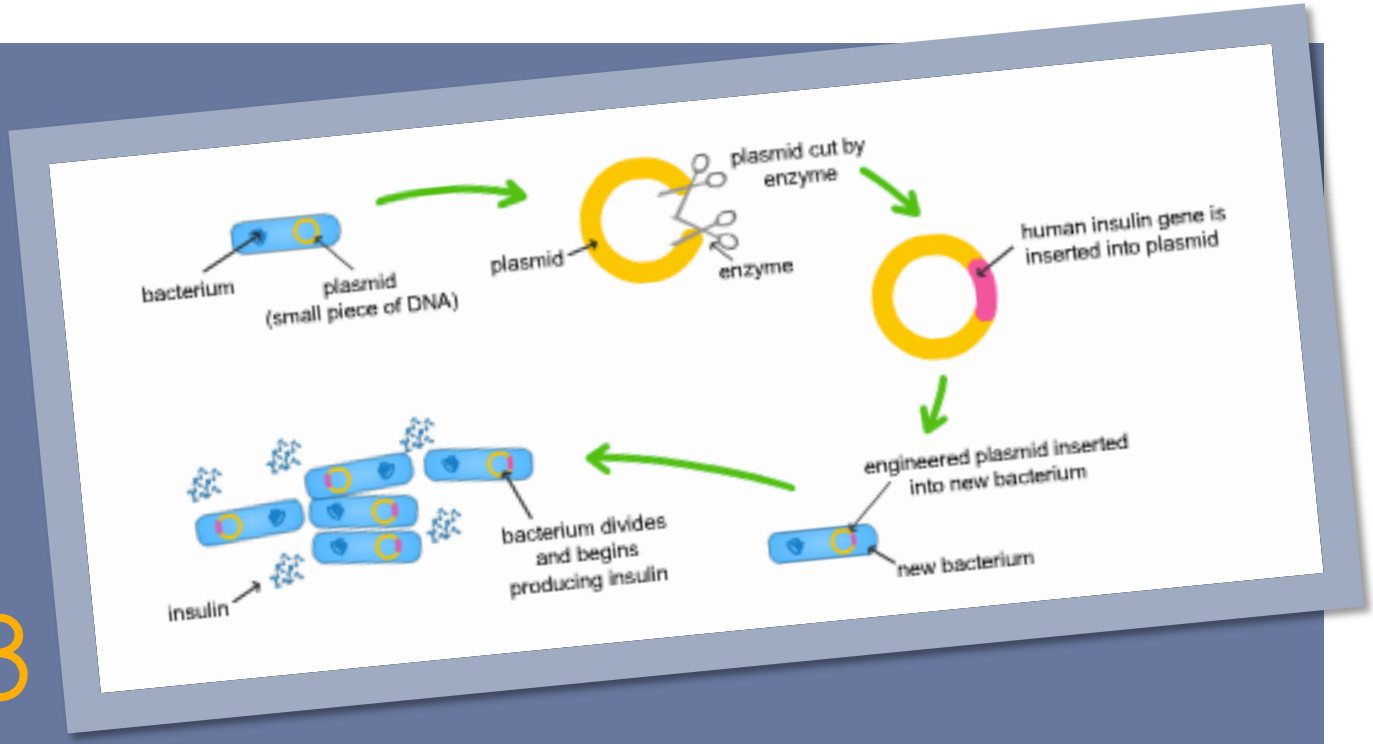


Wheat Germ DNA Extraction

Failure, to some level, is inevitable in this lab. Learning this is a critical element of persistence in research.

