

DESIGNER BACTERIA

TEACHER GUIDE



A Design-Based Immersion Learning Unit

Version 3: Autumn 2007

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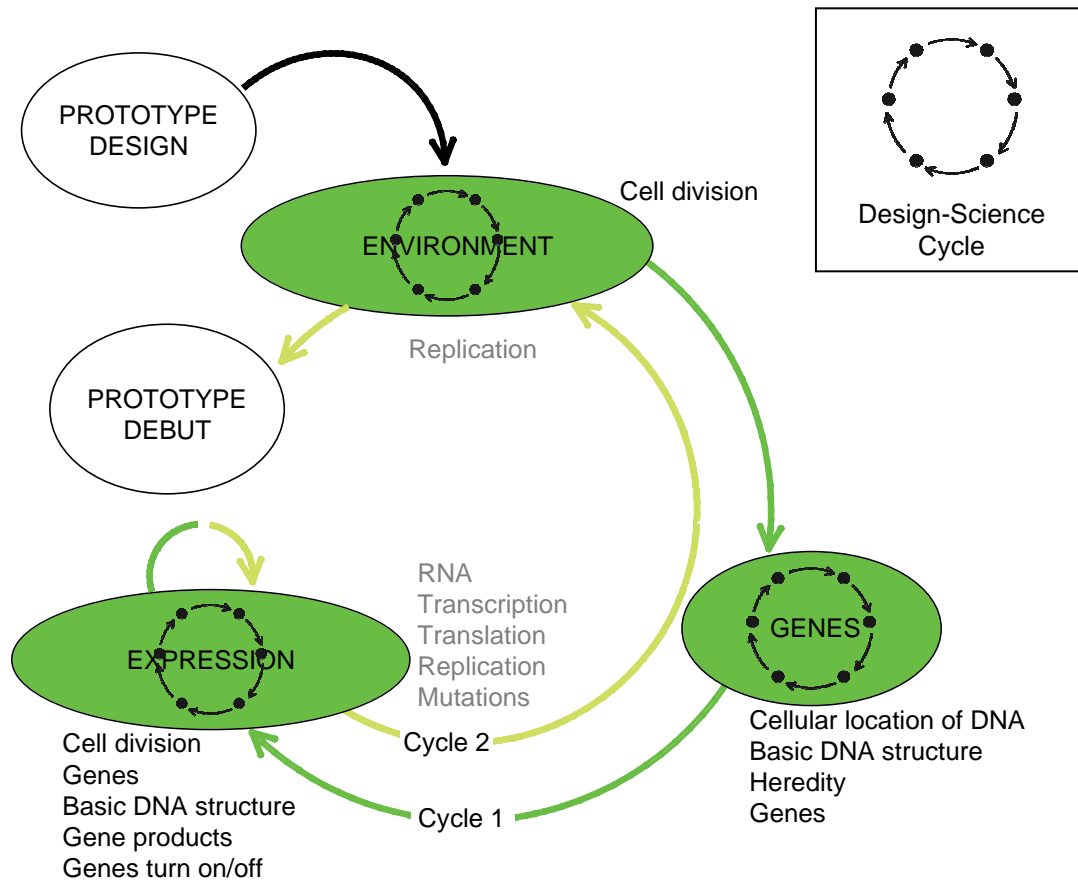
Learning Research and Development Center

DESIGNER BACTERIA



UNIT OVERVIEW

Designer Bacteria Immersion Unit Storyline



The model above is a graphic representation of the topics covered in the *Designer Bacteria Immersion Unit* for high school biology. This immersion unit uses a design-based learning approach. In design-based science units, students make decisions about how they want to design and develop a specific kind of prototype. Designing and improving that prototype allows students to engage deeply in various experiences, improving their science learning. In this unit, students will genetically modify bacteria so that it fluoresces or displays a blue pigment.

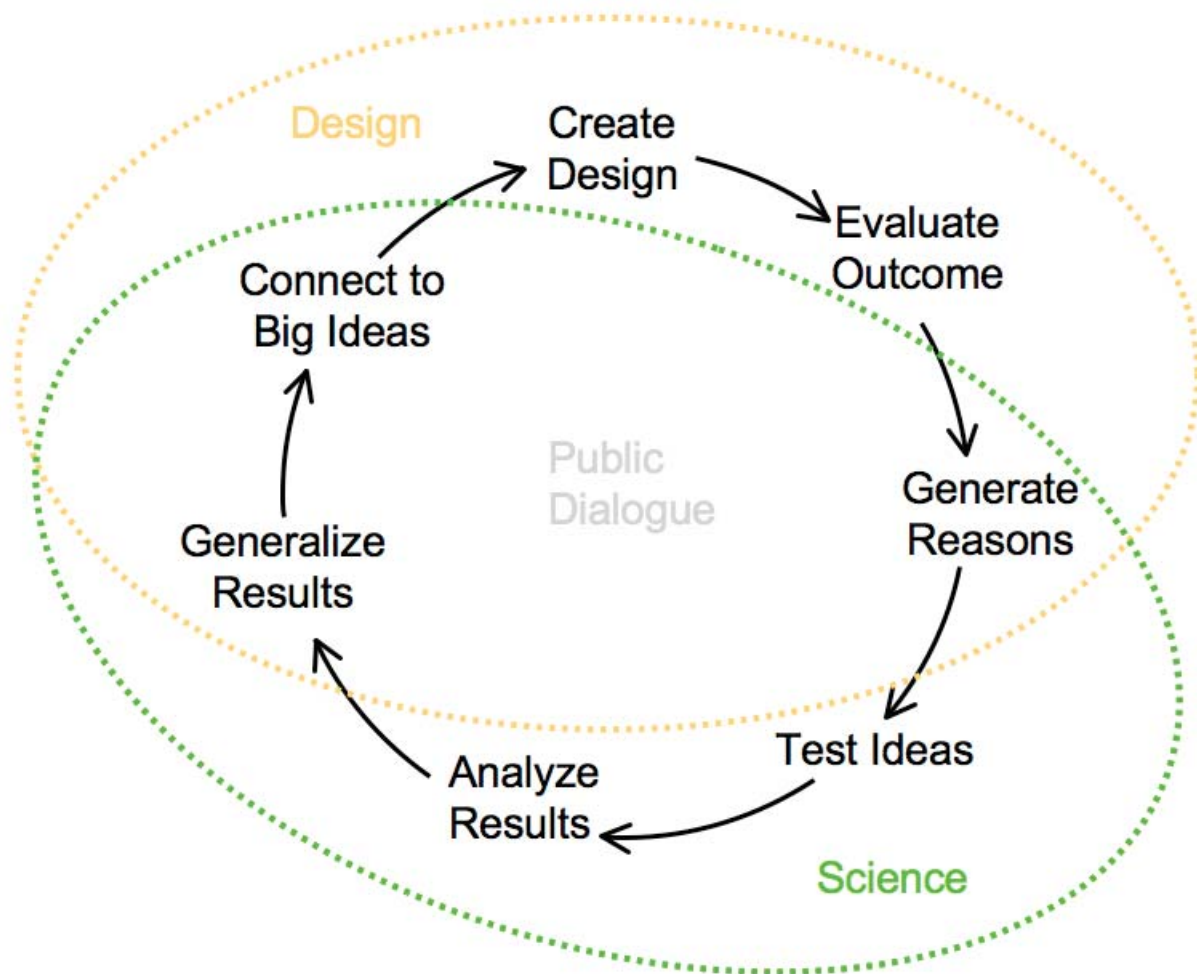
The fluorescent or pigmentation system is decomposed into three major topics (subsystems): *Environment*, *Genes*, and *Expression*. The students will make various modifications to their prototype as they cycle through each subsystem.

Once students determine what the needs and requirements are for their prototype in the *Prototype Design*, they will proceed through the *Environment* and the *Genes* subsystem to the *Expression* subsystem. Here, students will cycle through the *Expression* subsystem again, gaining a deeper knowledge of the key concepts addressed. Students will continue through the *Environment* subsystem once more. Finally, students conclude the unit with a mock patent application and science fair in the *Prototype Debut*.

Designer Bacteria Big Idea(s)

- In order to optimize cell division, the bacteria must be grown under the proper conditions.
- In order for the cells to divide and the colony to grow, the DNA in each parent cell must be replicated and a copy given to each daughter cell.
- DNA is a double-stranded, anti-parallel molecule located in the bacterial cytoplasm that codes for genes.
- Genes are inherited from previous generations and transmit a characteristic.
- Genes can be turned on and off, depending on the environment, to produce gene products (proteins) that give rise to a characteristic.
- The cell uses DNA as the blueprint for the proteins that give rise to a characteristic or trait.
- To make protein, the cell transcribes a gene from the DNA into RNA and translates that RNA into the needed protein.
- Mutations are mistakes in the DNA sequence that result in an incorrect protein blueprint and a range of cellular effects.

Design-Science Cycle



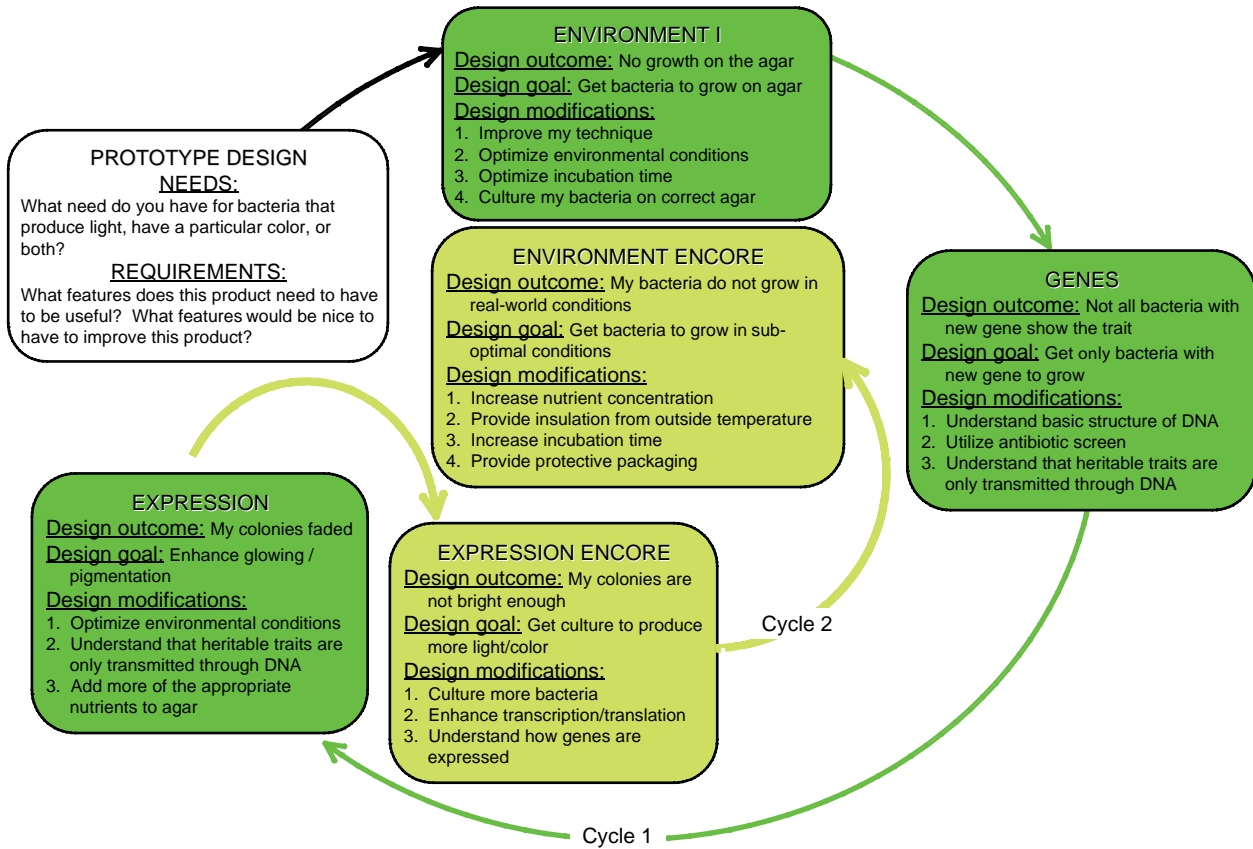
The model above is a graphic representation of the *Design-Science Cycle*. As students pass through each subsystem they will cycle through this learning cycle. Each cycle begins at the *Create Design* node and proceeds clockwise through the cycle, leaving the subsystem when they *Connect to Big Ideas*. As shown in the diagram, the design and the science space overlap in the *Public Dialogue* space. This *Public Dialogue* space becomes the part of the *Design-Science Cycle* where students will gain the most insight about improving their prototype.

Students begin the *Design-Science Cycle* in the *Design* space at the *Create Design* node. Here, students will develop a design idea and try it out. For various reasons, their initial design

may fail. These failures will become apparent when students enter the *Evaluate Outcome* node. Reasons for the outcomes and possible ways to test those reasons will be discussed as a class during *Generate Reasons*. From the *Generate Reasons* node, students will enter the *Science* space while they execute their proposed tests during *Test Ideas*. Students will analyze the results from their experiments in *Analyze Results*. They will discuss the results as a class during *Generalize Results* to uncover a pattern, theory, or trend. Finally, students will arrive at *Connect to Big Ideas* where they will link their prototype to the key science concept(s) behind it.

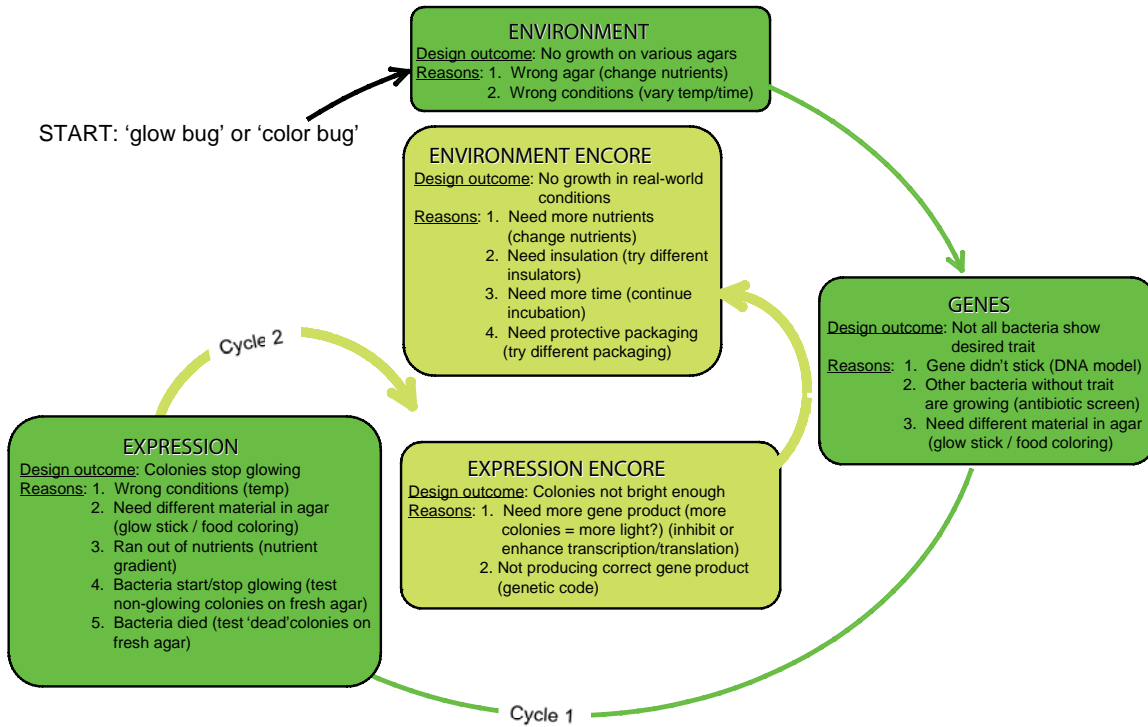
Unit At-A-Glance

Design



Unit At-A-Glance

Science



Unit Features

Teacher Actions

One feature of a design-based learning immersion unit that makes it different from more traditional methods of teaching is the role of the teacher. Instead of being the authority on the content or an endless fount of knowledge, the teacher takes on a more casual role in the classroom. He or she becomes a senior collaborator with the students. Below are some different strategies to maximize student learning and to guide you through this role as a collaborator in lieu of lecturer.

Instructional Strategies

Various instructional strategies that you may find useful include the sets of assessing and advancing questions that are included with each lesson to help probe student understanding. Assessing questions are geared toward the initial evaluation of student learning. The key questions included with the early lessons within a subsystem have this assessing quality. Advancing questions are stated in a way to push student thinking. Previous research has shown that these advancing type questions result in greater learning gains than assessing questions alone.

One of the goals of this unit is to include many opportunities for students to interact with each other and with their teacher. These interactions can be effective teaching opportunities when using the methods of Accountable Talk™. Accountable Talk™ includes teacher moves that can be used at various times during the unit. A reference table on the next page includes a list of these teacher moves that might encourage deeper student learning.

Implementing the Lessons

The *Teacher's Guide* information that will be useful for facilitating each lesson, e.g., big ideas, goals, activities, background information, assessing / advancing questions section, etc.

Each lesson contains a graphic representation of the current location in the unit's storyline and the *Design-Science Cycle*. This graphic tells you where each lesson falls within the unit, what you did previously, what you will do that day, and what is coming up.

Big Idea(s)

This section defines the major overarching concept(s) that students should learn in each subsystem. The big ideas for the *Designer Bacteria Immersion Unit* are:

- In order to optimize cell division, the bacteria must be grown under the proper conditions.
- In order for the cells to divide and the colony to grow, the DNA in each parent cell must be replicated and a copy given to each daughter cell.
- DNA is a double-stranded, anti-parallel molecule located in the bacterial cytoplasm that codes for genes.
- Genes are inherited from previous generations and transmit a characteristic.

- Genes can be turned on and off, depending on the environment, to produce gene products (proteins) that give rise to a characteristic.
- The cell uses DNA as the blueprint for the proteins that give rise to a characteristic or trait.
- To make protein, the cell transcribes a gene from the DNA into RNA and translates that RNA into the needed protein.
- Mutations are mistakes in the DNA sequence that result in an incorrect protein blueprint and a range of cellular effects.

Lesson Goal(s)

This section indicates the most important ideas, skills, etc., that students should take away from each lesson. The lesson goals related to the design of the prototype are distinguished from the lesson goals related to the underlying science concepts.

Assessing / Advancing Knowledge

This last section supplies a set of questions, strategies, and exercises to aid you in the process of getting students to reach the lesson goals and the big ideas. The key questions can be used for class discussions or they can be used in conversations with teams and/or individual students.

Student Activities

Students will experience a variety of activities within this unit. Below are features included to scaffold and assess student learning as they move through the unit.

Assessments

- **Pre-Unit Assessment:** This tool is used to understand the preconceptions that students have about genetics concepts.
- **Post-Unit Assessment:** This tool is used to assess student learning after completing the unit.
- **Formative Assessment:** Suggestion(s) of ways to assess students during each lesson.

Team Guides

The *Team Guide* serves as a lab notebook and includes most of the resources students will need to complete the unit. Each team should record their team name and the IDs of each member in *Team Guides*. The *Team Guides* will **not** leave the classroom, just as a lab notebook would not leave the laboratory.

The team guide is an effective way to assess student learning during group work. There are two major types of activities in the *Team Guide*. The design activities involve exercises geared toward prototype improvement. The *BUGs* (Biology to Understand Genetics investigations) focus on the science concepts behind the design.

Unit Features

Independent Work / Homework

There are three main types of independent work: readings, activities, and reflections. The student reflection is a critical part of learning. It allows students to think about what they have learned and how they will apply their knowledge to their design.

Case Profiles

There are several case profiles that students will read to situate design in a real world context. These articles provide examples of how one inventor was able think of a solution to a problem in his everyday life, how engineered products are far more common than students may realize, and how one woman overcame stereotypes to help design a life-saving medication.

Presentations

Presentations are a key part of the unit. They allow students to communicate their ideas and receive valuable feedback that informs their design. Also, these presentations provide an opportunity for teachers to probe students' reasoning through questions and justifications.

Mini-Symposia. The Mini-Symposia simulate a scientific or product presentation. Teams should prepare professional presentations and be prepared to respond to questions about their prototype and how it works. Teams that are not presenting should be encouraged to ask thoughtful questions about the prototype and the science behind the prototype.

Gallery Walk. A Gallery Walk simulates a science fair. Teams assign a person to act as the curator for their team. This person stays with that team's design and answers questions from other team members. Curators should change about half way through the Gallery Walk so that everyone has the opportunity to look at other projects. There are three goals for this activity. First, students explain and justify their designs. Second, teams receive feedback about their design. Third, students learn about other teams' designs.

Patent Application. An effective way for students to synthesize their knowledge at the end of this unit is through oral and written communication about their design. The patent application provides students the opportunity to practice authentic scientific writing.

Accountable Talk™ Moves

Functions Guide Sheet	
Marking	...direct attention to the value and importance of a student's contribution.
Challenging students	...redirect a question back to the students or use students' contributions as a source for a further challenge or query.
Modeling	...make one's thinking public and demonstrate expert forms of reasoning through talk.
Recapping	...make public in a concise, coherent form, the group's achievement at creating a shared understanding of the phenomenon under discussion.
Keeping the channels open	...ensure the students can hear each other, and remind them that they must hear what others have said.
Keeping everyone together	...ensure that everyone not only heard, but also understood, what a speaker said.
Linking contributions	...make explicit the relationship between a new contribution and what has gone before.
Verifying and clarifying	...revoice a student's contribution, thereby helping both speakers and listeners to engage more profitably in the conversation.
Pressing for accuracy	...hold students accountable for the accuracy, credibility, and clarity of their contributions.
Building on prior knowledge	...tie a current contribution back to knowledge accumulated by the class at a previous time.
Pressing for reasoning	...elicit evidence and to establish what contribution a student's utterance is intended to make within the group's larger enterprise.
Expanding reasoning	...open up extra time and space in the conversation for student reasoning.

Time Line Week 1

Lesson	Student Activities	Written Work / Presentations	D-S Cycle	Storyline
1	<ul style="list-style-type: none"> Pre-unit assessments Assign teams Students begin to consider their needs for glowing/colored bacteria Read about a modern use of genetically modified bacteria 	<ul style="list-style-type: none"> <i>HW1: Bacteria Can Save Your Teeth!</i> 	N/A	Prototype Design
2	<ul style="list-style-type: none"> Review a modern use of genetically modified bacteria to prevent tooth decay Discuss GM products Think about needs and new ideas for fluorescent / colored bacteria 	<ul style="list-style-type: none"> <i>Individual Needs and New Ideas</i> 	N/A	Prototype Design
3	<ul style="list-style-type: none"> Discuss system decomposition and Design - Science Cycle Brainstorm the physical features that the prototype must have to carry out the specific function (requirements) Begin preparing for <i>Mini-Symposium I</i> 	<ul style="list-style-type: none"> <i>Requirements</i> <i>Needs and New Ideas</i> <i>Mini-Symposium I</i> transparencies 	Create Design	Prototype Design
4	<ul style="list-style-type: none"> <i>Mini-Symposium I</i>: Present team prototype Modify prototype design based on comments 	<ul style="list-style-type: none"> <i>Mini-Symposium I</i> Revise <i>Requirements</i> 	Create Design	Prototype Design

Time Line Week 2

Lesson	Student Activities	Big Ideas	Written Work / Presentations	D-S Cycle	Storyline	
5	<ul style="list-style-type: none"> • Introduction to microbiology protocol • Discuss team roles • Practice dilution streak method on gelatin 	<ul style="list-style-type: none"> • To optimize cell division, the bacteria must be grown under the proper conditions. 		Create Design	Environment	
6	<ul style="list-style-type: none"> • Grow bacteria on different types of agar • Predict outcome 		• <i>Environment I</i>	Create Design	Environment	
7	<ul style="list-style-type: none"> • <i>Open Lab</i>: Observe plates and record results, share design outcome with the class • Generate reasons for design outcome • Develop ways to test reasons 		• <i>Environment I</i>	• <i>Open Lab</i>	Evaluate Outcome Generate Reasons	Environment
8	<ul style="list-style-type: none"> • Complete <i>BUGs I</i> experiments <ul style="list-style-type: none"> • Bigger cells vs. more cells • Continue incubation • Test for growth on different types of agar (identify nutrient in different types of agar) 		• <i>BUGs I: Cell Division</i>	Test Ideas	Environment	
9	<ul style="list-style-type: none"> • <i>Open Lab</i>: Observe plates and record results, share results with the class • Generalize results • Telling: Link cell division to generalized results • Read about how bacteria can produce lifesaving medical treatments 		• <i>BUGs I: Cell Division</i>	• <i>Open Lab</i>	Analyze Results Generalize Results Connect to Big idea	Environment

Time Line Week 3

Lesson	Student Activities	Big Ideas	Written Work / Presentations	D-S Cycle	Story-line
10	<ul style="list-style-type: none"> Introduction to Genes Subsystem Teams complete <i>Genes</i> investigations with predictions 		<ul style="list-style-type: none"> <i>Genes</i> 	Create Design	Genes
11	<ul style="list-style-type: none"> <i>Open Lab</i>: Observe plates and record results, share results with the class Generate reasons for design outcome Telling: <ul style="list-style-type: none"> Logical inferences to rule out 'untestable' ideas Discuss how new genes are inserted into bacteria on plasmids Jigsaw <i>BUGs II - Genes</i> investigations with predictions <ul style="list-style-type: none"> Glow stick Food coloring <i>Open Lab</i>: Share predictions 	<ul style="list-style-type: none"> DNA is a double-stranded, anti-parallel molecular structure located in the bacterial cytoplasm that codes for genes. Genes are inherited from previous generations and transmit a characteristic. 	<ul style="list-style-type: none"> <i>Genes</i> <i>BUGs II - Traits</i> 	Evaluate Outcome Generate Reasons Test Ideas	Genes
12 (2 days)	<ul style="list-style-type: none"> Introduction to transformation and plasmids Start bacteria transformation protocol (steps 1-5) Finish bacterial transformation protocol (steps 6-7) 		<ul style="list-style-type: none"> <i>BUGs III - Transformation</i> 	Test Ideas	Genes
13	<ul style="list-style-type: none"> <i>Open Lab</i>: Observe plates and record results, share results with the class Analyze results, and generalize results 		<ul style="list-style-type: none"> <i>BUGs III - Transformation</i> <i>Open Lab</i> 	Test Ideas Analyze Results Generalize Results	Genes
14	<ul style="list-style-type: none"> Purify transformants Jigsaw <i>BUGs IV - DNA</i> investigations <ul style="list-style-type: none"> DNA modeling 		<ul style="list-style-type: none"> <i>BUGs IV - DNA</i> 	Test Ideas Analyze Results Generalize Results	Genes
15 (2 days) Optional	<ul style="list-style-type: none"> Teams work through <i>BUGs V - Where is the DNA?</i> Investigations <ul style="list-style-type: none"> Wet Mounts Prokaryotes vs. Eukaryotes Recap observations, analyze results, and generalize results 		<ul style="list-style-type: none"> <i>BUGs V - Where's the DNA</i> 	Test Ideas Analyze Results Generalize Results	Genes
16	<ul style="list-style-type: none"> <i>BUGs VI - Replication</i> investigation Connect results from <i>BUGs II - VI</i> to big idea Think about progress and learning and how the science impacts the design prototype 		<ul style="list-style-type: none"> <i>BUGs VI - Replication</i> <i>What are Genes, Anyway?</i> <i>Reflection</i> 	Test Ideas Analyze Results Generalize Results Connect to Big Ideas	

Time Line Week 4

Lesson	Student Activities	Big Ideas	Written Work / Presentations	D-S Cycle	Storyline
17	<ul style="list-style-type: none"> Discuss how the science impacts the design <i>Open Lab</i>: Observe plates and record results, share design outcome with the class Generate reasons for the design outcome Develop ways to test reasons 	<ul style="list-style-type: none"> DNA is a double-stranded, anti-parallel molecular structure located in the bacterial cytoplasm that codes for genes. Genes can be turned on and off, depending on the environment, to produce gene products (proteins) that give rise to a characteristic. 	<ul style="list-style-type: none"> <i>Reflection</i> <i>Expression I</i> <i>Open Lab</i> 	Create Design Evaluate Outcome Generate Reasons	Expression
18	<ul style="list-style-type: none"> Jigsaw <i>BUGs V - Rescue</i> investigations <ul style="list-style-type: none"> Culture old colonies under ideal conditions Culture old colonies on enhanced agar <i>Open Lab</i>: Share predictions 		<ul style="list-style-type: none"> <i>BUGs VII - Rescue</i> <i>Open Lab</i> 	Test Ideas	
19	<ul style="list-style-type: none"> <i>Open Lab</i>: Observe plates and record results, share results with the class Generalize results, link to big ideas Telling: Link basic gene expression to the generalized experimental results Reflect on how the science impacts the design 		<ul style="list-style-type: none"> <i>BUGs VII - Rescue</i> <i>What is Expression, Anyway?</i> <i>Reflection</i> 	Analyze Results Generalize Results Connect to Big Ideas	
20	<ul style="list-style-type: none"> Read and discuss questions for <i>What is the Central Dogma, Anyway?</i> Complete <i>BUGs VIII - Decoding I</i> investigation 	<ul style="list-style-type: none"> The cell uses DNA as the blueprint for the proteins that give rise to a trait or characteristic. To make protein the cell transcribes a gene from the DNA into RNA and translates that RNA into the needed proteins. Mutations are mistakes in the DNA sequence that result in an incorrect protein and a range of cellular effects. 	<ul style="list-style-type: none"> <i>BUGs VIII - Decoding I</i> 	Create Design Evaluate Outcome	Expression Encore
21	<ul style="list-style-type: none"> Complete <i>BUGs IX - Decoding II</i> Read and discuss <i>Types of Mutations</i> 		<ul style="list-style-type: none"> <i>BUGs IX - Decoding II</i> <i>Types of Mutations</i> 	Create Design Evaluate Outcome Generate Reasons	
22	<ul style="list-style-type: none"> Complete <i>BUGs X - Enhancement</i> Teams present and summarize their <i>BUGs X - Enhancement</i> results Discuss how the enhancement investigation relates to the central dogma 		<ul style="list-style-type: none"> <i>BUGs X - Enhancement</i> 	Test Ideas Analyze Results Generalize Results Connect to Big Ideas	
23	<ul style="list-style-type: none"> Prepare for <i>Mini-Symposium II</i> Prepare quiz questions 		<ul style="list-style-type: none"> <i>Mini-Symposium II</i> transparencies 	Connect to Big Ideas	
24	<ul style="list-style-type: none"> <i>Mini-Symposium II</i>: Present team prototype Respond to quiz questions from teacher and peers Rate other teams' responses to quiz questions 		Create Design		

Time Line Week 5

Lesson	Student Activities	Big Ideas	Written Work / Presentations	D-S Cycle	Storyline
25	<ul style="list-style-type: none"> Culture bacteria under 'real-world' conditions <i>Open Lab</i>: share predictions 	<ul style="list-style-type: none"> To optimize cell division, the bacteria must be grown under the proper conditions. 	<ul style="list-style-type: none"> <i>Environment II</i> <i>Open Lab</i> 	Create Design	Environment Encore
26	<ul style="list-style-type: none"> <i>Open Lab</i>: Observe plates and record results, share design outcome with the class Generate reasons for design outcome Develop ways to test reasons 		<ul style="list-style-type: none"> <i>Environment II</i> <i>Open Lab</i> 	Evaluate Outcome Generate Reasons	
27	<ul style="list-style-type: none"> Jigsaw <i>BUGs XI - Real-World</i> investigations <ul style="list-style-type: none"> Test for growth when using more nutrients Test for growth when using insulation Test for growth after continued incubation Test for growth when using protective packaging <i>Open Lab</i>: Share predictions 	<ul style="list-style-type: none"> In order for the cells to divide and the colony to grow, the DNA in each parent cell must be replicated and a copy given to each daughter cell. Mutations are mistakes in the DNA sequence that result in an incorrect protein and a range of cellular effects. 	<ul style="list-style-type: none"> <i>BUGs XI - Real-World</i> <i>Open Lab</i> 	Test Ideas	
28	<ul style="list-style-type: none"> <i>Open Lab</i>: Observe plates and record results, share results with the class Generalize results, link to big ideas 		<ul style="list-style-type: none"> <i>BUGs XI - Real-World</i> <i>Open Lab</i> <i>How Do Genes and Environment Interact, Anyway?</i> 	Analyze Results Generalize Results Connect to Big Ideas	
29 (Multiple Days)	<ul style="list-style-type: none"> Preparation of presentations presentations <i>Patent Application</i> <i>Gallery Walk</i> 	<ul style="list-style-type: none"> Students should incorporate the Big Idea(s) of this unit into their presentations and patent applications. 	<ul style="list-style-type: none"> <i>Patent Application</i> <i>Gallery Walk</i> <i>Gallery Walk Evaluation</i> 	Create Design	

DESIGNER BACTERIA



LESSON PLANS

PROTOTYPE DESIGN AND LESSON FLOW

Lesson Flow

Allow 1-1 1/2 days for lessons 2-3

Lesson 1: Pre-unit assessments and Introduction to Unit

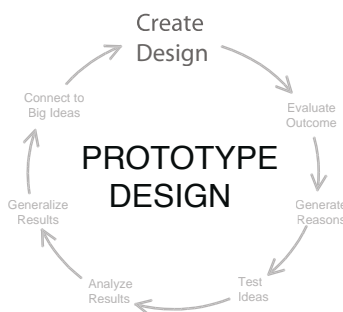
Lesson 2: Discussion of Needs and Genetic Modification (GM)

Lesson 3: Introduce Design-Science Cycle and Development of Requirements

Lesson 4: Presentation of Prototype Design

Lesson	Student Activities	Written Work / Presentations	D-S Cycle	Storyline
1	<ul style="list-style-type: none"> Pre-unit assessments Assign teams Students begin to consider their needs for glowing/colored bacteria Read about a modern use of genetically modified bacteria 	<ul style="list-style-type: none"> <i>HW1: Bacteria Can Save Your Teeth!</i> 	N/A	Prototype Design
2	<ul style="list-style-type: none"> Review a modern use of genetically modified bacteria to prevent tooth decay Discuss GM products Think about needs and new ideas for fluorescent / colored bacteria 	<ul style="list-style-type: none"> <i>Individual Needs and New Ideas</i> 	N/A	Prototype Design
3	<ul style="list-style-type: none"> Discuss system decomposition and Design - Science Cycle Brainstorm the physical features that the prototype must have to carry out the specific function (requirements) Begin preparing for <i>Mini-Symposium I</i> 	<ul style="list-style-type: none"> <i>Requirements</i> <i>Needs and New Ideas</i> <i>Mini-Symposium I</i> transparencies 	Create Design	Prototype Design
4	<ul style="list-style-type: none"> <i>Mini-Symposium I</i>: Present team prototype Modify prototype design based on comments 	<ul style="list-style-type: none"> <i>Mini-Symposium I</i> Revise <i>Requirements</i> 	Create Design	Prototype Design

Lesson 1: Pre-Unit Assessment and Introduction



Overview

Lesson Goal(s)

Design

Students should start thinking about their needs for glowing / colored bacteria.

Materials

- Pre-unit assessments (1/student)
- *Team Guide* (1/team):
 - *Introduction* (p. 1-2)
- HW1: *Bacteria Can Save Your Teeth!* (1/student)

Naive Conceptions

Most students mistakenly believe that . . .

- Good solutions are created on the first try and need no further improvements
- Bacteria are 'bad'
- Some students may have beliefs about GM that are very positive or very negative

Implementing This Lesson

Lesson Objectives

- Introduction to the Designer Bacteria unit
- Students will complete a pre-unit assessment, form teams, and gain experience with genetically modified products

Background Information

Technological systems form the basis for our survival on Earth. For thousands of years people have designed systems to meet needs and solve problems.

One's own experiences and thinking are the basis for designing systems that create new solutions for existing problems.

Logistics

Team formation is at your discretion and should not require much time. Team members may be assigned the roles below. These roles could rotate every few lessons. **Do not spend time explaining these roles during this lesson.** The roles can be discussed more during lesson 5

Lead Biologist: supervises team work, leads the procedures (conducts the experiment and receives assistance from the General Biologist as needed), and keeps other members on task

Analytical Biologist: collects the *Team Guide*, records the procedures, and completes the *Team Guide* based on team work

General Biologist: obtains all necessary supplies for the investigations, and assists the Lead Biologist in investigations as needed

Quality Assurance Biologist: makes sure the lab space is clean both before and after lab investigations, and rates each team member's performance for that activity on a scale of 1-5 (0-absent, 1-poor, 2-fair, 3-good, 4-excellent, 5-superior)

You may find it useful to consider student academic level and language if you decide to assign teams. For instance, you may want to team a strong Spanish speaking student with an English only student and a student who is equally comfortable with both languages. Prior studies show this grouping provides the students with an opportunity learn about a different language and culture in addition to the content of the unit.

Student Activities

- Complete the pre-unit assessments
- Read and discuss *Introduction* (p. 1-2)
- INDIVIDUAL HOMEWORK: *Bacteria can save your teeth!* (p. 3)

Teacher Activities

- Introduce unit and concept of design-based science
- Discuss team formation and assessments
- Discuss p. 4-5 of team guides after students read independently
- Brainstorming Activity: Ask the **Key Design Question** and chart class discussion on a transparency or whiteboard

When you complete your journal entry, consider the following questions

- Is the timing appropriate? Were you able to complete the lesson in one class period?
- What were the students' reactions to the lesson? Were any components boring or too difficult for the students?
- Is there any additional information that you would have liked for us to provide to you during this lesson?
- What could you do next time to make this lesson more successful?
- What are your general comments?

Assessing / Advancing Knowledge

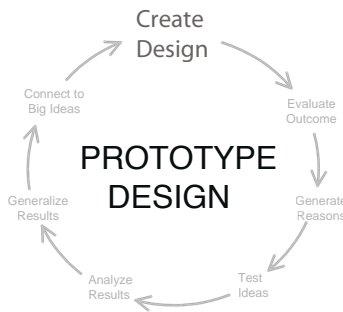
Key Design Question(s)

What needs do you have for a fluorescent / pigmentation system?

RESPONSE: Students should be encouraged to explore a variety of needs and remember, there are no 'bad' ideas.

Journal Space

Lesson 2: Determining Needs



Overview

Lesson Goal(s)

Design

Students should realize that genetic modifications can be used to solve many different problems and can be found in everyday life.

Science

Students should realize that not all bacteria are 'bad'.

Materials

- Team Guide:
 - *Bacteria Can Save Your Teeth!* (p. 3)
 - *Genetically Modified Products* (p. 4-5)
 - *Needs and New Ideas* (p. 6)
- *Individual Needs and New Ideas* handouts (1/student)

Naive Conceptions

Most students mistakenly believe that ...

- Some students may have difficulty thinking about needs and developing their prototype ideas
- Students may have difficulty determining what is required for their system to work and defining these requirements in a way that they can test during their prototype development
- Good solutions are created on the first try and need no further improvements
- Some students may have beliefs about GM that are very positive or very negative

Implementing This Lesson

Lesson Objectives

- Students will think of ways fluorescent / pigmented bacteria can be used to meet everyday needs in their lives
- Students will discuss needs and new ideas in their teams. During this discussion, the teams should determine which prototype idea they want to develop
- Students will be able to define and provide examples of genetically modified (GM) organisms

Background Information

A **need** refers to a problem that may be solved by engineering or a function that an object serves.

A **new idea** is a novel way to meet a need by modifying an existing design or creating a new design.

Logistics

Some resources about GM products that you might find useful:

- www.bt.ucsd.edu/overview.html
- www.oragenics.com
- www.ornl.gov/sci/techresources/Human_Genome/home.shtml
- http://en.wikipedia.org/wiki/Genetically_modified_food (there are good links off this site)
- <http://www.newscientist.com/channel/life/gm-food/dn9921>

Student Activities

- Review *HW1 - Bacteria Can Save Your Teeth!* [10 minutes]
- Read, Answer Questions, and Discuss *Genetically Modified Products* (p. 4-5)
- **INDEPENDENT TASK:** Think about needs and new ideas for bacteria that fluoresce or are pigmented blue

Teacher Activities

- Facilitate discussion of *HW1: Bacteria can save your teeth!* (question 5) and *Genetically Modified Products* worksheet (questions 1-4)
- Observe team discussions about needs and prototype discussion. Keep students thinking about real needs they have everyday

When you complete your journal entry, consider the following questions

- Is the timing appropriate? Were you able to complete the lesson in one class period?
- What were the students' reactions to the lesson? Were any components boring or too difficult for the students?
- Is there any additional information that you would have liked for us to provide to you during this lesson?
- What could you do next time to make this lesson more successful?
- What are your general comments?

Assessing / Advancing Knowledge

Key Design Question(s)

How have genetically modified products been useful for meeting societal needs?

RESPONSE: Based on the materials in their text, other resources that you provide, and their own experiences, students should give examples, with evidence, of how genetic modifications can meet societal needs.

How might you use genetically modified products to improve your life?

RESPONSE: Based on the materials in their text, other resources that you provide, and their own experiences, students should give examples, with evidence, of how genetic modifications can improve their own lives.

Reflect on the ideas you brainstormed yesterday as needs for fluorescent/pigmented bacteria. What new problems can you think of that would be solved with fluorescent / pigmented bacteria?

RESPONSE: Students should be encouraged to explore a variety of problems and remember, there are no 'bad' ideas.

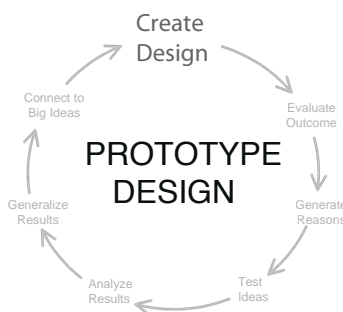
Key Science Question(s)

How did Dr. Hillman develop genetically modified bacteria to solve a dental problem?

RESPONSE: Through genetic modification, he changed the bacteria's virulence and ability to colonize the human mouth.

Journal Space

Lesson 3: Determining Functions and Requirements



Overview

Lesson Goal(s)

Design

Students should see design as a process and be able to state their design idea in logical way.

Materials

- Team Guide:
 - *Requirements* (p. 8)
 - *Design - Science Cycle* (p. 9)
 - *System Decomposition* (p. 10)
- *Mini-Symposium I* transparencies for team presentations (1/team)
- Transparency markers for team presentations (1/team)

Naive Conceptions

Most students mistakenly believe that ...

- Some students may have difficulty thinking about needs and developing their prototype ideas
- Students may have difficulty determining what is required for their system to work and defining these requirements in a way that they can test during their prototype development
- Good solutions are created on the first try and need no further improvements

Implementing This Lesson

Lesson Objectives

- Students will discuss the requirements for their prototype and prepare to give team presentations tomorrow

Background Information

System Decomposition in Prototype Design

The Wright Brothers used the strategy of breaking down a design to better understand how each component functions. Instead of trying to build an entire airplane all at once, they decided that there were three main problems they had to solve: (a) lift, (b) thrust, and (c) stability and control.

They tackled the problem of lift by designing and testing different wing configurations. Different propeller combinations were tested to solve the problem of thrust. Wing warping and movable control surfaces were tested to solve the problems of stability and control.

By designing and testing each of these components separately, and then putting them all together into one prototype, the Wright Brothers were the first to solve the challenge of flight!

Today, genetic engineers like Dr. Jeffrey Hillman break down their prototypes into subsystems, too.

Student Activities

- **CLASS DISCUSSION:** Discussion of subsystems and design-science cycle
- Teams develop prototype requirements
- Teams begin preparing their transparency for *Mini-Symposium I* if time permits

Teacher Activities

- Introduce *System Decomposition* (p. 7) and the *Design-Science Cycle* (p. 9)
- Observe teams as they develop their prototype requirements (p. 8). Make sure students are thinking about what is necessary to make the prototype work
- If time permits, allow teams to begin working on their transparency for *Mini-Symposium I*. **Make the short informal nature of the presentations explicit to the students**

When you complete your journal entry, consider the following questions

- Is the timing appropriate? Were you able to complete the lesson in one class period?
- What were the students' reactions to the lesson? Were any components boring or too difficult for the students?
- Is there any additional information that you would have liked for us to provide to you during this lesson?
- What could you do next time to make this lesson more successful?
- What are your general comments?

Assessing / Advancing Knowledge

Key Design Question(s)

What do you want your bacteria to be able to do?

RESPONSE: Students should be encouraged to clarify the function of their bacteria. All functions are valid, but need to be described clearly.

What is the function of each of the subsystems?

RESPONSE: Students should be encouraged to clarify the function of each subsystem. All functions are valid, but need to be described clearly.

Why are subsystems useful when designing a prototype?

RESPONSE: Subsystems allow the project to be broken apart so one issue can be solved at a time.

What requirements **must** your bacteria have to function properly?

RESPONSE: Students should be encouraged to clarify the requirements for their bacteria. All requirements are valid, but need to be described clearly.