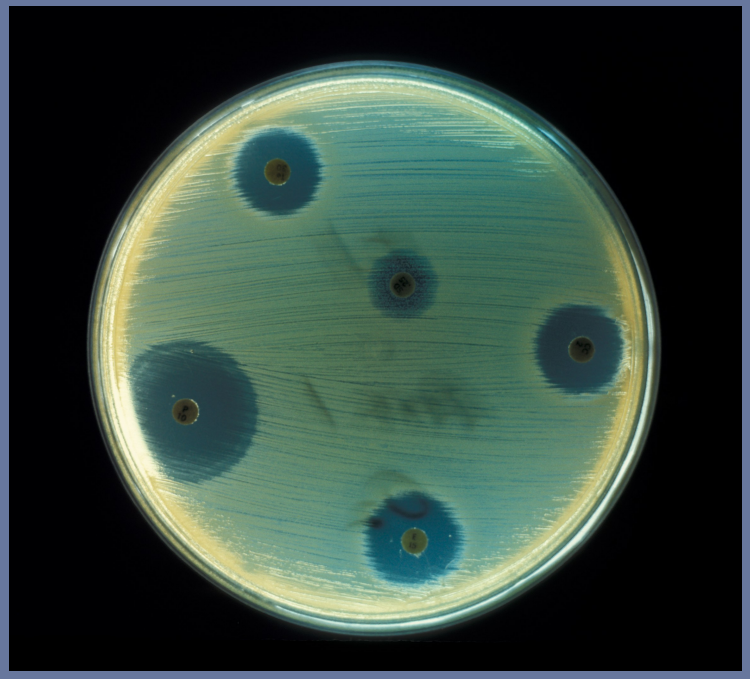
Module 3

Putting it Back Together



3.1 Bacterial Resistance to Antibiotic Demo

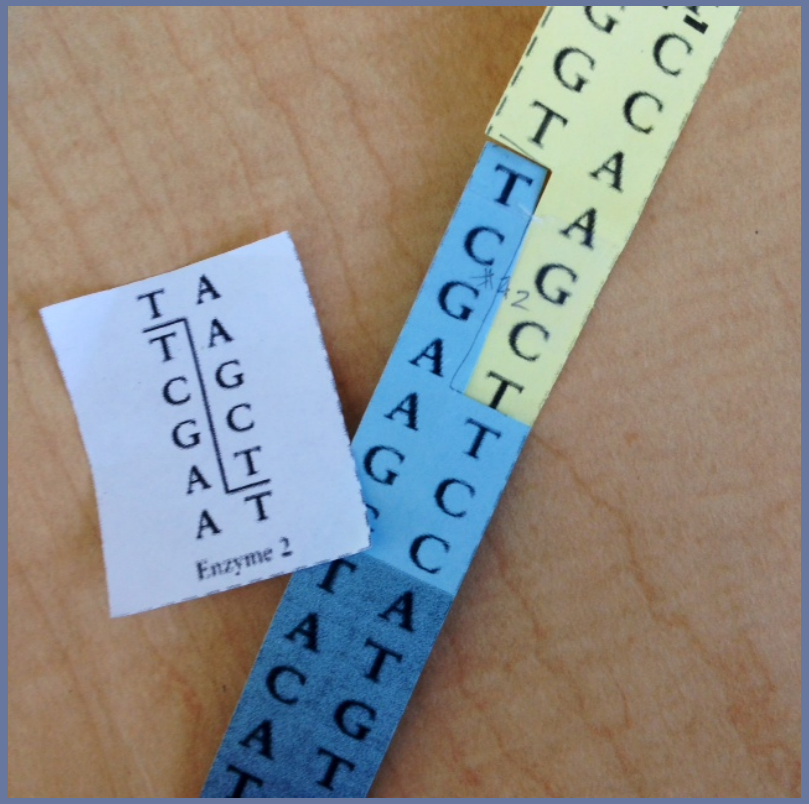
- Demo begins at the start of the module to produce results by the end of the module
- Up close look at bacterial growth and effect of antibiotic
- Direct applications to 3.2 and 3.3