What requirements are only **nice-to-have**?

RESPONSE: All requirements are valid but students need to distinguish what requirements are only nice-to-have vs. those requirements they must have to create a functional prototype.

Use these questions to guide students in their preparations for their presentations tomorrow.

What would an ideal outcome of your design look like?

What is the final goal for the design?

How would the ideal design work?

RESPONSE: Students should be encouraged to clarify how their design will work. All ideas are valid, but need to be described clearly.

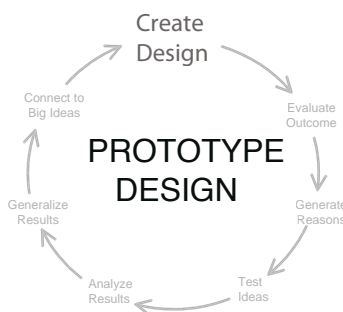
Key Science Question(s)

What do you think your bacteria require to do what you want them to do?

RESPONSE: Use this question to assess ideas and conceptions that students may have about bacteria, genes, and gene expression. All ideas are valid, but need to be described clearly. Do not correct naive conceptions at this point.

Journal Space

Lesson 4: Team Prototype Presentations



Overview

Lesson Goal(s)

Design

While creating their design, students should be able to explain the role culturing bacteria plays in designing their prototype.

Science

Students should realize that there are many varieties of bacteria that have (express) different characteristics.

Student Activities

- **MINI-SYMPOSIUM:** Informal short team presentations of prototype idea [30 minutes]
- Modify prototype design based on teacher's and peers' comments

Materials

- Team Guide:
 - *Requirements* (p. 8)
- *Mini-Symposium I* transparencies for team presentations
- Transparency markers (1/team)
- Overhead projector

Implementing This Lesson

CAUTION: TIME MANAGEMENT!!

Experimental preparations for Lesson 5 must be completed today!

Lesson Objectives

- Students will give short team presentations of their prototype

Logistics

Presentations

Depending on how many teams are in your classrooms, make sure that these presentations are short and informal so that they fit into one class period.

During each presentation, one team member should record questions that were asked so the team can consider them when revising their prototype.

Push the students' understanding of their prototypes' requirements. By this point all teams should have requirements that specify the following:

- Color
- Length of incubation
- Time for trait expression
- Appropriate environmental conditions

Experimental Preparation

For tomorrow, you will need to prepare gelatin plates for students to practice the dilution streak method.

- Gelatin plate recipe
 - Mix each packet with 1 cup hot water
 - Once dissolved, add 1/2 cup cold water
 - Pour into empty Petri dishes
 - Cover and refrigerate overnight

Student Activities

- *Mini-symposium I:* Presentations of prototypes using transparency

Teacher Activities

- Observe teams as they prepare for *Mini-symposium I*. Make sure students are thinking about what is necessary to make the prototype work.
- Evaluate presentations of prototypes based on team needs and requirements.

Overview (continued.)**Naive Conceptions**

Most students mistakenly believe that ...

- Some students may have difficulty thinking about needs and developing their prototype ideas.
- Students may have difficulty determining what is required for their system to work and defining these requirements in a way that they can test during their prototype development.
- Good solutions are created on the first try and need no further improvements.

Assessing / Advancing Knowledge**Key Design Question(s)**

What do you want your bacteria to be able to do?

RESPONSE: Students should be encouraged to clarify the function of their bacteria. All functions are valid, but need to be described clearly.

What is the function of each of the subsystems?

RESPONSE: Students should be encouraged to clarify the function of each subsystem. All functions are valid, but need to be described clearly.

How do the subsystems work together to perform that function?

RESPONSE: All functions are valid, but need to be described clearly.

How is a prototype need different from a requirement?

RESPONSE: Needs are the problems that are to be solved with the prototype. Requirements are objects/ processes that need to happen for the prototype to work.

What requirements must your bacteria have to function properly?

RESPONSE: Students should be encouraged to clarify the requirements for their bacteria. Students should specify how long and how bright their bacteria should fluoresce. All requirements are valid, but need to be described clearly.

What requirements are only nice to have?

RESPONSE: Students should specify how long and how bright their bacteria should fluoresce. All requirements are valid, but students need to distinguish what requirements are only nice-to-have vs. those requirements they must have to create a functional prototype.

What would an ideal outcome of your design look like? What is the final goal for the design? How would the ideal design work?

RESPONSE: Students should be encouraged to clarify how their design will work. Students should specify how long and how bright their bacteria should fluoresce. All ideas are valid, but need to be described clearly.

What changes can you make to your prototype based on feedback you received from your classmates?

RESPONSE: Students should be encouraged to make modifications to their prototype based on teacher and peer feedback.

What are some key steps to get you from where you are now to where you want to be with your design?

RESPONSE: Students should be encouraged to think about how they will create their prototype. All ideas are valid, but need to be described clearly.

Journal Space

ENVIRONMENT SUBSYSTEM

Lesson Flow

Lesson 5: Learn Basic Aseptic Techniques

Lesson 6: Create Design Based on Environmental Variables

Lesson 7: Evaluate Outcomes and Discussion of Reason for Those Outcomes

Lesson 8: Test Ideas About Environmental Variables and Microscopy of Bacteria

Lesson 9: Analyze and Generalize Results and Connect to the Big Idea of the Environment Subsystem

Key Reminders

Students are not familiar with this type of learning. Remind them that frustration, uncertainty, and lack of knowledge is allowed and expected.

Recommended Extensions

Bacterial Shapes

- Post bacterial microscopy lesson

Metacognition

- Explain the purpose of team roles and the design-science cycle if teams are struggling

Literature Review Topics

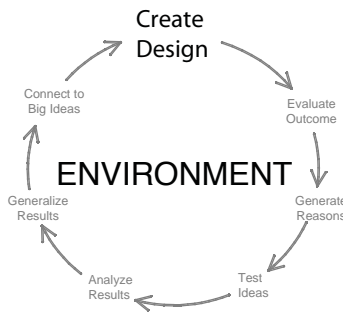
Set a number of articles, outside sources, product comparison, etc. to be read and summarized by each group member by the end of the subsystem (1 - 2 per person)

Suggested Topics:

- Agar and bacterial growth media
- Bacterial growth conditions
- Microbiological techniques
- Cell division
- Multicellular, colonial, and single-celled organisms

Lesson	Student Activities	Big Ideas	Written Work / Presentations	D-S Cycle	Storyline
5	<ul style="list-style-type: none"> Introduction to microbiology protocol Discuss team roles Practice dilution streak method on gelatin 	<ul style="list-style-type: none"> To optimize cell division, the bacteria must be grown under the proper conditions. 		Create Design	Environment
6	<ul style="list-style-type: none"> Grow bacteria on different types of agar Predict outcome 		<ul style="list-style-type: none"> <i>Environment I</i> 	Create Design	Environment
7	<ul style="list-style-type: none"> <i>Open Lab</i>: Observe plates and record results, share design outcome with the class Generate reasons for design outcome Develop ways to test reasons 		<ul style="list-style-type: none"> <i>Environment I</i> <i>Open Lab</i> 	Evaluate Outcome Generate Reasons	Environment
8	<ul style="list-style-type: none"> Complete <i>BUGs I</i> experiments <ul style="list-style-type: none"> Bigger cells vs. more cells Continue incubation Test for growth on different types of agar (identify nutrient in different types of agar) 		<ul style="list-style-type: none"> <i>BUGs I: Cell Division</i> 	Test Ideas	Environment
9	<ul style="list-style-type: none"> <i>Open Lab</i>: Observe plates and record results, share results with the class Generalize results Telling: Link cell division to generalized results Read about how bacteria can produce lifesaving medical treatments 		<ul style="list-style-type: none"> <i>BUGs I: Cell Division</i> <i>Open Lab</i> <i>Exponential Growth</i> <i>HW2: Bugs Produce Drugs!</i> 	Analyze Results Generalize Results Connect to Big idea	Environment

Lesson 5: Investigating Environmental Effects Part I



Overview

Big Idea(s)

To optimize cell division, the bacteria must be grown under the proper conditions.

Lesson Goal(s)

Design

While creating their design, students should be able to explain the role culturing bacteria plays in designing their prototype.

Materials

- Team Guide:
 - *Aseptic Technique* (p. 10)
 - *Dilution Streak Method* (p. 11)
- *Team Role Rotation* handouts (1 per team)
- Gelatin plates
- Sterile toothpicks (1 pack/team)

Naive Conceptions

Most students mistakenly believe that ...

- Bacteria are 'bad'
- Bacterial cells are like human cells.
- Initial failures indicate that the solution is not appropriate.
- Failure means nothing was / can be learned.

Implementing This Lesson

Lesson Objectives

- Students will discuss basic microbiology procedures including aseptic technique and practice dilution streaking using gelatin plates

Logistics

This is the students' first hands-on experience with the biology lab equipment. This lesson would be a good time to remind the students of their team roles and to explain how the role rotation will work.

Team roles are important for the proper implementation of this unit. Lesson 6 or Lesson 7 should be the first day students are using their team roles. Be sure that students are held accountable for their respective role responsibilities.

Lead Biologist: supervises team work, leads the procedures (conducts the experiment and receives assistance from the General Biologist as needed), and keeps other members on task

Analytical Biologist: collects the *Team Guide*, records the procedures, and completes the *Team Guide* based on team work

General Biologist: obtains all necessary supplies for the investigations, and assists the Lead Biologist in investigations as needed

Quality Assurance Biologist: makes sure the lab space is clean both before and after lab investigations, and rates each team member's performance for that activity on a scale of 1-5 (0-absent, 1-poor, 2-fair, 3-good, 4-excellent, 5-superior)



Biohazard Waste Container

Beakers of 10% bleach solution should be placed at each work station. At the end of the class, teams should dump the contents of their beakers into one of the large plastic buckets placed throughout the classroom. Discourage students from walking around the classroom with contaminated materials. (*Disposal of Contaminated Material*, Appendix p. 86)

Student Activities

- Read *Aseptic Technique* and *Dilution Streak Method* (p. 10 and 11)
- Observe demonstration of aseptic technique and dilution streak by teacher
- Practice aseptic technique and dilution streak method on gelatin plates

Teacher Activities

- CLASS DISCUSSION: Q&A on vocabulary, techniques, and equipment
- Observe and inquire about aseptic technique as teams practice the dilution streak method

Assessing / Advancing Knowledge

Formative Assessment

- An optional vocabulary quiz may be administered

When you complete your journal entry, consider the following questions

- Is the timing appropriate? Were you able to complete the lesson in one class period?
- What were the students' reactions to the lesson? Were any components boring or too difficult for the students?
- Is there any additional information that you would have liked for us to provide to you during this lesson?
- What could you do next time to make this lesson more successful?
- What are your general comments?

Key Design Question(s)

How will the techniques you learned today help with your design?

RESPONSE: Students should be encouraged to think about how these techniques promote bacterial growth without contamination resulting in a pure culture of bacteria to test.

Key Science Question(s)

Why is sterile technique so important?

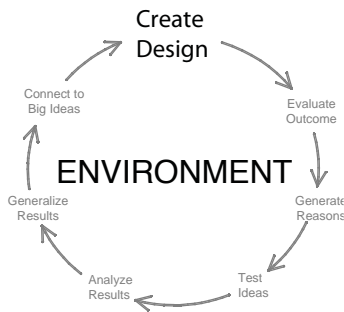
RESPONSE: To prevent contamination.

What is the purpose of the dilution streak method?

RESPONSE: The dilution streak method results in isolation of individual colonies, resulting in a purer culture of bacteria to test

Journal Space

Lesson 6: Investigating Environmental Effects Part II



Overview

Big Idea(s)

To optimize cell division, the bacteria must be grown under the proper conditions.

Lesson Goal(s)

Design

While creating their design, students should be able to explain the role culturing bacteria plays in designing their prototype.

Materials

- Team Guide:
 - *Dilution Streak Method* (p. 11)
 - *Environment I* (p. 12)
- *E. coli* DH5 and XL1 (1 colony/team)
- Agar plates: LB, LB/Amp, potato dextrose, nutrient, malt extract (any 1 plate/team)
- Sterile toothpicks (1 pack/team)
- 10% bleach spray bottle (3/ classroom)
- Biohazard waste container (1/team)
- 37° C incubator
- Gloves (2 pairs/team)
- Sharpies

Implementing This Lesson

Lesson Objective

- Students will explore the conditions needed for bacterial growth

Background Information

Basic Microbiology

E. coli grows best on LB (Luria Broth) or nutrient agar. The students will be given the option of choosing what type of media they will use to culture their bacteria. Some failure is built into this exercise because some of the agar will be fungi- or yeast-specific and will not support *E. coli*. The students will realize that different organisms require different types of nutrients.

Logistics

Colony Distribution

The students will select individual colonies from the starter plates that were prepared in advance. They can choose one colonies from DH5 or XL1. Instruct students to touch a colony with their toothpick. **Students should NOT scrape the culture.** If students scrape the bacterial cultures, then there will not be enough bacteria for all of the teams.

Instruct students to record the strain of bacteria that they used.

You might want to assign one student to act as your assistant. This assistant can bring the two starter plates around to each team, distributing the bacteria. The help of this assistant will make it possible for you to answer questions from other teams.



Biohazard Waste Container

Beakers of 10% bleach solution should be placed at each work station. At the end of the class, teams should dump the contents of their beakers into one of the large plastic buckets placed throughout the classroom. Discourage students from walking around the classroom with contaminated materials.

Student Activities

- Teams design an experiment to optimize bacterial growth based on their prototype requirements
 - Select an agar, inoculate, incubate overnight
- Complete *Environment I* (p. 12)

Teacher Activities

- Introduce available material space
 - Temperature
 - Agars (Nutrient, Potato Dextrose, Malt Extract, LB, LB/Amp)
 - *E. coli* Strains (DH5, XL1)
- Explain *Environment I* format and expected responses
- Observe and question teams as they perform the *Environment I* lab

Overview (continued.)**Naive Conceptions**

Most students mistakenly believe that ...

- Initial failures indicate that the solution is not appropriate
- Failure means nothing was / can be learned
- Bacteria are 'bad'
- Bacterial cells are like human cells
- Bacteria can grow anywhere
- All lab data is precise and accurate

Assessing / Advancing Knowledge**Formative Assessment**

- Collect and assess *Environment I* (p. 12)
- **CLASS DISCUSSION:** Teams present *Environment I* answers to class
- **HW:** Copy *Environment I* and send home with students. Have students rank each completed *Environment I* form and discuss during next lesson.

Key Design Question(s)

How will understanding the variables in the *Environment I* lab, help you to create your prototype?

RESPONSE: Students should be encouraged to think about what bacteria need to grow. Optimized growth conditions result in faster bacterial growth.

Key Science Question(s)

What type of agar do you think is best to grow bacteria on? Why?

RESPONSE: Students will have to guess which agar is best. All ideas are valid but need to be justified. Students should be reminded that it is okay to guess today, because tomorrow they will see the results and will find out which agar is best for their prototype.

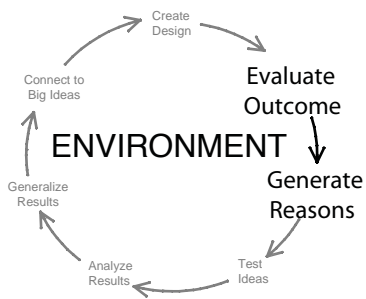
What do bacteria need to live?

RESPONSE: Use this question to assess ideas and conceptions that students may have about bacteria. All ideas are valid. Do not correct naive conceptions at this point.

What do you think you will see on your agar tomorrow?

RESPONSE: Students should clarify their predictions. All ideas are valid but need to be justified. Students should be reminded that it is okay to guess today. When they will see the results, they will find out which agar is best for their prototype in future lessons.

Lesson 7 : Investigating Environmental Effects Part III



Overview

Big Idea(s)

To optimize cell division, the bacteria must be grown under the proper conditions.

Lesson Goal(s)

Design

Students should be able to logically evaluate their plates from the previous lesson and generate plausible reasons for the outcomes.

Materials

- Team Guide:
 - *Environment I* (p. 12-13)
- *Generate Reasons Table* transparency (1/class)
- Overhead projector
- Plates from previous lesson
- ~5° C Refrigerator (1/school)
- 10% bleach spray bottle (3/ classroom)

Naive Conceptions

Most students mistakenly believe that ...

- Good solutions are created on the first try and need no further improvements
- Initial failures indicate that the solution is not appropriate
- Failure means nothing was / can be learned
- We cannot see bacteria without a microscope
- Bacteria can grow well anywhere

Implementing This Lesson

Lesson Objective

- Students will evaluate whether they were successful at getting bacteria to grow and they will generate reasons for why they were or were not successful

Logistics

Team sharing of results can be done from their desks or lab stations. **The *Open Lab* is a VERY quick report by each team about their design outcome.**

One option for this lesson would be in the form of a lab walk where one team member could stay with the plates to answer any questions and the rest of the team could walk around to look at the plates from other teams.

Generate Reasons Discussion

Use one of the *Generate Reasons Table* transparencies to help facilitate this discussion. As teams share their design outcomes, they can be recorded in this table under the appropriate column. This format should help your students see the patterns of outcomes across teams.

Student Activities

- OPEN LAB: Teams observe plates, record design outcomes, and share design outcomes with class
- CLASS DISCUSSION: Generate reasons for design outcomes and develop ways to test ideas
- Examples can be found in *Student Reasons and Investigations* (Appendix, p. 89)
- Teams complete *Environment I* (p. 12 and 13)

Teacher Activities

- Observe and questions teams during the Open Lab. Guide students to think about why their initial prototype design was a success or a failure and how they could test their reason for their success or failure.
- Lead class and chart team responses for *Generate Reasons Discussion*.

When you complete your journal entry, consider the following questions

- Is the timing appropriate? Were you able to complete the lesson in one class period?
- What were the students' reactions to the lesson? Were any components boring or too difficult for the students?
- Is there any additional information that you would have liked for us to provide to you during this lesson?
- What could you do next time to make this lesson more successful?
- What are your general comments?

Assessing / Advancing Knowledge

Formative Assessment

- Collect and assess *Envrionment I* (p. 12 - 13)
- CLASS DISCUSSION: Teams present *Envrionment I* answers to class
- HW: Copy *Envrionment I* and send home with students. Have students rank each completed *Envrionment I* form and discuss during next lesson.

Key Design Question(s)

What features are required for the design to work?

RESPONSE: Students should be encouraged to clarify the requirements for their bacteria. Students should specify how long and how bright their bacteria should luminesce. All requirements are valid, but need to be described clearly.

Key Science Question(s)

What type of agar do you think is best to grow bacteria? Why?

RESPONSE: Students should justify their response with data. Students may guess that there is something that has helped the bacteria to grow. Students should be encouraged to think about the 'something' as nutrients. Once students see that the agar has nutrients, discuss what nutrients are in each type of agar.

What do bacteria need to grow? How do we know that bacteria are growing?

RESPONSE: Use these questions to assess ideas and conceptions that students may have about bacteria. All ideas are valid. Do not correct naive conceptions at this point.

What happens to bacterial cells when colonies get larger? How can we test this idea?

RESPONSE: Use these questions to assess ideas and conceptions that students may have about bacteria. All ideas are valid. Do not correct naive conceptions at this point.

How do we know that bacteria are growing?

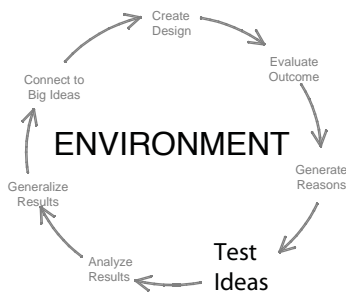
RESPONSE: Use these questions to assess ideas and conceptions that students may have about bacteria. All ideas are valid. Do not correct naive conceptions at this point.

What are experimental controls? Why is it so important to have controls in an experiment?

RESPONSE: Depending on students' prior experiences, these questions could be used to assess ideas and conceptions about the scientific method. Encourage students to see that controls are needed in experiments so that results can be trusted.

Journal Space

Lesson 8: Testing Environmental Variables



Overview

Big Idea(s)

To optimize cell division, the bacteria must be grown under the proper conditions.

Lesson Goal(s)

Design

Students will test how their ideas might be responsible for the outcomes witnessed in the previous lesson.

Science

By conducting these tests, students should be able to explain that bacterial colonies grow as the number of similar cells multiply.

Materials

- Team Guide:
 - *BUGs I - Cell Division* (p. 14 - 15)
- *BUGs I - Cell Division Procedures* handouts (1/student)
- Pipettes
- Microscope slides/cover slips (1 sets/team)
- Compound light microscopes
- Methylene blue stain
- Sterile toothpicks (1 pack/team)
- 10% bleach spray bottle (3/ classroom)
- Biohazard waste container (1/team)
- 37° C incubator (1/classroom)
- Agar plates: LB, potato dextrose, nutrient, malt extract (any 2 plates/ team)

Implementing This Lesson

CAUTION: TIME MANAGEMENT!!

Lesson Objectives

- Students will test the conditions needed to optimize bacterial growth
- Students will observe bacteria under the microscope

Logistics

Because of the time needed to conduct these experiments, *all* teams cannot complete *all* BUG investigations. Thus, you need to implement a jigsaw method of tackling all of the appropriate tests that the students designed.

Each team will have someone perform investigation (a.) and share their results and slide with the class.

Make sure the students realize that colonies grow in size because the cells are reproducing by simple cell division or binary fission.

Bacterial colonies for re-plating can be obtained from fellow classmates or from the original starter plate. Students should record the source of their new culture and justify why they chose that source. **There are no right or wrong answers.**

To facilitate time management, you might want to give students specific roles for today's activities.

- Lead Biologist - Wet mount
- Quality Assurance Biologist - Assist lead biologist with wet mount
- General Biologist - Streak second agar plate
- Analytical Biologist - Complete *BUGs I - Cell Division* in Team Guide



Biohazard Waste Container

Beakers of 10% bleach solution should be placed at each work station. At the end of the class, teams should dump the contents of their beakers into one of the large plastic buckets placed throughout the classroom. Discourage students from walking around the classroom with contaminated materials.

Student Activities

- BUGs: Jigsaw *BUGs I - Cell Division* experiments
 - All teams make a microscope slide of a colony and examine it under a light microscope to determine significance of individual cell size
 - Continue incubation
 - Test for growth on different types of agar
- Teams begin *BUGs I - Cell Division* (p. 14)

Teacher Activities

- Demonstrate wet mount preparation and light microscope care and use
- Observe and question teams during *BUGs I - Cell Division* lab

Overview (continued.)**Materials (continued)**

- *E. coli* DH5 and XL1 (2 colonies/team) [See notes]
- ~5° C Refrigerator (1/school)
- Gloves (2 pair/team)

Naive Conceptions

Most students mistakenly believe that ...