- Example of bacteria growth with inhibition zones

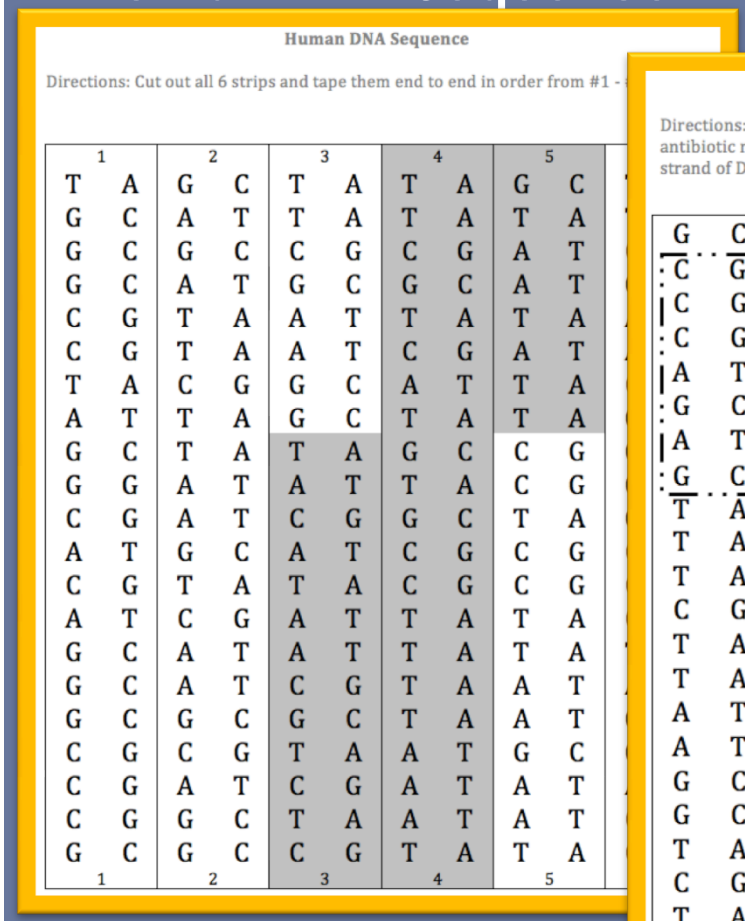
3.2 Recombinant DNA Lab

- Putting the components of Module 2 together
- Give the students a "hands-on" approach to engineering as it is often very abstract
- To model the protocol involved with recombinant engineering