- Initial failures indicate that the solution is not appropriate
- Failure means nothing was / can be learned
- Everybody's DNA is completely different
- We cannot see bacteria without a microscope
- Bacteria can grow anywhere

Assessing / Advancing Knowledge**Formative Assessment**

- Observe all wet mount preparations and microscopy technique. Do not focus microscopes for the students, advise on proper focusing technique, verify that teams have focused properly.
- Collect and assess *BUGs I - Cell Division* (p.14)
- CLASS DISCUSSION: Teams present *BUGs I - Cell Division* (p. 14) answers to class
- HW: Copy *BUGs I - Cell Division* and send home with students. Have students rank each completed *BUGs I - Cell Division* form and discuss during next lesson.

Key Science Question(s)

What type of agar do you think is best to grow bacteria on? Why? How do you know what nutrients are in the agar?

RESPONSE: Students should justify their response with data.

What are the key environmental variables that influence cell division?

RESPONSE: Students will have to guess which variables are most important. All ideas are valid, but need to be justified. Students should be reminded that it is okay to guess today, because tomorrow they will see the results and will find out which variables are indeed the most influential.

What process must happen to bacterial cells when colonies get larger?

RESPONSE: Students should justify their response with data.

What are experimental controls? Why is it so important to have controls in an experiment?

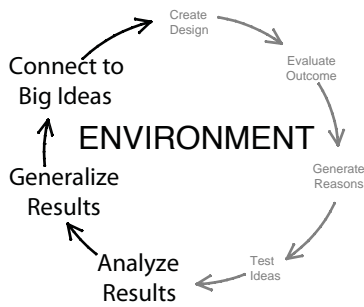
RESPONSE: Based on their *BUGs* results, students should see that controls are needed in experiments so that their results can be trusted.

Optional Extension

- Basic Microbiology
 - Various bacterial shapes and sizes

Journal Space

Lesson 9: Concluding Environmental Variables



Overview

Big Idea(s)

To optimize cell division, the bacteria must be grown under the proper conditions.

Lesson Goal(s)

Science

By analyzing the results from their BUGs investigations and generalizing those results with those from other BUG experiments, students should be able to connect to the big idea that cells divide to make more cells and identify the effects of the environment on cell division.

Materials

- Team Guide:
 - *BUGs I - Cell Division* (p. 14-16)
 - *What is Cell Division, Anyway?* (p. 17)
 - *Exponential Growth* (p. 18)
- *Generalize Results Table* transparency (1/class)
- *HW2: Bugs Produce Drugs!* handouts (1/student)
- Overhead projector
- 10% bleach spray bottle (3/classroom)
- Plates from previous lesson
- ~5° C Refrigerator (1/school)

Implementing This Lesson

Lesson Objectives

- Students will analyze the results of their tests, generalize those results and connect their work from this subsystem to the big idea of cell division
- Students will apply generalized results to improve their prototypes

Background Information

Students should see that temperature and nutrients in the agar greatly affect the number and size of the visible colonies. Refer back to the microscope experiment in *BUGs I* to get the students to see how cells divide to make more cells.

Link the growth conditions to cell division. For example,

Teacher: Why were the colonies on the LB agar plate bigger than the others?

Student: Because the LB agar had all of the nutrients *E. coli* need to divide.

Teacher: And what is happening when a colony gets bigger?

Student: Cells are dividing to make more cells.

Teacher: So, when we give our bacteria the best conditions what are encouraging?

Student: Cell division!!!!

Logistics

Generalize Results Discussion

Use one of the Generalize Results Table transparencies to help facilitate this discussion. During this first time through the Generalize Results discussion label the important variables in the column headers before the class (i.e., time, temperature, agar). As teams share their results, they can be recorded in this table under the appropriate column. This format should help your students see the patterns of results across teams for the different investigations.

During subsequent Generalize Results discussions, encourage the students to take more leadership in identifying the important variables and how the class' data should be organized.

Student Activities

- OPEN LAB: Teams observe plates, record experimental results, and share experimental results with the class
- Teams complete *BUGs I - Cell Division* (p. 14-15) and *Exponential Growth* (p.18)
- CLASS DISCUSSION: Generalize experimental results; connect these results to the key concepts
- Teams read *What is Cell Division, Anyway?* (p. 17) and answer questions
- *HW2: Bugs Produce Drugs!* (p. 19)

Overview (continued.)**Naive Conceptions**

Most students mistakenly believe that ...

- Initial failures indicate that the solution is not appropriate
- Failure means nothing was / can be learned
- Everybody's DNA is completely different
- We cannot see bacteria without a microscope
- Bacteria can grow anywhere

Teacher Activities

- Observe and question teams during Open Lab data collection
- Facilitate Generalize Results discussion using *Generalize Results* transparency
- Telling: Link cell division to generalized results

Assessing / Advancing Knowledge**Formative Assessment**

- Collect and assess *BUGS I - Cell Division* (p. 14 - 17) and *Exponential Growth* (p.18)
- CLASS DISCUSSION: Teams present *BUGS I - Cell Division* (p. 14 - 17) and *Exponential Growth* (p.18) answers to class

Key Design Question(s)

What have you learned from the the Environment subsystem that you can use to improve your prototype?

RESPONSE: Students should justify their response with data.

Based on your testing, what aspects of your design should be revised?

RESPONSE: Students should justify their responses with data.

Key Science Question(s)

What are the key environmental variables that influence cell division?

RESPONSE: Temperature, availability and type of nutrients, as well as the length of incubation.

What happens to bacterial cells when colonies get larger? What happens during cell division?

RESPONSE: Cells are increasing in number as they divide. The more cells there are, the bigger the colony. Cells copy everything inside the cytoplasm, including the genes (DNA) to give to the daughter cells (next generations).

Why do the divided cells exhibit the same traits?

RESPONSE: Cells copy everything inside the cytoplasm, including the genes (DNA) to give to the daughter cells (next generations). Because they have the same genes (DNA), they exhibit the same traits.

Can we change those traits? How?

RESPONSE: Yes. Students should link what they learned about GM fruit to their prototype, i.e., blending strains of bacteria.

What makes bacteria exhibit certain traits?

RESPONSE: The genes (DNA) they contain and inherited from the parent cell.

Optional Extension

- *Exponential Growth* activity (p.18)

Journal Space

GENES SUBSYSTEM

Lesson Flow

NOTE: Lessons 11 and 12 MUST be done on consecutive days!

Lesson 10: Introduction and Create Design within the Genes Subsystem
Experimenting with Food Coloring and Glow Sticks

Lesson 11: Evaluate and Generate Reasons for the Design Outcome and Test Some Ideas Using Contrasting Cases

Lesson 12 (2 days): Test Ideas About Genes Using Bacterial Transformation

Lesson 13: Analyze and Generalize Results of Bacterial Transformation and Discuss How Those Results Might Effect the Prototypes

Lesson 14: Analyze and Generalize Results of DNA Modelling Investigation and Discuss How Those Results Might Effect the Prototypes

OPTIONAL Lesson 15 (2 days): Analyze and Generalize Results of Eukaryotes vs. Prokaryotes Investigation and Discuss How Those Results Might Effect the Prototypes

Lesson 16: Connect to the Big Ideas of DNA Structure and Heredity by Generalizing Results from Previous BUGs Investigations

Recommended Extensions

Metacognition

- Explain the purpose of team roles and the design-science cycle if teams are struggling

Mendelian Genetics

Literature Review Topics

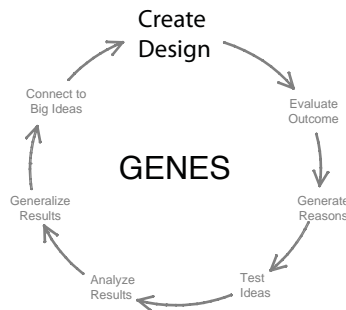
Set a number of articles, outside sources, product comparison, etc. to be read and summarized by each group member by the end of the subsystem (1 - 2 per person)

Suggested Topics:

- Plasmids
- Bacterial transformation
- DNA structure
- Gene structure
- Genetic traits and heredity
- Eukaryotes and prokaryotes

Lesson	Student Activities	Big Ideas	Written Work / Presentations	D-S Cycle	Storyline
10	<ul style="list-style-type: none"> Introduction to Genes Subsystem Teams complete <i>Genes</i> investigations with predictions 		<ul style="list-style-type: none"> <i>Genes</i> 	Create Design	Genes
11	<ul style="list-style-type: none"> <i>Open Lab</i>: Observe plates and record results, share results with the class Generate reasons for design outcome Telling: <ul style="list-style-type: none"> Logical inferences to rule out 'un-testable' ideas Discuss how new genes are inserted into bacteria on plasmids Jigsaw <i>BUGs II - Genes</i> investigations with predictions <ul style="list-style-type: none"> Glow stick Food coloring <i>Open Lab</i>: Share predictions 		<ul style="list-style-type: none"> <i>Genes</i> <i>BUGs II - Traits</i> 	Evaluate Outcome Generate Reasons Test Ideas	Genes
12 (2 days)	<ul style="list-style-type: none"> Introduction to transformation and plasmids Start bacteria transformation protocol (steps 1-5) Finish bacterial transformation protocol (steps 6-7) 	<ul style="list-style-type: none"> DNA is a double-stranded, anti-parallel molecular structure located in the bacterial cytoplasm that codes for genes. Genes are inherited from previous generations and transmit a characteristic. 	<ul style="list-style-type: none"> <i>BUGs III - Transformation</i> 	Test Ideas	Genes
13	<ul style="list-style-type: none"> <i>Open Lab</i>: Observe plates and record results, share results with the class Analyze results, and generalize results 		<ul style="list-style-type: none"> <i>BUGs III - Transformation</i> <i>Open Lab</i> 	Test Ideas Analyze Results Generalize Results	Genes
14	<ul style="list-style-type: none"> Purify transformants Jigsaw <i>BUGs IV - DNA</i> investigations <ul style="list-style-type: none"> DNA modeling 		<ul style="list-style-type: none"> <i>BUGs IV - DNA</i> 	Test Ideas Analyze Results Generalize Results	Genes
15 (2 days) Optional	<ul style="list-style-type: none"> Teams work through <i>BUGs V - Where is the DNA?</i> Investigations <ul style="list-style-type: none"> Wet Mounts Prokaryotes vs. Eukaryotes Recap observations, analyze results, and generalize results 		<ul style="list-style-type: none"> <i>BUGs V - Where's the DNA</i> 	Test Ideas Analyze Results Generalize Results	Genes
16	<ul style="list-style-type: none"> <i>BUGs VI- Replication</i> investigation Connect results from <i>BUGs II - VI</i> to big idea Think about progress and learning and how the science impacts the design prototype 		<ul style="list-style-type: none"> <i>BUGs VI - Replication</i> <i>What are Genes, Anyway?</i> <i>Reflection</i> 	Test Ideas Analyze Results Generalize Results Connect to Big Ideas	

Lesson 10: Investigating Genes Part I



Overview

Big Idea(s)

DNA is a double-stranded, anti-parallel molecular structure located in the bacterial cytoplasm that codes for genes.

Genes are inherited from previous generations and transmit a characteristic.

Lesson Goal(s)

Design

Students will create the improved design for their prototype based on their new knowledge of cell division, their reflections, and peer reviews of their prototype presentations..

Science

By trying to get their bacterial colonies to turn blue or glow by artificial coloring and luminescence, students will see that traits are not inherited via the environment.

Materials

- Team Guide:
 - *Genes* (p. 20)
 - *Genes Procedures* handouts (1/team)
- Plates from previous lesson
- Glow sticks
- Food coloring
- Sterile toothpicks (1 pack/team)
- Sterile swabs (2/team)

Implementing This Lesson

Lesson Objectives

- Students will improve their prototype by trying to get their bacteria to turn blue or glow
- Students will investigate if traits are inherited from the environment

Logistics

Genes

Students should use their plates from the *Environment* subsystem investigations. One half of the plate should be used for the food coloring investigation. The other half of the plate should be used for the glow stick investigation.

The *Genes* investigations will take most of the class period, however if time permits each team should report their *Genes* investigation and what they predict will happen.

Student Activities

- Teams complete *Genes* investigations with predictions (p. 20)
 - Enhance the agar with glow stick material
 - Enhance the agar with food coloring
- OPEN LAB: Teams share predicted results for their *Genes* experiment with the class

Teacher Activities

- Class Discussion: Introduce the *Genes* Subsystem
 - Review what prototype requirement(s) were met in the *Environment* subsystem.
 - Brainstorm what the next design goal might be for their prototype. [i.e. So we now know how to grow bacteria. Are your bacteria colonies the proper color for your prototype?]
 - Connect to the *Environment* Subsystem [i.e. We know that environmental conditions can effect bacterial growth. Can you change the environment to make your prototype meet your requirements?]
- Provide supplies and handouts but do not instruct teams on how to set up their investigation.
- Observe and question teams during *Genes* investigations. Guide students to begin thinking about how traits are inherited.

Overview (continued.)**Materials (continued)**

- 30° C and 37° C incubators
- 10% bleach spray bottle (3/class)
- Biohazard waste container
- Gloves (2 pairs/team)

Naive Conceptions

Most students mistakenly believe that ...

- Gene expression happens via methods other than protein synthesis
- Traits / genes may be acquired from the environment
- Genes are small particles that make up chromosomes
- Genes and DNA are completely different
- Genes necessarily determine traits
- Genes are passive particles passed on from previous generations
- Genes carry miniature forms of the trait
- Bacteria have human tendencies
- Good solutions are created on the first try and need no further improvements
- Failure means nothing was / can be learned

Assessing / Advancing Knowledge**Formative Assessment**

- An optional vocabulary quiz may be administered

Key Design Question(s)

What prototype requirement are you trying to meet with this experiment? How do you think this experiment will impact your design as a whole?

RESPONSE: Students should be encouraged to think about how the way their *Genes* subsystem should work and how the function of the *Genes* subsystem fits with the function of the *Environment* subsystem.

Key Science Question(s)

Are bacteria able to pick up traits or abilities from the environment? Why or why not?

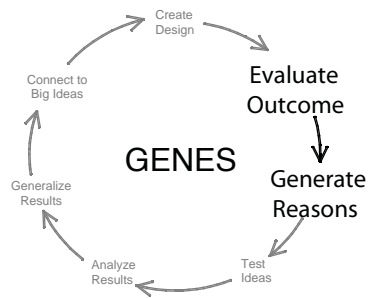
RESPONSE: Use this question to assess students' predictions about whether the bacteria will take up the glow stick material or food dye from the environment. Do not correct naive conceptions at this point, but offer challenges to those conceptions so that students realize that they will have to collect more data or learn more to answer those challenges.

What does the structure of DNA have to do with a trait or ability?

RESPONSE: Use this question to assess ideas and conceptions that students may have about bacteria and genes. Do not correct naive conceptions at this point, but offer challenges to those conceptions so that students realize that they will have to collect more data or learn more to answer those challenges. This question is intended to get students to start thinking about how science may impact their design.

Journal Space

Lesson 11: Investigating Genes Part II



Overview

Big Idea(s)

DNA is a double-stranded, anti-parallel molecular structure located in the bacterial cytoplasm that codes for genes.

Genes are inherited from previous generations and transmit a characteristic.

Lesson Goal(s)

Design

Students should be able to logically evaluate their plates from the previous lesson and generate plausible reasons for the outcomes.

Materials

- Team Guide
 - *Genes* (p. 20-21)
 - *BUGs II - Traits* (p. 22-25)
- *Generate Reasons Table Transparency*
- 10% bleach spray bottle (3/ classroom)
- Plates from previous lesson
- ~5° C Refrigerator (1/school)

Implementing This Lesson

CAUTION: TIME MANAGEMENT!!

Lessons 11 and 12 must be done on consecutive days. Prepare Overnight Cultures for tomorrow's Lesson!

Lesson Objective

- Students evaluate the outcome of their prototype improvement and generate reasons as to why / why not their improvement worked / did not work
- Students investigate why traits are not inherited from the environment

Logistics

Keep all glowing/colored transformants covered with plastic wrap and refrigerated to prevent the agar from dehydrating.

If some teams have agar that is still colored or glowing, guide those teams to try re-culturing on untreated agar.

Experiment Preparation: Overnight Culture

PLAN ACCORDINGLY: You will need fresh overnight broth cultures for the next lesson's transformations. It is best to prepare these cultures from starter colonies that are no older than 10 days. **Subcultures will need set up early tomorrow morning!** [*Broth Culture Preparation, Appendix, p. 86*]

Lessons 11 through 12 must be done on consecutive days and CANNOT be left over the weekend.

Generate Reasons Discussion

Use one of the *Generate Reasons Table* transparencies to help facilitate this discussion. As teams share their design outcomes, they can be recorded in this table under the appropriate column. This format should help your students see the patterns of outcomes across teams.

Student Activities

- **OPEN LAB:** Teams observe plates, record experimental results, and share experimental results with class
- Teams complete *Genes* (p. 20 - 21)
- Teams complete *BUGs II - Traits* and report their results (p. 22 - 25)

Teacher Activities

- Observe and question teams during Open Lab and *BUGs II - Traits*
- **Class Discussion:** Lead Generate Reasons Discussion utilizing *Generate Reasons Table Transparency* guiding student thinking to creative ways of improving their prototypes to meet their genetic requirements
 - Examples can be found in *Student Reasons and Investigations* (Appendix, p. 89)

Assessing / Advancing Knowledge

Formative Assessment

- Collect and assess *BUGs II - Traits* (p. 22 - 25)
- **CLASS DISCUSSION:** Teams present *BUGs II - Traits* (p. 22 - 25) answers to class

Overview (continued.)**Naive Conceptions**

Most students mistakenly believe that ...

- Good solutions are created on the first try and need no further improvements
- Failure means nothing was / can be learned
- Genes and DNA are completely different
- All genes and / or mutations are inherited by future generations
- Traits determine genes
- Traits and genes are the same thing
- Gene expression happens via methods other than protein synthesis
- Genes carry miniature forms of the trait
- Traits may be acquired from the environment
- Bacteria have human tendencies

Experimental Preparation:**Overnight Culture Materials**

- LB broth
- Sterile 15 mL tubes (2)
- Sterile pipettes (2)
- Tube rack
- E. coli DH5
- E. coli XL1
- Sterile toothpicks
- 10 % bleach spray bottle
- Biohazard waste container
- 37° C incubator (Room temperature is acceptable for over the weekend incubation)

- HW: Copy *BUGs II - Traits* and send home with students. Have students rank each completed *BUGs II - Traits* form and discuss during next lesson.

Key Science Question(s)

Why didn't the bacteria start to glow or take up color when you added the glow stick or food coloring to the agar?

RESPONSE: The bacteria do not inherit traits from the environment. Traits come from genes and genes are coded in the DNA.

What about genes gives rise to the expected trait?

RESPONSE: Students should begin to see how genes are linked to expressed traits. They have introduced new genetic material into their bacteria and should see new traits. Students should be able to see how they have changed the appearance of their colonies by introducing new genes.

What are genes made of? What type of macromolecule is a gene? What are the molecules that compose it?

RESPONSE: Use this question to assess ideas and conceptions that students may have about bacteria and genes. Do not correct naive conceptions at this point, but offer challenges to those conceptions so that students realize that they will have to collect more data or learn more to answer those challenges. More detailed responses to this question should be expected after students see the results of their BUGs investigation in the next lesson.

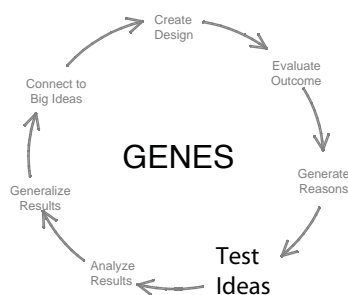
Where do genes come from?

RESPONSE: Based on what they have learned from the BUGs investigations, students should see that genes are coded for in the DNA and that genes are not inherited and do not come from the environment.

Do all of the cells in a transformed colony have the new gene?

RESPONSE: Students should be able to see that the transformed bacteria express the new trait. This new trait comes from the new genes (DNA). Thus, by logical inference, all of the transformed bacteria have the new gene.

Lesson 12: Testing Genetic Variables Part I (2 days)



Overview

Big Idea(s)

DNA is a double-stranded, anti-parallel molecular structure located in the bacterial cytoplasm that codes for genes.

Genes are inherited from previous generations and transmit a characteristic.

Lesson Goal(s)

Design

Students will test the genetic design for their prototype by selecting the appropriate plasmid, bacterial strain, and agar.

Science

By testing the idea that traits may be inherited through DNA, students will see that traits are not inherited via the environment.

Materials

- Team Guide:
 - *Transformation Procedures* (p. 26 - 27)
 - *BUGs III - Transformation* (p. 29)
- Transformation Kit (1/team) [SEE LOGISTICS]
- Centrifuge (1/teacher)
- Biohazard waste container
- ~5° C Refrigerator (1/school)
- 30° C and 37° C incubators

Implementing This Lesson

CAUTION: TIME MANAGEMENT!!

Lessons 11, 12, & 13 must be done on 3 consecutive days.

YOU MUST SUBCULTURE THE OVERNIGHT CULTURES FIRST THING THIS MORNING!

Lesson Objective

- Students will introduce new genetic material, i.e., a new plasmid, into their bacteria
- Students will read about the properties of bacterial plasmids and the connection between plasmids and traits

Background Information

Plasmids are circular pieces of DNA that do not get incorporated into the bacterial chromosome. Instead, they replicate themselves to make many copies that remain in the cell's cytoplasm. [*Team Guide*, p. 26; *Plasmid Maps*, Appendix p. 91]

Experiment preparation: Subcultures

PLAN ACCORDINGLY! Subcultures of the overnight cultures you prepared yesterday, need to be prepared as early as possible today. The purpose of a subculture is to keep the bacteria rapidly dividing and healthy to maximize transformation success. [*Subculture Preparation*, Appendix 86]

Logistics

Each transformation kit must contain enough materials for 2 transformations (1 control and 1 experimental) and must be kept refrigerated or frozen [*Transformation Kit Contents*, Appendix p. 90]

Across teams, the bacterial strain and media should vary. Make sure teams document everything in their *Team Guides* and justify their choices. REMEMBER: there are no wrong answers.

It might be effective to give students a demonstration of transformation steps 1-5 before they begin their own transformations.

Student Activities

- Day 1
 - Teams follow *Transformation Procedures - Day 1* (p. 26)
 - Teams begin *BUGs III - Transformation* (p. 29)
- Day 2
 - Teams follow *Transformation Procedures - Day 2* (p. 27)
 - Teams complete *BUGs III - Transformation* (p. 29 - 30)

Overview (continued.)**Naive Conceptions**

Most students mistakenly believe that ...

- Good solutions are created on the first try and need no further revision
- All genes and / or mutations are inherited by future generations
- Genes are small particles that make up chromosomes.
- Traits determine genes
- Traits and genes are the same thing
- Traits may be acquired from the environment.
- Genes and DNA are completely different.

Teacher Activities

- During incubation periods, review the *Transformation Procedures* information (p. 28)
- Explain laboratory instruments: proper use and care
- Demonstrate proper transformation technique
- Observe and question teams as they perform *Transformation Procedures*, and *BUGS III - Transformation*

Assessing / Advancing Knowledge**Formative Assessment**

- Optional quiz on transformation procedures

Key Design Question(s)

How will the transformation improve your prototype?

RESPONSE: Students should be able to explain why they are using genetic transformations in their design.

What trait do you want your bacteria to have?

RESPONSE: Students should refer to their requirements.

What problem are you really trying to solve with this transformation?

RESPONSE: Students should refer to their needs (and requirements).

What purpose does the *Genes* subsystem serve for your prototype?

RESPONSE: Students should refer to their needs (and requirements) and begin thinking about DNA and the connection between DNA and traits.

Key Science Question(s)

What are genes made of?

RESPONSE: Students should be encouraged to express their ideas about genes. Ideas related to ideas about DNA (gene) structure should be encouraged as the addition of luminescence, and dye, provided reason to refute trait transmission from the environment.

Where do genes come from?

RESPONSE: Use this question to assess ideas and conceptions that students may have about genes. Ideas related to DNA (gene) structure should be encouraged as the addition of luminescence, and dye, provided reason to refute trait transmission from the environment.

What is the difference between the environment changing or selecting for traits? Provide observations that show which of our two experiments in this subsystem performed each.

RESPONSE: The glowstick / food coloring experiment provided evidence that the environment cannot change the traits of an organism. Therefore it was proving that environment did not CHANGE the traits. The amp-R gene allowed the transformed bacteria to grow on agar with ampicillin. This is an example of the environment SELECTING for a trait.

What is in the plasmid that will make your bacteria fluorescent or blue? What is 'it' made of? ['it' --> gene]

RESPONSE: Use these questions to assess ideas and conceptions that students may have about bacteria and genes. Do not correct naive conceptions at this point.

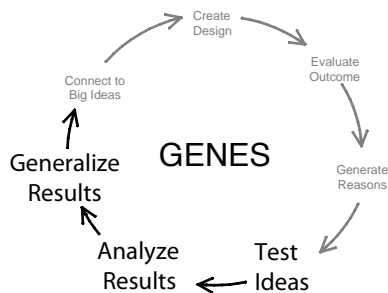
What are you doing when you "transform" bacteria?

RESPONSE: Inserting new genes (DNA).

What do the bacteria do with the new gene?

RESPONSE: Use this question to assess ideas and conceptions that students may have about bacteria and genes. Do not correct naive conceptions at this point.

Lesson 13: Testing Genetic Variables Part II



Overview

Big Idea(s)

DNA is a double-stranded, anti-parallel molecular structure located in the bacterial cytoplasm that codes for genes.

Genes are inherited from previous generations and transmit a characteristic.

Lesson Goal(s)

Design

Students will test the genetic design for their prototype by selecting the appropriate plasmid, bacterial strain, and agar.

Science

By testing the idea that traits may be inherited through DNA, students will see that traits are not inherited via the environment.

Materials

- Team Guide:
 - *BUGs III - Transformation* (p. 29 - 30)
- *Plasmid* transparency (1/teacher)
- *Generalize Results Table* transparency (1/class)
- Overhead projector
- Plates from previous lesson
- ~5° C Refrigerator (1/school)
- 10% bleach spray bottle (3/ classroom)

Implementing This Lesson

Lesson Objective(s)

- Students will analyze the success of their genetic transformation, generalize results across all teams and determine why or why not their transformations were or were not successful

Background Information

For teams that had successful transformations: Explain why each plate looks the way it does.

Plate Selection	Contents	Expected Observations	Interpretation
Control +	Bacteria, plasmid	Lawn	Plasmid does not hurt the bacteria
Control -	Bacteria	Lawn	Protocol does not hurt the bacteria
Exp: amp +	Bacteria, plasmid	Colonies (blue / glowing)	Transformants
Exp: amp -	Bacteria	No growth	Bacteria need plasmid to be resistant to antibiotic

Logistics

Any plates that failed can be destroyed. (*Disposal of Contaminated Material*, Appendix, p. 86)

If transformations fail, students can 'buy' the cultures from you. Inform students that you have cultures of these bacteria that have already been transformed. To obtain these colonies, students should complete an additional activity that is geared toward gene theory. Alternatively, students may pirate transformants from other teams.

Students with failed transformants may provide a variety of reasons for the failure. At this point, the most plausible reasons include technique, incubation, temperature, and nutrients. Depending on your schedule and left-over materials, these teams may want to try the transformation again.

Generalize Results Discussion

Use one of the *Generalize Results Table* transparencies to help facilitate this discussion. Encourage students to create labels for the important variables in the column headers. As teams share their results, they can be recorded in this table under the appropriate column. This format should help your students see the patterns of results across teams for the different investigations.

Student Activities

- **OPEN LAB:** Teams observe plates, record experimental results, and share experimental results with class
- Teams complete *BUGs III - Transformation* (p. 29 - 30)
- Teams purify their transformants

Teacher Activities

- Facilitate class discussion of results to advance understanding of transformation, experimental controls, and the design process using the *Generalize Results Table* or wall chart.
- Observe and question teams as they complete *BUGs III - Transformation*.

Overview (continued.)**Naive Conceptions**

Most students mistakenly believe that ...

- Good solutions are created on the first try and need no further revision
- Traits may be acquired from the environment
- All genes and / or mutations are inherited by future generations
- Traits determine genes
- Traits and genes are the same thing
- All lab data is precise and accurate

Journal Space**Assessing and Advancing Knowledge****Key Design Question(s)**

Why do the plate halves look different?

RESPONSE: Students should be able to express how the data from the four sections can be used to tell them whether their transformation was successful (refer to Background Knowledge section above).

Does the design meet the specified needs and requirements?

RESPONSE: Students should evaluate how well their prototype met their specified needs and requirements. Students should justify their responses with data.

What are the reasons why you were or were not able to meet your specified needs and requirements?

RESPONSE: Students should be encouraged to brainstorm reasons why they did or did not meet their requirements. These reasons should be ideas that can be tested. All ideas are valid initially, but as a class, students should narrow down their ideas to those that are the most useful to test. At this point, the most useful tests include technique, incubation, temperature, and nutrients.

Key Science Question(s)

What are genes made of?

RESPONSE: Students should be encouraged to express their ideas about genes. Ideas related to the addition of luminescence, dye, and ideas about DNA (gene) structure should be encouraged because they will be tested directly in the next set of BUGs investigations.

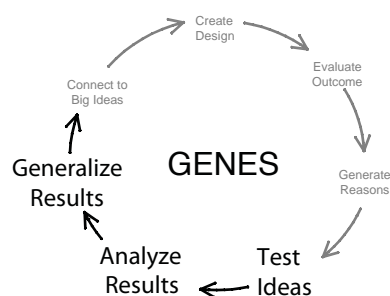
Where do genes come from?

RESPONSE: Use this question to assess ideas and conceptions that students may have about genes. Ideas related to the addition of luminescence and dye should be encouraged because they will be tested directly in the next set of BUGs investigations. Do not correct naive conceptions at this point, but offer challenges to those conceptions so that students realize that they will have to collect more data or learn more to answer those challenges. They will investigate this question in the next set of BUGs investigations.

What are experimental controls? Why is it so important to have controls in an experiment?

RESPONSE: Based on their BUGs results in the *Environment I* subsystem, students should see that controls are needed in experiments so that their results can be trusted. Encourage students to brainstorm the controls for the next set of BUGs investigations based on their ideas about where genes come from and what genes are made of.

Lesson 14: Testing Genetic Variables Part II



Overview

Big Idea(s)

DNA is a double-stranded, anti-parallel molecular structure located in the bacterial cytoplasm that codes for genes.

Genes are inherited from previous generations and transmit a characteristic.

Lesson Goal(s)

Design

Students will test the genetic design for their prototype by building part of a gene with a DNA model, enabling students to see gene structure is an integral part of their prototype.

Science

By analyzing their results from the BUGs investigations, students should begin to see how DNA structure, genes and inheritance are related.

Materials

- Team Guide:
 - *BUGs IV - DNA* (p. 31 - 32)
- Plates from previous lesson
- Fresh agar plates
- Sterile toothpick packs
- Biohazard waste container
- 30° C and 37° C incubators
- Goggles (1/student)
- Gloves (2 pair/team)

Implementing This Lesson

Lesson Objective(s)

- Students will purify their transformants
- Students will build DNA models

Logistics

DNA models

Have students team up in pairs. These pairs can be within their original team or with someone from another team. Each pair of students gets one DNA model kit.

Purify Transformants

Transformants will need to be purified before they can be manipulated. Teams with transformants should dilution streak (*Dilution Streak Method*, Appendix, p. 88) their transformants on ½ plates of their choice. Once those cultures are grown up, then they can be used for further experiments.

If transformations fail, students can ‘buy’ the cultures from you. Inform students that you have cultures of these bacteria that have already been transformed. To obtain these colonies, students should complete an additional activity that is geared toward gene theory. Alternatively, students may pirate transformants from other teams.

Student Activities

- Teams purify transformants by dilution streaking transformed colonies onto fresh agar and incubating overnight
- Teams complete *BUGs IV - DNA* (p. 31 - 32)

Teacher Activities

- Review dilution streak method with class before groups purify their colonies
- Observe and questions teams as they complete *BUGs IV - DNA*

Assessing / Advancing Knowledge

Formative Assessment

- Collect and assess *BUGs IV - DNA* (p. 31 - 32)
- CLASS DISCUSSION: Teams present *BUGs IV - DNA* (p. 31 - 32) answers to class
- HW: Copy *BUGs IV - DNA* and send home with students. Have students rank each completed *BUGs IV - DNA* form and discuss during next lesson

Overview (continued.)**Naive Conceptions**

Most students mistakenly believe that ...

- Traits determine genes
- Traits and genes are the same thing
- Genes are small particles that make up chromosomes
- Genes and DNA are completely different
- Gene expression happens via methods other than protein synthesis

Key Design Question(s)

How will the transformation improve your prototype?

RESPONSE: Students should be able to explain why they are using genetic transformations in their design.

What is required for the design to work?

RESPONSE: Students should be encouraged to think about how their requirements influence how they create their prototype.

What are the functions of the *Genes* subsystem?

RESPONSE: Students should be encouraged to think about how the way their *Genes* subsystem should work relates to the decisions that they make when creating their prototype.

Key Science Question(s)

What are genes made of?

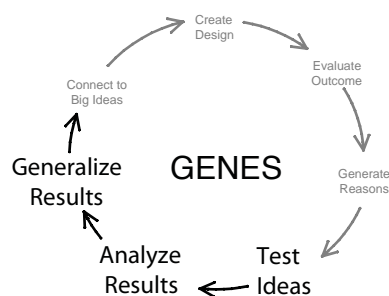
What do genes do?

Do all of the individual bacterium in each colony have the same genes?

RESPONSE: Use these questions to assess ideas and conceptions that students may have about bacteria and genes. Do not correct naive conceptions at this point, but offer challenges to those conceptions so students realize that they will have to collect more data or learn more to answer those challenges.

Journal Space

Optional Lesson 15: Finding DNA [Eukaryotes vs. Prokaryotes]



Implementing This Lesson

These lessons are optional. If you have not already compared eukaryotes and prokaryotes yet in your lesson plan, these lessons provide a creative and interactive way of engaging your students on this topic.

If you do not want to spend two whole lessons on this topic, a few suggestions are:

- Use some or all of the student activities listed in this lesson plan as homework
- Review p. 34 - 35 in class, assign p. 36 as homework

Overview

Big Idea(s)

DNA is a double-stranded, anti-parallel molecular structure located in the bacterial cytoplasm that codes for genes.

Genes are inherited from previous generations and transmit a characteristic.

Lesson Goal(s)

Design

By connecting to the big ideas of DNA structure, and gene theory, students will be able to make better design choices for their prototype.

Science

By analyzing their results from the BUGs investigations, students should be able to connect to the big idea that genes are made of DNA floating inside the cell and that genes transmit traits or abilities.

Materials

- Team Guide
 - *BUGs V - Where is the DNA?* (p. 33 - 36)
- Light microscopes (1/team)
- Microscope slides (1/team)
- Microscope cover slips (1/team)
- Team transformation plates
- Sterile tooth picks (1 pack/team)
- Methylene blue stain
- Onion root tip prepared slides (12/teacher)

Lesson Objective(s)

- Students will look for DNA in both prokaryotes and eukaryotes. Along with this activity, students will learn more about the similarities and differences of prokaryotes and eukaryotes

Background Information

Typically, prokaryotes are single-celled organisms that have no internal membranes. Generally, they are much smaller than eukaryotes. Both eukaryotes and prokaryotes have ribosomes for protein synthesis. However, prokaryotes have no true nucleus. All prokaryotic intracellular DNA manipulations occur in the cytoplasm, whereas eukaryotic DNA replication and transcription happen inside the cell's nucleus.

Logistics

This is an optional lesson.

The purpose of *BUGs V - Where is the DNA?* is to get the students to see the differences in DNA location between these two cell types. Students should realize that the same processes occur for both cell types, despite their differences.

Key for *BUGs V - Where is the DNA?* activity (p. 36)

Item	Cell Type	Species
A	Eukaryote	Kangaroo rat cells
B	Prokaryote	<i>E. coli</i>
C	Prokaryote	<i>Chlorobium</i> (green sulfur bacteria)
D	Eukaryote	<i>Volvox</i> (algae)
E	Eukaryote	<i>Paramecium</i> (protozoa)
F	Prokaryote	<i>Chloroflexus</i> (green non-sulfur bacteria)
G	Eukaryote	Fungus
H	Prokaryote	<i>Pseudomonas aeruginosa</i> (green) <i>Bacillus cereus</i> (orange)
I	Prokaryote	Bacteria from a dog's water bowl
J	Eukaryote	Onion root tip
K	Prokaryote	<i>Staphylococcus aureus</i> (purple) <i>E. coli</i> (pink)
L	Eukaryote	Yeast

Overview (continued.)**Materials (continued)**

- ~5° C refrigerator (1/school)
- 10% bleach spray bottle (3/classroom)
- Biohazard waste container (1/team)
- Gloves (2 pairs/team)

Naive Conceptions

Most students mistakenly believe that ...

- Bacterial cells and human cells are the same
- We cannot see bacteria without a microscope
- Genes and DNA are completely different

Student Activities

- **BUGs:** Teams begin *BUGs V - Where is the DNA?* (p. 33) investigations
 - Teams stain colonies from their transformation plate and compare them to an onion root tip slide
- Teams read and complete *BUGs V - Where is the DNA?* (p. 34 - 36)
- **CLASS DISCUSSION:** Recap, analyze results, and generalize results [10 minutes]

Teacher Activities

- Observe and question teams as they work through *BUGs V - Where is the DNA?*
- Facilitate class discussion using *Generalize Results Table*

Assessing / Advancing Knowledge**Formative Assessment**

- Collect and assess *BUGs V - Where's the DNA?* (p. 33 - 36)
- **CLASS DISCUSSION:** Teams present *BUGs V - Where's the DNA?* (p. 33 - 36) answers to class
- **HW:** Copy *BUGs V - Where's the DNA?* and send home with students. Have students rank each completed *BUGs V - Where's the DNA?* form and discuss during next lesson.

Key Science Question(s)

Which cell type do you think evolved first?

What processes are the same/different between prokaryotes and eukaryotes?

Are genes located in the free DNA of prokaryotes passed on in the same manner as genes located in the nucleus of eukaryotes?

What are genes made of? What type of macromolecule is a gene? What are the molecules that compose it?

RESPONSE: Use these questions to assess ideas and conceptions that students may have about bacteria and genes. Do not correct naive conceptions at this point, but offer challenges to those conceptions so that students realize that they will have to collect more data or learn more to answer those challenges. More detailed responses to this question should be expected after students see the results of their BUGs investigation in the next lesson.

Where do genes come from?

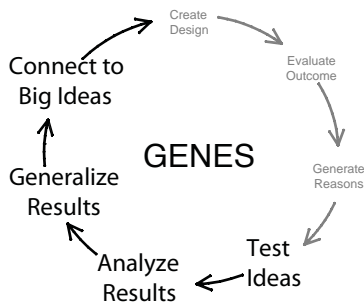
RESPONSE: Based on what they have learned from the BUGs investigations, students should see that genes are coded for in the DNA and that genes are not inherited and do not come from the environment.

Optional Extension(s)

- Mitosis and Meiosis
- Organelle function

Journal Space

Lesson 16: Concluding Genes



Overview

Big Idea(s)

DNA is a double-stranded, anti-parallel molecular structure located in the bacterial cytoplasm that codes for genes.

Genes are inherited from previous generations and transmit a characteristic.

Lesson Goal(s)

Design

By connecting to the big ideas of DNA structure, and gene theory, students will be able to make better design choices for their prototype.

Science

By analyzing their results from the BUGs investigations and generalizing those results as a class, students should be able to connect to the big idea that genes are made of DNA floating inside the cell and transmit traits or abilities from one generation to the next.

Materials

- Team Guide
 - *BUGs VI - Replication* (p. 37)
 - *What are Genes, Anyway?* (p. 38)
- *HW - Reflection* handouts (1/ student)
- DNA models (1/team)
- *Generalize Results Table* transparency (1/class)
- Overhead projector

Implementing This Lesson

Lesson Objective(s)

- Students will model DNA Replication
- Students will use what they have seen in each of the BUGs investigations in the Genes subsystem to connect to the big ideas of DNA structure and heredity
- Students will use these big ideas to improve their prototype

Logistics

Generalize Results Discussion

Use one of the Generalize Results Table transparencies to help facilitate this discussion. Encourage students to create labels for the important variables in the column headers. As teams share their results, they can be recorded in this table under the appropriate column. This format should help your students see the patterns of results across teams for the different investigations.

Connect to the Big Idea Discussion

The replication BUGs investigation is intended for introducing the students to the structure of DNA and how it copies itself to make two, semi-conservation strands.

Link DNA structure/location, genes, protein, and heredity to the generalized experimental results.

DNA structure and location

Results from DNA model exercise

TEACHER: What did we learn about DNA in the last lesson?

STUDENT: Double-stranded, anti-parallel, Adenine <--> Thymine and Guanine <--> Cytosine

TEACHER: Do bacteria have a nucleus?

STUDENT: No, they are prokaryotic and lack internal membranes

TEACHER: So, where do they keep their DNA?

STUDENT: Free, in the cytoplasm

Genes/Heredity

Results from continued incubation and colony size quantification

TEACHER: After continued incubation, what happens to the colonies in addition to getting bigger?

STUDENT: They kept the same properties (color, fluorescence)

TELLING: When a cell divides to form two identical daughter cells, it is considered one generation.

TEACHER: So, what is happening to the genes when the cells divide?

STUDENT: A copy of the gene is passed from one generation to the next.

Results from glow stick and food coloring experiments

TEACHER: Did adding glow stick or food coloring change the appearance of your colonies?

STUDENT: No

TEACHER: Why didn't these experiments have an effect on the appearance of the colonies?

STUDENT: The color or the glowing of the bacteria is a result of the new gene we inserted.

Overview (continued.)**Naive Conceptions**

Most students mistakenly believe that ...

Genes are small particles that make up chromosomes.

- Bacterial cells and human cells are the same
- Traits determine genes
- Traits and genes are the same thing
- Genes and DNA are completely different
- GM products are very positive or very negative
- All genes and / or mutations are inherited by future generations

TELLING: The colonies didn't look the way we wanted. We plated them on the agar with the glow stick or the food coloring. None of the colonies that we manipulated had the new gene and continued to look the same, demonstrating the nature heredity.

Student Activities

- **BUGS**: Teams complete *BUGs VI - Replication* investigation on anti-parallel, semi-conservative replication
- Teams read *What are Genes, Anyway?* (p. 38)
- CLASS DISCUSSION: Generalize results from *BUGS II - VI*, connect those results to the big ideas about genes
- STUDENT HOMEWORK: *Reflection* (p. 39)

Teacher Activities

- Observe and question teams as they complete *BUGs VI - Replication* investigation
- Facilitate discussion of *BUGS II - VI* and connect those results to the big ideas of the Genes subsystem

Assessing / Advancing Knowledge**Formative Assessment**

- Collect and assess *BUGs VI - Replication* (p. 37)
- CLASS DISCUSSION: Teams present *BUGs VI - Replication* answers to class
- HW: Copy *BUGs VI - Replication* and send home with students. Have students rank each completed *BUGs VI - Replication* form and discuss during next lesson.
- Post-Subsystem Quiz

Key Design Question(s)

If DNA replication was not semi-conservative, how would this impact your prototype?

RESPONSE: If DNA replication was conservative, then replication would not happen and cell division would not occur. If DNA replication was non-conservative, then replication would produce two additional pieces of DNA, resulting in excess genetic material.

Key Science Question(s)

How would you design a plasmid if you wanted to insert a new gene?

RESPONSE: Students should use their experiences with the DNA models to explain that DNA molecules are double-stranded and anti-parallel.

What are some differences and similarities between individual cells in a colony and a multicellular organism?

RESPONSE: Similarities: identical cells in colonies and organisms, cell # increases by cell division. Differences: The cells in a colony can live independently, cells of an organism usually cannot, no multicellular organisms are prokaryotic, multicellular organisms can have differentiated/specialized cells [due to control of gene expression]

How is cell division related to cloning? How is it different from the cloning that has resulted in Dolly the Sheep?

RESPONSE: Clones are offspring that have the same genetic makeup. Therefore, binary fission of bacteria is a type of natural cloning because the colonies contain genetically identical bacteria. Other types of asexual reproduction are also natural. Dolly the Sheep was the first cloned mammal which is a type of animal that does not clone itself naturally.