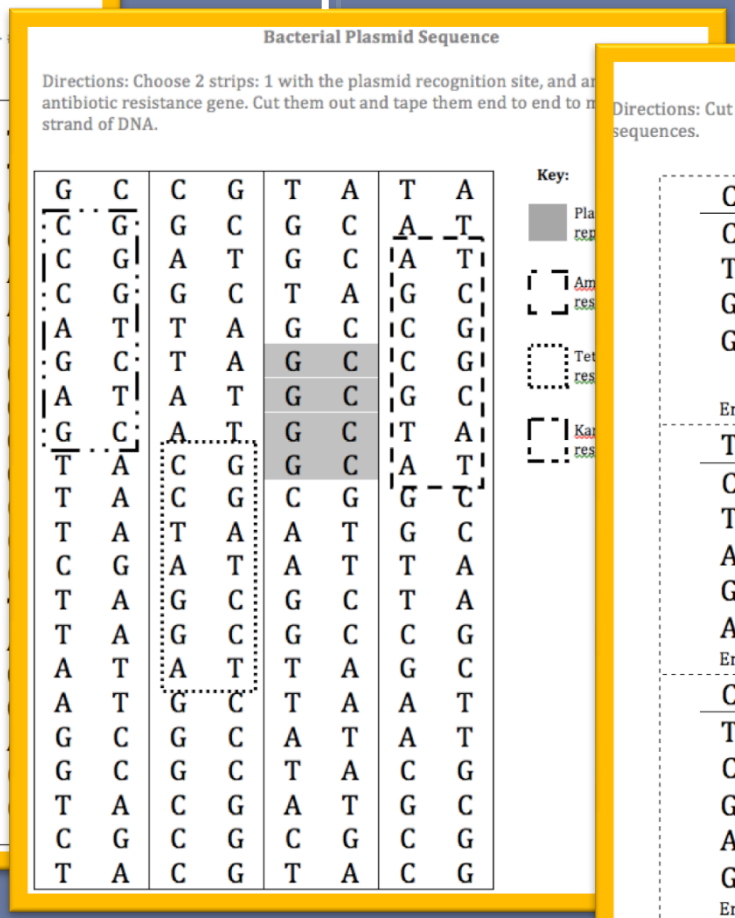


3.2 Recombinant DNA Lab

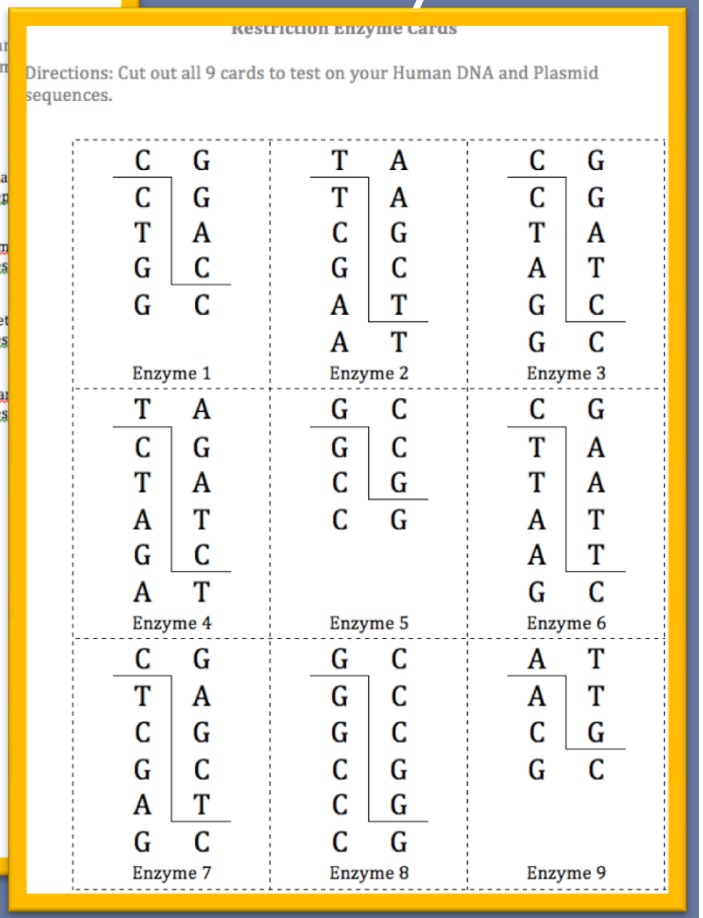
Human DNA Sequence



Bacterial Plasmid Sequence



Restriction Enzymes

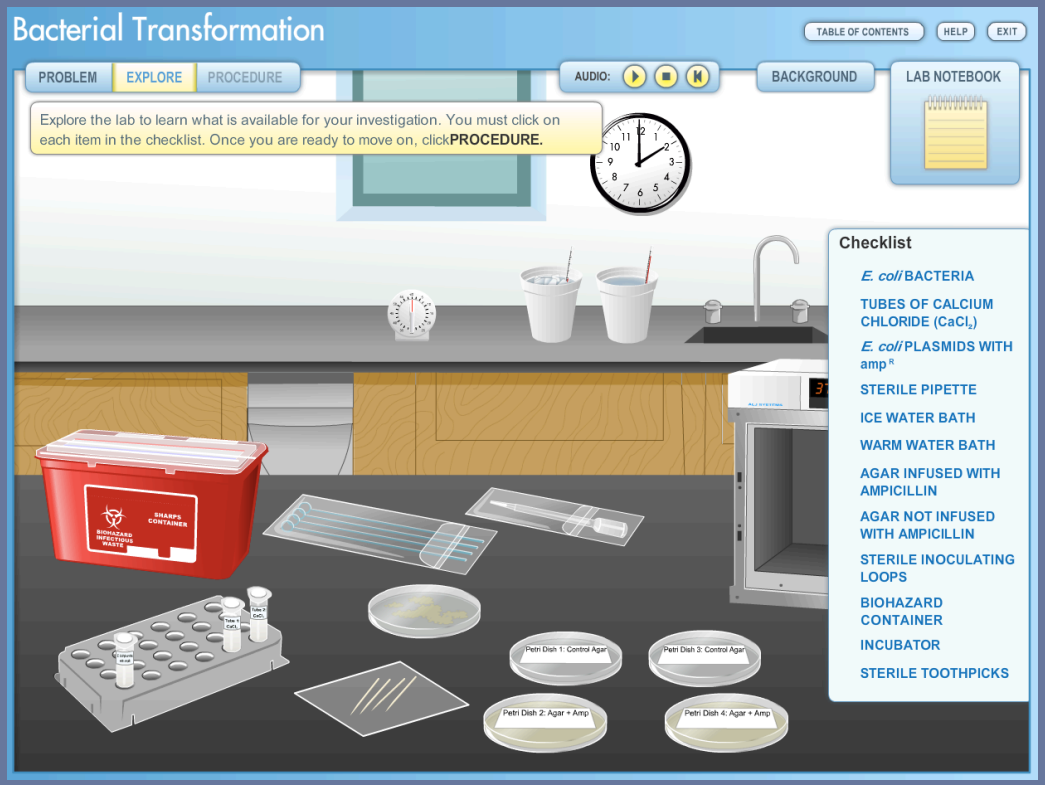


Recombinant DNA Lab

Students use the restriction enzyme cards to identify a location a each DNA strand that can be cut by one enzyme

3.3 Bacterial Transformation Simulation

- Continuation of 3.1 activity
- Transform recombinant plasmid into *E. coli* using actual lab methods
- Students record lab protocol



https://www.classzone.com/books/hs/ca/sc/bio_07/virtual_labs/virtualLabs.html

Module 4

Synthetic Biology Ethics

4.1 Syn. Bio. Ethics Debate

* Armed with the knowledge of how and why one would want to synthetically engineer organisms
* Additional resources presented: TED Talk, NPR Story of the Day Podcast, ethics study report
* Students team up to debate both sides of the argument and use evidence to back up their claim

4.1 Debate Scaffolding & Rubric

Sentence Frames for Synthetic Biology Ethics Debate

Introductory argument

1. **Hook:** (Can be a question, fact, or short story. This is the way you engage your audience in what you have to say.)
2. **Claim: (for or against):** Evidence suggests that…
3. **Transition sentence:** Our team will provide two points to support our claim.
4. **Point 1:** Our first point is that…
5. **Point 2:** Our second point is that…
6. **Concluding sentence (restating the claim):** Our team will provide sufficient evidence that…

Point 1

1. **State your first point**:This should not be evidence, but something you are going to prove.
2. **Evidence**: According to ___(source)_____, _____(evidence)_____.
3. **Commentary**: Explain why this is important or how it relates to your point.
4. **Evidence**: Another piece of evidence is…
5. **Commentary**: Explain why this is important or how it relates to your point.

Point 2