EXPRESSION AND EXPRESSION ENCORE SUBSYSTEMS

Lesson Flow

- Lesson 17:** Evaluate the brightness or color of the prototypes and brainstorm ways to enhance the trait
- Lesson 18:** Test the ideas that students developed in the previous lesson
- Lesson 19:** Connect to the big ideas of the Expression subsystem by analyzing and generalizing results from the *BUGs VII - Resucue* Investigation
- Lesson 20:** Consider the importance of correct transcription and translation in creating prototype designs
- Lesson 21:** Continue to consider the importance of correct transcription and translation in creating prototype designs when the effects of DNA mutations are encountered
- Lesson 22:** Consider the effects of gene enhancement and the ethical issues surrounding artificial enhancement
- Lesson 23:** Preparation of presentations and quiz questions for *Mini - Symposium II*
- Lesson 24:** Connect to the big ideas encountered so far in the Designer Bacteria unit by logically defending their prototypes to their peers

Literature Review Topics

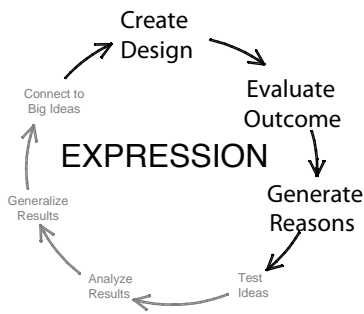
Set a number of articles, outside sources, product comparison, etc. to be read and summarized by each group member by the end of the subsystem (1 - 2 per person)

Suggested Topics:

- Transcription and Translation
- RNA
- Gene Expression
- Genetic Mutations
- Mutagens
- Heritability of Mutations

Lesson	Student Activities	Big Ideas	Written Work / Presentations	D-S Cycle	Storyline
17	<ul style="list-style-type: none"> Discuss how the science impacts the design <i>Open Lab</i>: Observe plates and record results, share design outcome with the class Generate reasons for the design outcome Develop ways to test reasons 	<ul style="list-style-type: none"> DNA is a double-stranded, anti-parallel molecular structure located in the bacterial cytoplasm that codes for genes. Genes can be turned on and off, depending on the environment, to produce gene products (proteins) that give rise to a characteristic. 	<ul style="list-style-type: none"> <i>Reflection</i> <i>Expression I</i> <i>Open Lab</i> 	Create Design Evaluate Outcome Generate Reasons	Expression
18	<ul style="list-style-type: none"> Jigsaw <i>BUGs V - Rescue</i> investigations <ul style="list-style-type: none"> Culture old colonies under ideal conditions Culture old colonies on enhanced agar <i>Open Lab</i>: Share predictions 		<ul style="list-style-type: none"> <i>BUGs VII - Rescue</i> <i>Open Lab</i> 	Test Ideas	
19	<ul style="list-style-type: none"> <i>Open Lab</i>: Observe plates and record results, share results with the class Generalize results, link to big ideas Telling: Link basic gene expression to the generalized experimental results Reflect on how the science impacts the design 		<ul style="list-style-type: none"> <i>BUGs VII - Rescue</i> <i>What is Expression, Anyway?</i> <i>Reflection</i> 	Analyze Results Generalize Results Connect to Big Ideas	
20	<ul style="list-style-type: none"> Read and discuss questions for <i>What is the Central Dogma, Anyway?</i> Complete <i>BUGs VIII - Decoding I</i> investigation 	<ul style="list-style-type: none"> The cell uses DNA as the blueprint for the proteins that give rise to a trait or characteristic. To make protein the cell transcribes a gene from the DNA into RNA and translates that RNA into the needed proteins. Mutations are mistakes in the DNA sequence that result in an incorrect protein and a range of cellular effects. 	<ul style="list-style-type: none"> <i>BUGs VIII - Decoding I</i> 	Create Design Evaluate Outcome	Expression Encore
21	<ul style="list-style-type: none"> Complete <i>BUGs IX - Decoding II</i> Read and discuss <i>Types of Mutations</i> 		<ul style="list-style-type: none"> <i>BUGs IX - Decoding II</i> <i>Types of Mutations</i> 	Create Design Evaluate Outcome Generate Reasons	
22	<ul style="list-style-type: none"> Complete <i>BUGs X - Enhancement</i> Teams present and summarize their <i>BUGs X - Enhancement</i> results Discuss how the enhancement investigation relates to the central dogma 		<ul style="list-style-type: none"> <i>BUGs X - Enhancement</i> 	Test Ideas Analyze Results Generalize Results Connect to Big Ideas	
23	<ul style="list-style-type: none"> Prepare for <i>Mini-Symposium II</i> Prepare quiz questions 		<ul style="list-style-type: none"> <i>Mini-Symposium II</i> transparencies 	Connect to Big Ideas Create Design	
24	<ul style="list-style-type: none"> <i>Mini-Symposium II</i>: Present team prototype Respond to quiz questions from teacher and peers Rate other teams' responses to quiz questions 				

Lesson 17: Introducing Basic Gene Expression



Overview

Big Idea(s)

DNA is a double-stranded, anti-parallel molecular structure located in the bacterial cytoplasm that codes for genes.

Genes can be turned on and off, depending on the environment, to produce gene products (proteins) that give rise to a trait or ability.

Lesson Goal(s)

Design and Science

Students gain exposure to the authentic scientific practice of collaboration as they analyze their design outcome, generate reasons for that outcome, and brainstorm ideas to test those reasons.

Materials

- Team Guide:
 - *Expression I* (p. 40)
- *Generate Reasons Table* Transparency
- Transformation plates
- *Expression Measure* (1/team)
- 5° C refrigerator (1/school)
- 10% bleach spray bottle (3/teacher)

Experimental Preparations

- Tetradecanol (T.2, T.3, T.4)
- N-(B-ketocaproyl)-DL-homoserine lactone (L.2, L.3, L.4)
- LB agar plates
- Sterile cotton swabs
- Refrigerator

Implementing This Lesson

CAUTION: TIME MANAGEMENT!!

Teacher or Students must prepare enhanced agars for tomorrow's lesson

Lesson Objective(s)

- Students will evaluate the brightness or color of their prototype and brainstorm ways to enhance the trait

Logistics

Students should record all observations.

Keep all plates refrigerated.

You will need to prepare the enhanced nutrient plates for the next lesson in advance. [*Nutrient Enhancement Protocol*, Appendix, p. 87] Alternatively, students could prepare the enhanced nutrient plates themselves (include enough time for drying).

Generate Reasons Discussion

Use one of the *Generate Reasons Table* transparencies to help facilitate this discussion. As teams share their design outcomes, they can be recorded in this table under the appropriate column. This format should help your students see the patterns of outcomes across teams.

- Guide students to the physical variables that might increase expression. Enhanced agar is the most logical idea to test next. *Refer students to pg. 16 as a hint.*

Student Activities

- Students share *HW - Reflection* with their teams (p. 39)
- **OPEN LAB:** Teams observe their plates, record design outcomes, and share design outcomes with the class
 - Rank color or glowing in comparison to *Expression Measure*
- **CLASS DISCUSSION:** Generate reasons for outcome and develop ways to test those reasons
- Complete *Expression I* (p. 40)

Teacher Activities

- Observe and question teams as they share their reflections and during Open Lab
- Facilitate *Generate Reasons Discussion* guiding student thinking to creative ways of improving their prototypes to meet their environmental requirements
 - Examples can be found in *Student Reasons and Investigations* (Appendix, p. 89)
- Introduce the *Expression Measure*
- Introduce available enhancements:

Tetradecanol	Homoserine Lactone
T.2 = 0.2 M	L.2 = 0.2 M
T.3 = 0.3 M	L.3 = 0.3 M
T.4 = 0.4 M	L.4 = 0.4 M

Overview (continued.)**Naive Conceptions**

Most students mistakenly believe that ...

- Genes and DNA are completely different
- Traits are only influenced by genes
- Genes carry miniature forms of the trait
- Traits may be acquired from the environment
- Gene expression does not involve protein synthesis

Assessing / Advancing Knowledge**Formative Assessment**

- Collect and assess *Expression I* (p. 37)
- **CLASS DISCUSSION:** Teams present *Expression I* answers to class
- Vocabulary Quiz

Key Design Question(s)

Does the design meet the specified needs and requirements?

RESPONSE: Students should evaluate how well their prototype met their specified needs and requirements. Students should justify their responses with data.

What are the reasons why you were or were not able to meet your specified needs and requirements?

RESPONSE: Students should be encouraged to brainstorm ideas for why they did or did not meet their requirements. These reasons should be ideas that can be tested. All ideas are valid initially, but as a class, students should narrow down to the most useful tests. The most useful test at this point will be related to nutrient supplement / enhancement.

Key Science Question(s)

What happened to the gene when the colonies stopped glowing?

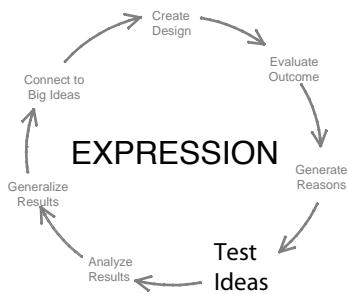
Why do the colonies seem bleached out? Is it the gene (DNA) or something else?

How do you think a cell uses the DNA to get to a trait or ability?

RESPONSE: Use these questions to assess ideas and conceptions that students may have about genes and gene expression. Ideas related to nutrients should be encouraged because they will be tested directly in the next set of BUGs investigations. Do not correct naive conceptions at this point, but offer challenges to those conceptions so that students realize that they will have to collect more data or learn more to answer those challenges.

Journal Space

Lesson 18: Testing Basic Gene Expression



Overview

Big Idea(s)

DNA is a double-stranded, anti-parallel molecular structure located in the bacterial cytoplasm that codes for genes.

Genes can be turned on and off, depending on the environment, to produce gene products (proteins) that give rise to a trait or ability.

Lesson Goal(s)

Design

By testing their ideas about DNA structure, and gene theory, students will be able to make better design choices for their prototype.

Science

By testing their ideas, students should be able to explain that genes produce something that results in a trait or ability.

Implementing This Lesson

Lesson Objective(s)

- Students will test the ideas that they developed in the previous lesson

Logistics

Jigsaw *BUGs VII - Rescue* over several groups, varying the concentration of N-[B-ketocaproyl]-DL-homoserine lactone and/or tetradecanol. Make sure each team records what supplement, concentration, and quantity they used.

Student Activities

- **BUGs:** Jigsaw *BUGs VII - Rescue* experiments with predictions
 - Culture old colonies under ideal conditions
 - Culture old colonies on enhanced agar
- **OPEN LAB:** Teams share predicted results for their *BUGs VII - Rescue* experiment with the class and begin p. 41

Teacher Activities

- Observe and question teams as they share their reflections and during Open Lab

Assessing / Advancing Knowledge

Key Design Question(s)

What part of your prototype are you manipulating? What are you trying to improve? How do you think these manipulations will impact your design as a whole?

RESPONSE: Students should evaluate how well their prototype met their specified needs and requirements. Students should justify their responses with data.

Based on the specified goals, constraints, and measurement criteria, which of the BUGs investigations do you think would be the most informative?

RESPONSE: Students should be encouraged to think about how the way their expression subsystem should work relates to the decisions that they make when creating their prototype. Students should be encouraged to think about how their requirements influence how they create their prototype.

Key Science Question(s)

What happened to the gene when the colonies stopped glowing?

RESPONSE: Use these questions to assess ideas and conceptions that students may have about genes and gene expression. Do not correct naive conceptions at this point, but offer challenges to those conceptions so that students realize that they will have to collect more data or learn more to answer those challenges. More detailed responses to these questions should be expected after students see the results of their BUGs investigation in the next lesson.

Optional Extension(s)

- Gene Enhancement
- Gene Regulation

Overview (continued.)**Materials**

- Team Guide:
 - *BUGs VII - Rescue* (p. 41)
- Transformant plates
- Fresh agar plates
- Enhanced plates (tetradecanol and N-[β-ketocaproyl]-DL-homoserine lactone)
- 30° and 37° C incubators (1/teacher)
- Refrigerator (1/school)
- Sterile toothpicks (1 pack/team)
- Biohazard waste container (1/team)
- 10% bleach spray bottle (1)
- Goggles (4/team)
- Gloves (2 pairs/team)

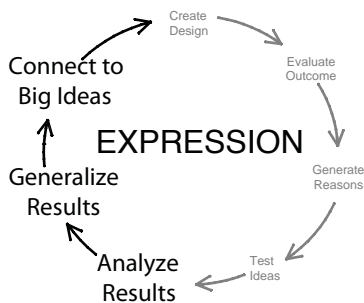
Naive Conceptions

Most students mistakenly believe that ...

- Genes and DNA are completely different.
- Traits are only influenced by genes.
- Genes carry miniature forms of the trait.
- Traits may be acquired from the environment.
- Bacteria have human tendencies.
- Gene expression does not involve protein synthesis.
- Traits determine the genes.
- Traits are the same as the genes.

Journal Space

Lesson 19: Concluding Basic Gene Expression



Overview

Big Idea(s)

DNA is a double-stranded, anti-parallel molecular structure located in the bacterial cytoplasm that codes for genes.

Genes can be turned on and off, depending on the environment, to produce gene products (proteins) that give rise to a trait or ability

Lesson Goal(s)

Design

By linking their generalized results to the big idea of basic gene expression, students will be able to save time and money in trouble shooting their prototype, if it should fade.

Science

By analyzing their results from the BUG tests and generalizing those results as a class, students should be able to connect to the big idea that genes can be turned on or off by molecules in their environment which result in gene products that give rise to a characteristic.

Materials

- Team Guide:
 - *BUGs VII - Rescue* (p 41-42)
 - *What is Expression, Anyway?* (p 43)
- *HW - Reflection* handouts (1/student)

Implementing This Lesson

Lesson Objective(s)

- Students will connect to the big ideas of the Expression subsystem by analyzing and generalizing their results from the *BUGs VII - Rescue* investigation

Background Information

Link genes, protein, and basic expression to the generalized experimental results.

Genes, protein, and basic expression

Results from *BUGs V - Rescue*

TEACHER: What happened when we re-plated a colony that was losing its desired characteristic on fresh or enhanced agar?

STUDENT: It was able to glow or be colored again.

TEACHER: Is the new gene still inside the cells, if they have lost their new trait?

STUDENT: Yes, once a gene is put in a cell it gets passed from one generation to the next.

TEACHER: Then why are the bacteria not expressing the gene?

STUDENT: Something to do with the environment.

TELLING: In the real world, bacteria use various molecules from their environment to tell them what genes need to be turned on or off. Not all genes are on/off at the same time. Your bacteria ran out of a particular nutrient that it required to express the new gene. The nutrients that you added to the growing environment of your bacteria are what caused the gene to be turned on again and the characteristic to return.

Logistics

Keep all glowing/colored transformants and other interesting results wrapped in plastic wrap and refrigerated.

Generalize Results Discussion

Use one of the *Generalize Results Table* transparencies to help facilitate this discussion. Encourage the students to take more leadership in identifying the important variables and how the class' data should be organized. As teams share their results, they can be recorded on the table. This format should help your students see the patterns of results across teams for the different investigations.

Student Activities

- **OPEN LAB:** Teams observe plates, record experimental results, and share experimental results with class
- **CLASS DISCUSSION:** Generalize experimental results, connect these results to basic gene expression
- Teams complete *BUGs VII - Rescue* (p 41-42) and evaluate their prototype with their requirements
- Student Homework: *Reflection* (p 44)

Overview (continued.)**Materials (continued)**

- *Generalize Results Table* Transparency
- Plates from previous lesson
- ~5° C Refrigerator (1/school)
- 10% bleach spray bottle

Naive Conceptions

Most students mistakenly believe that ...

- Bacterial cells and human cells are the same
- Genes and DNA are completely different
- All genes and / or mutations are inherited by future generations
- Traits may be acquired from the environment
- Gene expression does not involve protein synthesis
- Traits determine the genes
- Traits are the same as the genes
- All genes and / or traits in a cell are expressed at the same time
- The environment has no bearing on gene expression

Teacher Activities

- Observe and question teams as they share their reflections and during Open Lab
- **CLASS DISCUSSION:** Generalize results from *BUGS II - VI*, connect those results to the big ideas about genes
 - Telling: Link basic gene expression to the generalized experimental results and discuss *What is Expression, Anyway?* (p 43)
- Plastic wrap plates and refrigerate for long-term storage

Optional Extension(s)

- Cell differentiation

Assessing / Advancing Knowledge**Formative Assessment**

- Collect and assess *BUGsVII - Rescue* (p 41 - 42)
- **CLASS DISCUSSION:** Teams present *BUGsVII - Rescue* answers to class
- HW: Copy *BUGsVII - Rescue* and send home with students. Have students rank each completed *BUGsVII - Rescue* form and discuss during next lesson.

Key Design Question(s)

How can you objectively measure the brightness/color of your prototype? Do you need to apply this technique to meet the needs of your design?

RESPONSE: Students should consider using the *Expression Measure* to quantify brightness.

What are the reasons why you were or were not able to meet your specified needs and requirements?

RESPONSE: Students should be encouraged to brainstorm ideas for why they did or did not meet their requirements. These reasons should be ideas that can be tested. All ideas are valid initially, but as a class, students should narrow down to the most useful tests. The most useful test at this point will be related to nutrient supplement / enhancement.

Key Science Question(s)

When a gene is turned off, what is it made of? Does it get passed on to the next generation the same way as if it were turned on?

RESPONSE: Based on the results of the BUGs investigation, students should see that genes can be turned on and off. Students should see that the gene is the same whether it is turned on or off because the genetic material in their BUGs investigation did not change, only the environment changed.

Can a cell have all of its genes turned on at the same time? Why or why not?

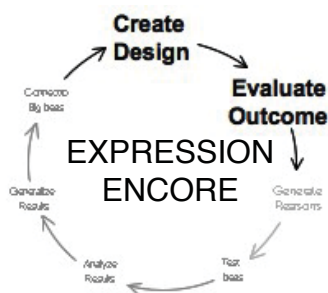
RESPONSE: Use this question to encourage students to think about gene expression and regulation on a deeper level. Students should start thinking about the process of the central dogma and how genes are regulated. Students should begin to consider how genes make a trait.

Is the environment important for predicting whether genes are turned on or off?

RESPONSE: Based on the results of the BUGs investigation, students should be able to see that the environment is an important variable in determining whether genes are turned on or off.

Journal Space

Lesson 20: Decoding DNA Sequences without Mutations



Overview

Big Idea(s)

The cell uses DNA as the blueprint for the proteins that give rise to a trait or characteristic.

To make protein, the cell transcribes a gene from the DNA into RNA and translates that RNA into the needed protein.

Mutations are mistakes in the DNA sequence that result in an incorrect protein and a range of cellular effects.

Lesson Goal(s)

Design

By learning how to decode DNA sequences, students should be able to see how important the processes of transcription and translation are in the proper expression of the gene in their prototype.

Materials

- Team Guide:
 - *BUGs VIII - Decoding I* (p. 47)
 - *What is the Central Dogma, Anyway?* (p. 45 - 46)
- DNA transcription/translation models

Implementing This Lesson

Lesson Objectives

- Students will consider the importance of correct transcription and translation in creating their design

Background Information

Central Dogma

In this lesson, describe each process by comparing and contrasting RNA structure to DNA structure, elaborating on different types of RNA, and the location in the cell where each process takes place. REMEMBER: we are with dealing prokaryotes that have no nucleus. Make sure the students keep this in mind, these processes are very similar in eukaryotes, only more complicated.

DNA Transcription / Translations Models

Within each kit are enough materials to work through the process of transcribing DNA into mRNA and then from mRNA into a protein on a ribosome.

Demonstrate the process of transcription and translation with the kits for the class. Encourage students to complete their BUGs investigation in teams, provide support as necessary.

During this lesson, stress the process of information flow and probe for understanding. Make explicit that both transcription and translation are highly regulated and efficient processes that must occur together in order for a protein (trait or characteristic) to be seen.

Student Activities

- Class Discussion: Read and discuss questions for *What is the Central Dogma, Anyway?* (p 45 - 46)
- Teams complete *BUGs VIII - Decoding I* (p 47)

Teacher Activities

- Facilitate class discussion of *What is the Central Dogma, Anyway?* (p 45 - 46)
- Introduce students to DNA kits. (Students will use the non-mutated sequence for this exercise)
- Observe and question teams as they work through *BUGs VIII - Decoding I* (p 47)

Assessing / Advancing Knowledge

Formative Assessment

- Collect and assess *BUGs VIII- Decoding I* (p 47) and / or *What is the Central Dogma, Anyway?* (p 45 - 46)
- CLASS DISCUSSION: Teams present *BUGs VIII- Decoding I* and / or *What is the Central Dogma, Anyway?* answers to class

Overview (continued.)**Naive Conceptions**

Most students mistakenly believe that ...

- Genes and DNA are completely different
- Traits determine the genes
- Gene expression does not involve protein synthesis
- Traits are the same as the genes

Key Design Question(s)

Based on the specified goals, constraints, and measurements criteria, is your current prototype the best you can do? How would you improve it?

Does the design meet the specified needs and goals?

What requirements does the design meet? What still needs work?

RESPONSE: Using the success of their prototypes and the results of their BUGs investigations, students should be able to respond logically to these and other design questions posed in the unit to this point.

Key Science Question(s)

How does a cell express a trait?

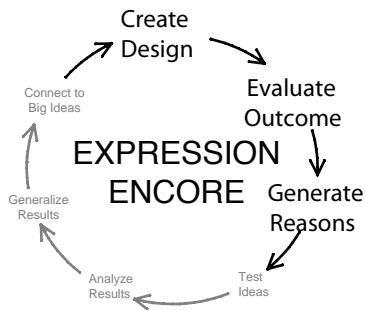
RESPONSE: After completing the BUGs investigation, students should begin to see that genes code for a trait through the central dogma. A gene in the DNA is transcribed into RNA and that RNA is translated into protein, which gives rise to a trait or characteristic.

What part of the central dogma turns RNA into protein? DNA into RNA?

RESPONSE: Translation. Transcription.

Journal Space

Lesson 21: Decoding DNA Sequences with Mutations



Overview

Big Idea(s)

The cell uses DNA as the blueprint for the proteins that give rise to a trait or characteristic.

To make protein, the cell transcribes a gene from the DNA into RNA and translates that RNA into the needed protein.

Mutations are mistakes in the DNA sequence that result in an incorrect protein and a range of cellular effects.

Lesson Goal(s)

Design

By learning how to decode DNA sequences with mutations, students should see that gene expression requires both transcription and translation and that mutations might occur anywhere in the process and may effect the way their prototype works.

Materials

- Team Guide:
 - *BUGs IX - Decoding II* (p. 48)
 - *Types of Mutations* (p 49 - 50)
- DNA transcription/translation models
- *Generalize Results Table* transparency

Implementing This Lesson

Lesson Objective(s)

- Students will continue to consider the importance of correct transcription and translation in creating their design when they encounter the effects of DNA mutations and how mutations may effect their prototype

Logistics

During this lesson, stress the process of information flow and probe for understanding. Make explicit that both transcription and translation are highly regulated and efficient processes that must occur together in order for a protein (trait or characteristic) to be seen.

Generate Reasons Discussion

Use one of the *Generate Reasons Table* transparencies to help facilitate this discussion. As teams share their design outcomes, they can be recorded in this table under the appropriate column. This format should help your students see the patterns of outcomes across teams.

Guide students to the physical variables that might increase expression. Enhanced gene expression is the most logical idea to test next.

Student Activities

- Teams complete *BUGs IX - Decoding II* (p 48) and share results with the class
- Class Discussion: Read and discuss questions for *Types of Mutations* (p 49 - 50)

Teacher Activities

- Introduce students to DNA kits. Students will use the mutated sequences (gray box) for this exercise
- Observe and question teams as they work through *BUGs IX - Decoding II* (p 48)
- Facilitate class discussion of *Types of Mutations* (p 49 - 50)
- Facilitate Generate Reasons Discussion guiding student thinking to creative ways of improving their prototypes to meet their environmental requirements
 - Examples can be found in *Student Reasons and Investigations* (Appendix, p. 89)

Assessing / Advancing Knowledge

Formative Assessment

- Collect and assess *BUGs IX- Decoding II* (p 48) and / or *Types of Mutations* (p 49 - 50)
- CLASS DISCUSSION: Teams present *BUGs IX- Decoding II* and / or *Types of Mutations* answers to class

Overview (continued.)**Naive Conceptions**

Most students mistakenly believe that ...

- Genes and DNA are completely different
- Traits are only influenced by genes
- Genes carry miniature forms of the trait
- Traits may be acquired from the environment
- Gene expression does not involve protein synthesis
- Traits determine the genes
- Traits are the same as the genes
- All mutations are inherently good or bad

Key Design Question(s)

Based on the specified goals, constraints, and measurements criteria, is your current prototype the best you can do? How would you improve it?

Does the design meet the specified needs and goals?

What requirements does the design meet? What still needs work?

How might you utilize mutations in your prototype? What mutations might be useful for reaching your design requirements?

RESPONSE: Using the success of their prototypes and the results of their BUGs investigations, students should be able to respond logically to these and other design questions posed in the unit to this point.

Key Science Question(s)

How does a cell express a trait?

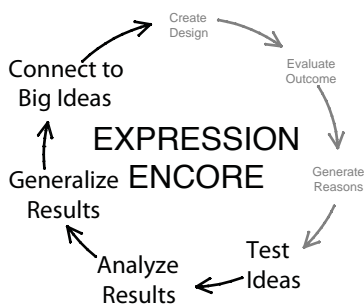
RESPONSE: After completing the BUGs investigation, students should begin to see that genes code for a trait during the central dogma. A gene in the DNA is transcribed into RNA and that RNA is translated into protein, which gives rise to a trait or characteristic.

What happens if the cell makes a mistake in replication? How does this affect transcription? Translation?

RESPONSE: That mistake, called a mutation, is passed on to future generations. In future generations, this mutation is transcribed and translated like any other gene. This mutation could change the cell's traits.

Journal Space

Lesson 22: Enhancing Transcription and Translation



Overview

Big Idea(s)

The cell uses DNA as the blueprint for the proteins that give rise to a trait or characteristic.

To make protein, the cell transcribes a gene from the DNA into RNA and translates that RNA into the needed protein.

Mutations are mistakes in the DNA sequence that result in an incorrect protein and a range of cellular effects.

Lesson Goal(s)

Science

By analyzing data from transcription and translation enhancement tests, students should be able to see that both transcription and translation must be manipulated simultaneously to enhance or inhibit expression.

Materials

- Team Guide:
 - *BUGs X - Enhancement* (p. 51)
 - *BUGs X - Enhancement Results* handouts (1/team)

Implementing This Lesson

Lesson Objective(s)

- Students will consider the effects of gene enhancement and the ethical issues surrounding artificial enhancement

Background Information

The data included in *BUGs X* are fictitious. They were created to illustrate the potential changes in concentration of DNA, mRNA, and cellular protein when transcription and/or translation are enhanced.

BUGs X includes three proteins: A, B, and C. Protein A is the desired protein, i.e., the hot pink pigment. Protein B is an undesired, but harmless protein that has a sulfur-like scent. Protein C is an undesired and harmful protein representing BoTox. Exposure to BoTox, also known as botulism toxin, causes paralysis of the nervous system. High concentrations of this protein in the culture will kill the cells and may harm the environment around the cells.

BUGs X was designed so that students can consider both positive and negative effects of genetic engineering.

Logistics

There are seven sets of data. Distribute one set of data to each team within a class. These sets of data show enhancement of transcription, translation, both and neither.

Process	Data Set	Reason
Neither (Transcription Nor Translation)	Set 4	No significant difference between Control data and Experimental data for any molecule.
Transcription Only	Set 3	Increase in mRNA concentration with steady protein concentrations.
Translation Only	Set 5	Steady protein concentrations with the decrease of mRNA concentration.
Both (Transcription and Translation)	Sets 1, 2, 6, 7	Steady mRNA concentration with the increase of protein concentrations.

If there are not six groups within a class, additional sets of data can be discussed across the entire class after each group presents their findings.

Student Activities

- Teams read and complete *BUGs X - Enhancement* (p 51)
- CLASS DISCUSSION: Teams present and summarize their *BUGs X - Enhancement* results

Overview (continued.)**Naive Conceptions**

Most students mistakenly believe that ...

- Genes and DNA are completely different
- Gene expression does not involve protein synthesis
- Traits determine the genes
- Traits are the same as the genes
- Mutations are always bad
- GM is always good or always bad
- All lab data is valid and accurate

Teacher Activities

- Orient students with the *BUGs X - Enhancement* data sheets.
- Observe and question teams as they work through *BUGs X - Enhancement* (p 51)
- Facilitate class discussion of results

Assessing / Advancing Knowledge**Formative Assessment**

- Collect and assess *BUGs X- Enhancement* (p 51)
- CLASS DISCUSSION: Teams present *BUGs X- Enhancement* (p 51) answers to class

Key Design Question(s)

Of the DNA, RNA and protein involved in the central dogma, which one(s), if any, might be best to enhance in order to reach the requirements of your prototype?

RESPONSE: Students should refer to their prototype requirements and justify their answers with data. Based on the results of the *BUGs* investigation, students will see that in order to enhance protein production in the cell, both transcription and translation must be enhanced. However, students may be satisfied with the current protein production of their prototype.

Key Science Question(s)

What happens when you enhance transcription and hold translation constant? Vice versa? What does this tell you about the central dogma?

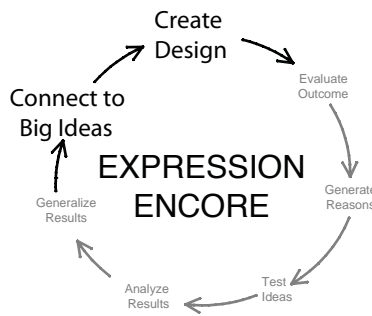
RESPONSE: Based on the results of the *BUGs* investigation, students will see that having more cells might not be the best way to see more expression. Encourage students to brainstorm other ways pertaining to enhancement of the central dogma.

What might be some negative effects of genetic engineering?

RESPONSE: Based on the results of the *BUGs* investigation, students will see that sometimes genetic engineering may produce harmful results. Students may be interested in discussing some of the ethical issues involved with genetic engineering.

Journal Space

Lesson 23: Preparing for Mini-Symposium II



Overview

Big Idea(s)

The cell uses DNA as the blueprint for the proteins that give rise to a trait or characteristic.

To make protein, the cell transcribes a gene from the DNA into RNA and translates that RNA into the needed protein.

Mutations are mistakes in the DNA sequence that result in an incorrect protein and a range of cellular effects.

Lesson Goal(s)

Design

By utilizing the knowledge gained from connecting to the big ideas of gene expression and the central dogma, students will be able to assemble a justifiable prototype presentation.

Science

By pulling together a presentation on their prototype students will connect with the big ideas of gene expression and the central dogma and apply the knowledge gained from previous subsystems.

Implementing This Lesson

Lesson Objective(s)

- Students will prepare their presentations and quiz questions for *Mini-Symposium II*

Background Information

This symposium format may be useful for student learning because the students will experience authentic scientific practice by logically defending their work to their peers.

Logistics

You can handle the team quizzes how you like. One strategy could include questions from each team in the audience after each presenting team has completed their presentation. Another strategy could include questions from the presenting team to each team in the audience. Both strategies will encourage student engagement and will allow you to assess and advance student thinking.

When all teams have asked their questions, you may want to ask additional questions as needed. Regardless of the specific organization of the mini-symposium, each team will ask each of the other teams a different question and rank the response.

Use the moves and practices that support accountability to Accurate Knowledge and Rigorous Thinking to during the presentations to assess and advance thinking (see Unit Overview, p. 9 and the Accountable Talk™ handouts for additional information).

Student Activities

- MINI-SYMPOSIUM II:
 - Teams read and complete *Mini-Symposium II* (p 52 - 53)
 - Teams prepare transparencies
 - Teams prepare quiz questions (p 54 - 56)

Teacher Activities

- Facilitate discussion of Mini-Symposium information (p 52)
- Observe and question teams as they work on their presentations

Assessing / Advancing Knowledge

Key Design Question(s)

Based on the specified goals, constraints, and measurements criteria, is your current prototype the best you can do? How would you improve it?

Does the design meet the specified needs and goals?

What requirements does the design meet? What still needs work?

RESPONSE: Using the success of their prototypes and the results of their BUGs investigations, students should be able to respond logically to these and other design questions posed in the unit to this point.

Overview (continued.)**Materials**

- Team guide:
 - *Mini-Symposium II* (p. 52-56)
- *Mini-Symposium II* transparencies for team presentations (1/team)
- Transparency markers

Naive Conceptions

Most students mistakenly believe that ...

- Good solutions are created on the first try and need no further improvements
- Initial failures indicate that the solution is not appropriate
- Failure means nothing was / can be learned
- The prototype must be perfect, or is currently perfect and needs no further improvement. Students may have difficulty seeing where their own prototype should be improved.
- Genes and DNA are completely different
- Traits may be acquired from the environment
- Gene expression does not involve protein synthesis
- Traits determine the genes
- Traits are the same as the genes
- Mutations are always bad
- GM is always good or always bad

Key Science Question(s)

What is happening in the cells if they stop glowing or get bleached out?

How does the environment impact the expression of the new gene?

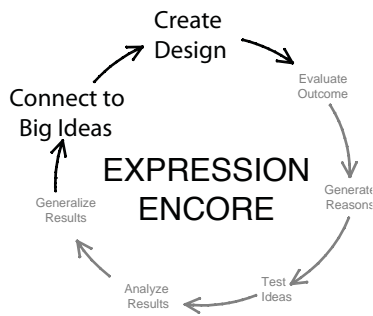
How does a cell express a gene?

RESPONSE: Using the results of their BUGs investigations and the success of their prototypes, students should be able to respond to these and other science questions posed in the unit to this point.

NOTE: Use the moves and practices that support accountability to Accurate Knowledge and Rigorous Thinking to encourage your students to ask create quiz questions that both assess and advance thinking (see Unit Overview, p. 9 and the Accountable Talk™ handouts for additional information).

Journal Space

Lesson 24: Mini-Symposium II



Overview

Big Idea(s)

The cell uses DNA as the blueprint for the proteins that give rise to a trait or characteristic.

To make protein, the cell transcribes a gene from the DNA into RNA and translates that RNA into the needed protein.

Mutations are mistakes in the DNA sequence that result in an incorrect protein and a range of cellular effects.

Lesson Goal(s)

Design

By presenting their prototype design in a mini symposium, students will experience authentic scientific practice of defending their work, resulting in a well thought out plan for prototype improvement.

Science

By defending their prototype in a symposium, students will connect with the big ideas of gene expression and the central dogma and apply the knowledge gained from previous subsystems.

Implementing This Lesson

Lesson Objective(s)

- Students will connect to the big ideas of the Designer Bacteria unit by logically defending their prototypes to their peers

Logistics

You can handle the team quizzes how you like. One strategy could include questions from each team in the audience after each presenting team has completed their presentation. Another strategy could include questions from the presenting team to each team in the audience. Both strategies will encourage student engagement and will allow you to assess and advance student thinking.

When all teams have asked their questions, you may want to ask additional questions as needed. Regardless of the specific organization of the mini-symposium, each team will ask each of the other teams a different question and rank the response.

Use the moves and practices that support accountability to Accurate Knowledge and Rigorous Thinking to during the presentations to assess and advance thinking (see Unit Overview, p. 9 for additional information).

Student Activities

- MINI-SYMPOSIUM II
 - Team presentations of prototype idea
 - After the presentation the Analytical Biologist should record any questions / comments regarding the team's prototype
 - Teams respond to quiz questions from teacher and peers
 - Teams evaluate other teams using their *Mini-Symposium II* questions and the rating guide
 - Teams consider revising their prototype based on feedback received during their presentation

Teacher Activities

- Facilitate discussion after each Mini-Symposium presentation
- Evaluate presentations

Assessing / Advancing Knowledge

Formative Assessment

- Collect and assess *Mini-Symposium II* (p 53 - 56)
- Develop a rubric to assess each teams presentation

Key Design Question(s)

Based on the specified goals, constraints, and measurements criteria, is your current prototype the best you can do? How would you improve it?

Does the design meet the specified needs and goals?

What requirements does the design meet? What still needs work?

RESPONSE: Using the success of their prototypes and the results of their BUGS investigations, students should be able to respond logically to these and other design questions posed in the unit to this point.

Overview (continued.)**Materials**

- Team Guide
 - *Mini-Symposium II* (p. 52-56)
- *Mini-Symposium II* transparencies for team presentations
- Transparency markers
- Overhead projector

Naive Conceptions

Most students mistakenly believe that ...

- Good solutions are created on the first try and need no further improvements
- Initial failures indicate that the solution is not appropriate
- Failure means nothing was / can be learned
- The prototype must be perfect, or is currently perfect and needs no further improvement. Students may have difficulty seeing where their own prototype should be improved.
- Genes and DNA are completely different
- Traits may be acquired from the environment
- Gene expression does not involve protein synthesis
- Traits determine the genes
- Traits are the same as the genes
- Mutations are always bad
- GM is always good or always bad

Key Science Question(s)

What is happening in the cells if they stop glowing or get bleached out?

How does the environment impact the expression of the new gene?

How does a cell express a gene?

RESPONSE: Using the results of their BUGs investigations and the success of their prototypes, students should be able to respond to these and other science questions posed in the unit to this point.

Journal Space

ENVIRONMENT ENCORE SUBSYSTEM

Lesson Flow

Lesson 25: Create a prototype under real world conditions

Lesson 26: Evaluate the prototype design and determine if the current design is successful in the 'real-world' and generate reasons why it was / was not successful

Lesson 27: Test the prototype modifications that were developed in the previous lesson

Lesson 28: Connect what has been learned during the BUGs investigations to the big ideas of cell division, replication, and mutations

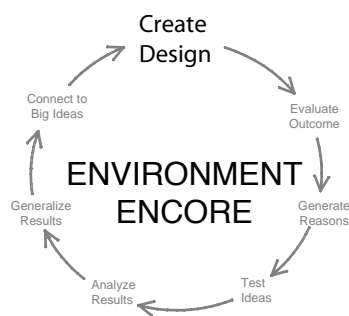
Lesson 29 (Multiple days): Synthesize the ideas and concepts encountered during this unit as they prepare both written and oral presentations off their prototype

CONGRATULATIONS!

YOU HAVE REACHED THE END OF THE UNIT!

Lesson	Student Activities	Big Ideas	Written Work / Presentations	D-S Cycle	Storyline
25	<ul style="list-style-type: none"> Culture bacteria under 'real-world' conditions <i>Open Lab</i>: share predictions 	<ul style="list-style-type: none"> To optimize cell division, the bacteria must be grown under the proper conditions. 	<ul style="list-style-type: none"> <i>Environment II</i> <i>Open Lab</i> 	Create Design	Environment Encore
26	<ul style="list-style-type: none"> <i>Open Lab</i>: Observe plates and record results, share design outcome with the class Generate reasons for design outcome Develop ways to test reasons 		<ul style="list-style-type: none"> <i>Environment II</i> <i>Open Lab</i> 	Evaluate Outcome Generate Reasons	
27	<ul style="list-style-type: none"> Jigsaw <i>BUGs XI - Real-World</i> investigations <ul style="list-style-type: none"> Test for growth when using more nutrients Test for growth when using insulation Test for growth after continued incubation Test for growth when using protective packaging <i>Open Lab</i>: Share predictions 	<ul style="list-style-type: none"> In order for the cells to divide and the colony to grow, the DNA in each parent cell must be replicated and a copy given to each daughter cell. Mutations are mistakes in the DNA sequence that result in an incorrect protein and a range of cellular effects. 	<ul style="list-style-type: none"> <i>BUGs XI - Real-World</i> <i>Open Lab</i> 	Test Ideas	
28	<ul style="list-style-type: none"> <i>Open Lab</i>: Observe plates and record results, share results with the class Generalize results, link to big ideas 		<ul style="list-style-type: none"> <i>BUGs XI - Real-World</i> <i>Open Lab</i> <i>How Do Genes and Environment Interact, Anyway?</i> 	Analyze Results Generalize Results Connect to Big Ideas	
29 (Multiple Days)	<ul style="list-style-type: none"> Preparation of presentations presentations <i>Patent Application</i> <i>Gallery Walk</i> 	<ul style="list-style-type: none"> Students should incorporate the Big Idea(s) of this unit into their presentations and patent applications. 	<ul style="list-style-type: none"> <i>Patent Application</i> <i>Gallery Walk</i> <i>Gallery Walk Evaluation</i> 	Create Design	

Lesson 25: Introducing the 'Real World' Environment



Overview

Big Idea(s)

To optimize cell division, the bacteria must be grown under the proper conditions.

In order for the cells to divide and the colony to grow, the DNA in each parent cell must be replicated and a copy given to each daughter cell.

Mutations are mistakes in the DNA sequence that result in an incorrect protein and a range of cellular effects.

Lesson Goal(s)

Design

By creating their design for the 'real-world', students will begin to appreciate the difficulties encountered during prototype development.

Materials

- Team Guide
 - *Environment II* (p. 57)
- Transformant plates
- Sterile toothpicks (1 pack/team)
- Wood
- Rubber
- Glass
- Aluminum foil

Implementing This Lesson

Lesson Objective(s)

- Students will create a prototype under real world conditions

Logistics

Students will be simulating the conditions that their prototype will have to withstand. This is where things get creative! Try to accommodate them as best as possible. There are two features that they can manipulate, incubation temperature and growth medium.

Students will need informed of how to work with media. Make sure students have a logical experimental design before proceeding.

Sample agar manipulation ideas:

- Uncultured, sterile agar can be melted down and . . .
 - repoured.
 - painted with sterile paintbrushes.
 - used to soak fabric.
 - kept warm to use instead of liquid broth.

Sample temperature ideas:

- Refrigerator: fall / winter outdoor temperature
- Lab bench: bedroom, household temperature
- Hot incubator (38° C - 42° C): Tropical temperatures

Sample growth media ideas:

- Aluminum foil: street sign, car
- Cloth: clothes, curtains, shoes
- Glass: windows, doors, dish ware
- Leather: skin, hair
- Rubber: tires, shoes, dish ware, sports equipment
- Wood: trees, doors, floors, furniture
- Ziploc bags: plastic materials

Student Activities

- Teams culture their transformants under 'real-world' conditions
- OPEN LAB: Each team shares predictions with class [5 minutes]
- Teams complete *Environment II* (p 57)

Teacher Activities

- Facilitate brainstorming on how students can meet the their prototype requirements in real-world conditions
 - Hint toward agar, temperature, growth media manipulations
- Chart student solutions to real-world prototype challenges
- Observe and question teams as they work through *Environment II* (p 57)

Overview (continued.)**Materials (cont.)**

- Cloth
- Leather
- Ziploc bags
- Empty petri dishes
- Other: _____
- Other: _____
- 30° C, 37° C, 42° C incubators
- ~5° C Refrigerator
- 10% bleach spray bottle (1/team)
- Biohazard waste container (1/team)
- Gloves (2 pair/team)

Naive Conceptions

Most students mistakenly believe that ...

- Genes carry miniature forms of the trait
- Traits may be acquired from the environment
- Bacteria have human tendencies
- Bacteria grow in the real-world in the same way as in the laboratory

Many students will ask the teacher how they should conduct their 'real world' tests. Encourage students to try whatever they think might be the most effective.

Assessing / Advancing Knowledge**Formative Assessment**

- Collect and assess *Environment II* (p 57)
- CLASS DISCUSSION: Teams present *Environment II* (p 57) answers to class

Key Design Question(s)

Does your design meet all of your requirements? Does your design work in the 'real-world'?

RESPONSE: Students should be encouraged to focus on the requirements related to how their prototype should function in the 'real-world'.

Key Science Question(s)

What do you predict will happen to your transformants under 'real-world' conditions? What does this tell you about cell division?

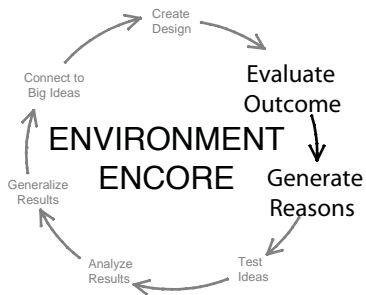
RESPONSE: Use these questions to assess ideas and conceptions that students may have about genes, gene expression, and the central dogma, and the how they interact with the environment. Offer challenges to naive conceptions, especially the conceptions that students would have investigated previously. By this point, students should be integrating what they have learned from the previous investigations to create their best prototype.

Journal Space

When you complete your journal entry, consider the following questions

- Is the timing appropriate? Were you able to complete the lesson in one class period?
- What were the students' reactions to the lesson? Were any components boring or too difficult for the students?
- Is there any additional information that you would have liked for us to provide to you during this lesson?
- What could you do next time to make this lesson more successful?
- What are your general comments?

Lesson 26: Investigating the 'Real-World'



Overview

Big Idea(s)

To optimize cell division, the bacteria must be grown under the proper conditions.

In order for the cells to divide and the colony to grow, the DNA in each parent cell must be replicated and a copy given to each daughter cell.

Mutations are mistakes in the DNA sequence that result in an incorrect protein and a range of cellular effects.

Lesson Goal(s)

Design

Students should be able to logically evaluate their plates from the previous lesson and generate plausible reasons for the outcomes.