1. **State your second point:** This should not be evidence, but something you are going to prove.
2. **Evidence:** The article/movie titled _____, suggests that _____.
3. **Commentary:** Explain why this is important or how it relates to your point.
4. **Evidence:** Secondly, it is important to note that…
5. **Commentary:** Explain why this is important or how it relates to your point.

Concluding Statement

1. **First sentence:** (restate your overall claim with your two points) In conclusion _____ because ___(point 1)_____ and _____(point 2)_____.
2. **State what the other side may say:** The other team may argue that…
3. **State why this is not correct:** We think this is incorrect because…
4. **Transition sentence:** Further, we have two questions we would like the other team to address.
5. **Question 1:** First…
6. **Question 2:** And second…

Group Member Evaluation

Directions: Score your group members on the assessment statements below. Place the number of points in the blanks below their name. **Be honest in your evaluations. Rewarding someone points for work they did not do is not fair to the group.** Total the points at the bottom. All group members' scores will be averaged from each evaluation sheet and recorded.

5 points	*Strongly Agree*
4 points	*Very Much Agree*
3 points	*Agree*
2 points	*Somewhat Agree*
1 Point	*Somewhat Disagree*
0 Points	*Disagree*

Your Name:	**Group Member Names:**				
Assessment:					
This person helped the group work hard to research, write the speech, and practice.					
This person completed their assigned work without a having to be re-directed by group members.					
This person did not spend time socializing with other groups.					
This person listened to the other group members ideas, and offered their own input.					
Total Score					

Acknowledgments

* Dr. Kevin Solomon
* Dr. Michelle O'Malley Lab
* Frank Kinnaman
* Marilyn Garza
* Shannon Carpenter Yorke