Materials

- Team Guide
 - *Environment II* (p. 57-58)
- *Generate Reasons* transparencies
- Plates from previous lesson
- ~5° C Refrigerator (1/school)
- 10% bleach spray bottle (3/classroom)

Implementing This Lesson

Lesson Objective(s)

- Students will evaluate their prototype design and determine if their current design is successful in the 'real-world' and generate reasons why they were or were not successful

Background Information

Generate Reasons Discussion

Use one of the *Generate Reasons Table* transparencies to help facilitate this discussion. As teams share their design outcomes, they can be recorded in this table under the appropriate column. This format should help your students see the patterns of outcomes across teams.

Guide students to the physical variables that might increase bacterial growth. Protective packaging, insulation, and varied incubation are the most logical ideas to test next.

Student Activities

- OPEN LAB: Teams observe plates, record experimental results, and share experimental results with class
- CLASS DISCUSSION: Generate reasons for design outcome and develop ways to test ideas
- Teams complete *Environment II* (p 57-58)

Teacher Activities

- Observe and question teams during the Open Lab as they complete *Environment II* (p 57)
- Facilitate Generate Reasons Discussion guiding student thinking to creative ways of improving their prototypes to meet their environmental requirements
 - Examples can be found in *Student Reasons and Investigations* (Appendix, p. 89)

Assessing / Advancing Knowledge

Formative Assessment

- Collect and assess *Environment II* (p 57-58)
- CLASS DISCUSSION: Teams present *Environment II* (p 57-58) answers to class

Key Design Question(s)

What are the reasons why you were or were not able to meet your specified needs and requirements?

RESPONSE: Students should be encouraged to brainstorm ideas for why they did or did not meet their requirements. These reasons should be ideas that can be tested. All ideas are valid initially, but as a class, students should narrow down to the most useful tests.

Was the rate of cell division occurring fast enough for your prototype?

RESPONSE: Students should use data to support their responses.

Overview (continued.)**Naive Conceptions**

Most students mistakenly believe that ...

- Genes carry miniature forms of the trait
- Traits may be acquired from the environment
- Bacteria have human tendencies
- Bacteria grow in the real-world in the same way as in the laboratory

Key Science Question(s)

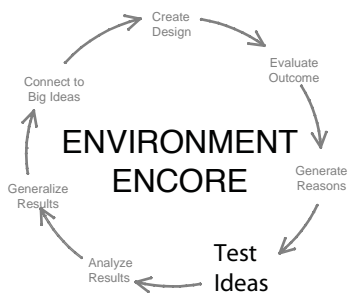
Why did or did not your transformants grow?

How would you go about manipulating the rate of cell division?

RESPONSE: Use these questions to assess ideas and conceptions that students may have about genes, gene expression, and the central dogma, and the how they interact with the environment. Suggestions about modifying the environment should be encouraged because they will be investigated in the next set of BUGs. Offer challenges to naive conceptions, especially the conceptions that students would have investigated previously. By this point, students should be integrating what they have learned from the previous investigations to create their best prototype.

Journal Space

Lesson 27: Testing Modifications in 'Real-World' Conditions



Overview

Big Idea(s)

To optimize cell division, the bacteria must be grown under the proper conditions.

In order for the cells to divide and the colony to grow, the DNA in each parent cell must be replicated and a copy given to each daughter cell.

Mutations are mistakes in the DNA sequence that result in an incorrect protein and a range of cellular effects.

Lesson Goal(s)

Science

By conducting these tests, students should be able to explain that as bacterial cells are dividing they have to accurately copy their DNA to keep their traits.

Materials

- Team Guide: *BUGs XI - Real World* (p. 59)
- Transformant plates
- Fresh enhanced plates
- Socks
- Oven mitts
- Aluminum foil
- Ziploc bags
- Saran wrap
- Empty petri dishes
- Other: _____
- Other: _____
- 30° C, 37° C, 42° C incubators
- ~5° C Refrigerator
- 10% bleach spray bottle (1/team)
- Biohazard waste container (1/team)

Implementing This Lesson

Lesson Objective(s)

- Students will test the prototype modifications that they developed in the previous lesson

Logistics

The BUGs investigations will take most of the class period, however if time permits each team should report their BUGs investigations and what they predict will happen.

Depending on your time constraints, you may want to allow students more than one day to conduct and develop more tests for their prototype.

By this point, students may begin to see that the type of bacteria used in this unit (i.e., *E. coli*) or other parts of their prototype might not be appropriate for their final prototype design. This is okay. Encourage students to consider what changes they would have to make if they had more resources and time. For example, students might suggest that they need to genetically modify bacteria that live on skin to create a prototype that was used on the skin.

Student Activities

- Teams begin *BUGs XI - Real World* (p 59)
- **BUGs:** Jigsaw *BUGs XI - Real-World* investigations
 - Test for growth when using more nutrients
 - Test for growth when using insulation
 - Test for growth after continued incubation
 - Test for growth when using protective packaging
- **OPEN LAB:** Share predicted experimental results with class

Teacher Activities

- Observe and question teams during *BUGs XI - Real-World* (p 59)
 - Encourage students to begin considering what changes they might make if given more time and resources

Assessing / Advancing Knowledge

Formative Assessment

- Collect and assess *BUGs XI - Real-World* (p 59)
- **CLASS DISCUSSION:** Teams present *BUGs XI - Real-World* (p 59) answers to class
 - Good class discussion about prototype modifications at this point should result in a deeper understanding of what is necessary for a successful prototype

Key Design Question(s)

Based on the specified goals, constraints, and measurement criteria, how do the results of the BUGs investigations help you improve your prototype?

RESPONSE: Students should be encouraged to think about how the way their *Environment* subsystem should work relates to the decisions that they make when creating their prototype. Students should be encouraged to think about how their requirements influence how they create their prototype.

Overview (continued.)**Naive Conceptions**

Most students mistakenly believe that ...

- Traits may be acquired from the environment
- Bacteria grow in the real-world in the same way as in the laboratory
- The prototype is not good because it does not use the most appropriate bacteria or because not all of the requirements have been addressed.

Key Science Question(s)

Do you think that your bacteria will be able to grow under 'real-world' conditions in the same way that they grow in the lab?

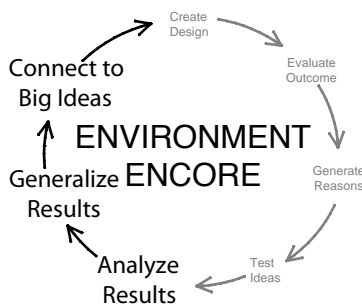
What will your bacteria require so that they can continue to express the desired characteristic(s) in the 'real-world'?

What are some reasons why your transformants might stop expressing the desired characteristic(s) when they are grown in the 'real-world'?

What happens to the gene/DNA when your bacteria stop expressing the desired characteristic(s)?

RESPONSE: Use these questions to assess ideas and conceptions that students may have about genes, gene expression, and the central dogma, and the how they interact with the environment. Offer challenges to naive conceptions, especially the conceptions that students would have investigated previously. By this point, students should be integrating what they have learned from the previous investigations to create their best prototype.

Lesson 28: Concluding the 'Real-World' Environment



Overview

Big Idea(s)

To optimize cell division, the bacteria must be grown under the proper conditions.

In order for the cells to divide and the colony to grow, the DNA in each parent cell must be replicated and a copy given to each daughter cell.

Mutations are mistakes in the DNA sequence that result in an incorrect protein and a range of cellular effects.

Lesson Goal(s)

Design

By linking their generalized results to the big idea of replication, students will be able to develop prototypes that could be successful in the 'real-world'.

Science

By analyzing the results from their BUG tests and generalizing those results with those from other BUG experiments, students should be able to connect to the big idea that when cells divide they must accurately copy their DNA to pass on their traits to the next generation.

Implementing This Lesson

Lesson Objective(s)

- Students will conclude the Environment Encore subsystem by connecting what they have learned during their BUGs investigations to the big ideas of cell division, replication, and mutations

Background Information

Link replication and cell division to generalized experimental results.

Replication and Cell division

Results from: 'Real-world' environmental variable manipulations

TEACHER: What do we already know about bacterial growth conditions?

STUDENT: They need the proper nutrients and need to be grown at an optimal temperature.

TEACHER: If we provide the cell with those two variables, what are the cells going to do?

STUDENT: They will divide at a rapid rate.

TEACHER: What is happening to the DNA in each cell when it is dividing?

STUDENT: Each cell is copying its DNA to pass on to the next generation.

TEACHER: How does replication occur? What significance does this have for your prototype?

STUDENT: [Describe process of DNA replication without errors] The process of replication must occur without errors in order for my transformants to continue to glow or be pigmented.

Logistics

Generalize Results Discussion

Use one of the *Generalize Results Table* transparencies to help facilitate this discussion. Encourage the students to take more leadership in identifying the important variables and how the class' data should be organized. As teams share their results, they can be recorded on the table. This format should help your students see the patterns of results across teams for the different investigations.

Student Activities

- OPEN LAB:** Teams observe plates, record experimental results, and share experimental results with class
- Teams complete *BUGs XI - Real World* (p 59-60)
- CLASS DISCUSSION:** Generalize experimental results, connect these results to the key concepts using *How Do Genes and the Environment Interact, Anyway?* (p 61-62)

Teacher Activities

- Observe and question teams during Open Lab
- Facilitate class discussion linking BUGs investigations to the Big Ideas
 - Telling: Link replication and cell division to generalized results

Overview (continued.)**Materials**

- Team Guide:
 - *BUGs X - Real-World* (p. 59-60)
 - *How Do Genes and the Environment Interact, Anyway?* (p 61-62)
- 10% bleach spray bottle (3/ classroom)
- Plates from previous lesson
- ~5° C Refrigerator (1/school)
- *Generalize Results Table* transparency

Naive Conceptions

Most students mistakenly believe that ...

- Genes carry miniature forms of the trait
- Traits may be acquired from the environment
- Bacteria have human tendencies
- Bacteria grow in the real-world in the same way as in the laboratory

Assessing / Advancing Knowledge**Formative Assessment**

- Collect and assess *BUGs XI - Real-World* (p 59-60) and / or *How Do Genes and the Environment Interact, Anyway?* (p 61-62)
- CLASS DISCUSSION: Teams present *BUGs XI - Real-World* (p 59-60) *How Do Genes and the Environment Interact, Anyway?* (p 61-62) answers to class

Key Design Question(s)

What have you learned from the BUGs that you can use to improve your prototype?

RESPONSE: Students should justify their response with data.

Does the design meet the specified needs and requirements?

RESPONSE: Students should use the data to support their responses.

Based your investigations, which aspects of the design should be revised?

RESPONSE: Students should brainstorm their ideas about how else they might be able to manipulate their prototype. Encourage creativity and challenge naive conceptions where appropriate.

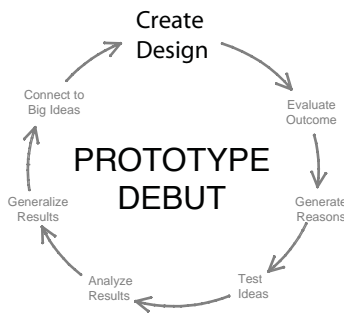
Key Science Question(s)

What are the key environmental variables that influence cell division?

RESPONSE: Temperature, availability and type of nutrients, as well as the length of incubation.

Journal Space

Lesson 29 (Multiple Days): Prototype Debut



Overview

Big Idea(s)

Students should incorporate the Big Idea(s) of this unit into their presentations and patent applications.

Lesson Goal(s)

Design and Science

Students should use their presentations and patent applications to describe how they designed their prototype, what their prototype does, and the science behind how their prototype functions.

Materials

- Team Guide
 - *What is a Patent Application?* (p. 63)
 - *Patent Application* (p. 64-65)
 - *Gallery Walk* (p. 66)
- *Gallery Walk Evaluation* handouts (1/student)
- Poster paper
- Poster markers

Implementing This Lesson

Congratulations! You've reached the end of the unit!

This is the FINAL LESSON.

Take as much time as needed to thoroughly complete the Patent Application and the Gallery Walk.

Lesson Objective(s)

- During the final lesson of the unit, students will synthesize the ideas and concepts encountered during this unit as they prepare both written and oral presentations of their prototype

Logistics

Patent Application

The *Patent Application* and the poster preparation can be completed simultaneously.

Gallery Walk

Before the *Gallery Walk* begins, teams should set up their posters around the room. Teams should divide up into pairs. One pair will act as curators, while the other pair will act as evaluators. These roles will switch half way through the *Gallery Walk*.

The evaluators will visit two other posters. They should spend about 5 minutes at each poster, asking enough questions to be able to complete the *Gallery Walk Evaluation* form for each poster that they visit. To reduce the work load, writing up the evaluations can be split between the pair of evaluators.

The curators present the team prototype and answer questions from the evaluators from other teams.

To make sure that every poster receives an equitable number of evaluations, it might work well to have the first pair of evaluators visit the posters that are one and two locations to the left of the team's poster. When roles switch, then the second group of evaluators should visit the posters that are one and two locations to the right of the team's poster.

Student Activities

- **CLASS DISCUSSION:** *What is a Patent Application?* (p 63)
- **PATENT APPLICATION:** Prepare and complete patent applications (p 64 -65)
- **GALLERY WALK:** Prepare posters (p 66)
 - Teams go on their class *Gallery Walk*
 - Teams complete *Gallery Walk Evaluation* handout for two posters

Teacher Activities

- Facilitate class discussion on *What is a Patent Application?* (p 63)
- Coach, observe and question teams during the preparation of Patent Applications and Gallery posters (p 64-66)
- Facilitate the Gallery Walk, explaining procedure and team roles (*Curator* and *Evaluator*)

NOTE: Use the moves and practices that support accountability to Accurate Knowledge and Rigorous Thinking during these lessons to assess and advance thinking (see Unit Overview, p. 9 for additional information).

Overview (continued.)

When you complete your journal entry, consider the following questions

- Is the timing appropriate? Were you able to complete the lesson in one class period?
- What were the students' reactions to the lesson? Were any components boring or too difficult for the students?
- Is there any additional information that you would have liked for us to provide to you during this lesson?
- What could you do next time to make this lesson more successful?
- What are your general comments?

Assessing / Advancing Knowledge**Formative Assessment**

- Collect and assess the patent application, posters and Gallery Walk Evaluations
- CLASS DISCUSSION: Teams present *BUGs X - Real-World* (p 59-60) *How Do Genes and the Environment Interact, Anyway?* (p 61-62) answers to class

Key Design Question(s)

Any questions from the previous lessons may be suitable here.

How do all of your subsystems work together so that your entire prototype works the way that you want it to work?

RESPONSE: Students should synthesize what they have learned about design during the entire unit to explain how their prototype works.

Key Science Question(s)

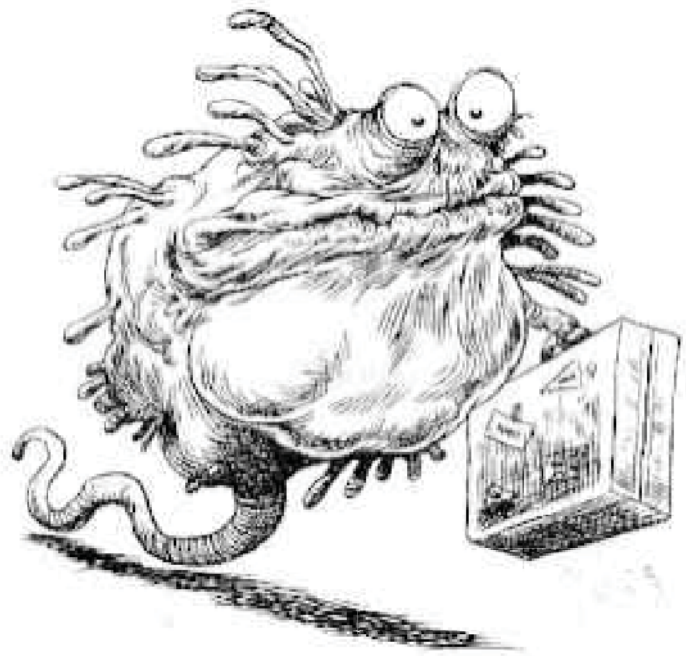
Any questions from the previous lessons may be suitable here.

What caused your bacteria to express different traits than when you started?

RESPONSE: Use these questions to synthesize the ideas and conceptions that students may have about genes, gene expression, and the central dogma, and the how they interact with the environment. Offer challenges to naive conceptions, especially the conceptions that students would have investigated previously.

Journal Space

DESIGNER BACTERIA



APPENDIX

Disposal of Contaminated Material

1. Prepare a 10% bleach solution in a bucket and distribute to teams in beakers.
 - 200 mL Bleach
 - 1800 mL Water
 2. Soak all contaminated materials in the bleach water for at least 24 hours before disposing in the garbage.
 - Suction water into all transfer pipettes
 - Open all plates and make sure they are completely submerged
-

Broth Culture Preparations

1. Add 5 mL of LB broth to 2 sterile 15 mL tubes.
2. Warm in water bath.
3. Inoculate each warm broth with one colony from XL1 or DH5 starter plate (< 10 days old).
 - Use the wooden end of a sterile swab to touch the colony.
 - Submerge the stick in the broth and snap off the cotten.
4. Incubate in tube rack in a 37° incubatore overnight.

Note: This amount will cover 5 transformations

5. Next day, subculture the overnight culture.
 - Add 5 mL of fresh LB broth to sterile 15 mL tube.
 - Inoculate with 0.25 mL of Overnight Culture.
 - Incubate in tube rack at 37° C for 45 - 90 minutes.
-

Nutrient Enhancement Protocol

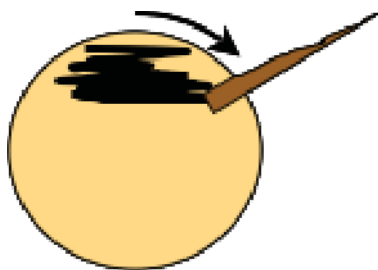
1. Determine a concentration gradient for each supplement, such as . . .

DL - Homoserine lactone hydrobromide (M.W. 182)		
Aliquot 1 (L 0.2)	Aliquot 2 (L 0.3)	Aliquot 3 (L 0.4)
Vol = 15 mL water	Vol = 15 mL water	Vol = 15 mL water
Mass = 0.5 g Homoserine	Mass = 0.8 g Homoserine	Mass = 1 g Homoserine
Conc = 0.2 M	Conc = 0.3 M	Conc = 0.4 M

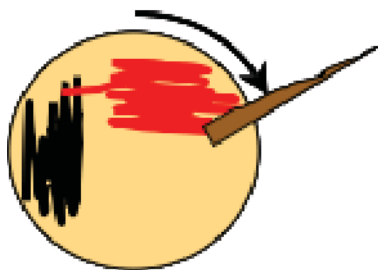
Tetradecanol (M.W. 214.39)		
Aliquot 1 (T 0.2)	Aliquot 2 (T 0.3)	Aliquot 3 (T 0.4)
Vol = 15 mL ethanol	Vol = 15 mL ethanol	Vol = 15 mL ethanol
Mass = 0.6 g Tetradecanol	Mass = 0.9 g Tetradecanol	Mass = 1.3 g Tetradecanol
Conc = 0.2 M	Conc = 0.3 M	Conc = 0.4 M

2. Prepare aliquots of each concentration of both supplements.
3. Label fresh LB plates with supplement and its concentrations.
4. Spread 1 mL of various concentrations tetradecanol on fresh LB agar plates.
5. Spread 1 mL of various concentrations of N-(B-ketocaproyl)-DL-homoserine lactone on fresh LB agar plate.
6. Allow supplement to dry, store inverted in refrigerator.

Dilution Streak Method



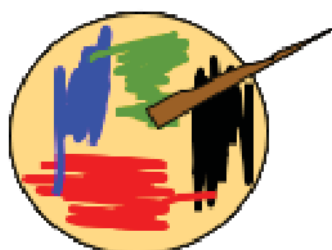
1. Glide the fat end of a toothpick back and forth across the agar surface to make several zigzags across the top of the plate. Avoid gouging the agar. Discard the toothpick in biohazard receptacle. Rotate the plate a quarter turn.



2. With fresh sterile toothpick, draw the fat end once through the primary streak and continue streaking a zigzag across the agar surface. Discard the toothpick in biohazard receptacle. Rotate the plate a quarter turn.



3. With fresh sterile toothpick, draw the fat end once through the secondary streak and continue streaking a zigzag across the agar surface. Discard the toothpick in biohazard receptacle. Rotate the plate a quarter turn.



4. With fresh sterile toothpick, draw the fat end once through the tertiary streak and continue streaking a final zigzag across the agar surface. Discard the toothpick in biohazard receptacle.

Example Student Reasons and Investigations

The Environment Subsystem

Design Task:

- Culture *E. coli* on various agars
- Culture *E. coli* in real-world conditions

Design Outcome:

- No growth

Reasons and investigations:

- Wrong growing conditions
 - Re-culture and look for trait under ideal growing conditions
- Not enough time for the bacteria to grow
 - Continue incubation
- The bacteria don't like my agar
 - Re-culture on different types of agar
 - Identify nutrient in different types of agar
- Need more nutrients
 - Change the nutrients
- Need insulation
 - Try different insulators
- Need protective packaging
 - Try different packaging

The Genes Subsystem

Design Task:

- Bacterial transformation with student selected plasmid

Design Outcome:

- Not all bacteria show the desired trait
- No growth

Reasons and investigations:

- Gene did not stick; Gene did not go into the right part of the cell
 - DNA model investigations
 - Other bacteria (i.e. without the gene) are growing
 - Explain purpose of antibiotic screen
- Adding fluorescent / pigmented material will make the non-glowing bacteria glow
 - Enhance agar with glow stick material
 - Adding the right dye will make the bacteria the right color
 - Enhance agar with food coloring
- Other reasons related to 'bacteria behavior', 'gender', etc.
 - Ruled out by the results of other investigations or through logical inference
- Experiment did not work / Procedural error
 - Repeat transformation

The Expression Subsystem

Design Task:

- Observe original transformation plates

Design Outcome:

- Colonies faded, i.e., less bright / colorful
- Colonies are not bright / colorful enough

Reasons and investigations:

- Wrong environmental conditions
 - Re-culture and look for trait under ideal growing conditions
- Bacteria need luminescent material added to agar to make them glow
 - Discuss previous glow stick experiment results and reject this by logical inference
- Bacteria ran out of glow material
 - Re-culture on nutrient gradient
- Bacteria can stop and start glowing
 - Transfer non-glowing bacteria to nutrient rich agar
- The bacteria have died
 - See whether a non-glowing ('dead') colony can grow and regain the trait
- Other reasons related to 'bacteria behavior', etc.
 - Ruled out by the results of other investigations or through logical inference
- Need more gene product
 - Manipulate transcription / translation
- Did not produce correct gene product (genetic code)
 - Investigate the genetic code

Transformation Kit Contents

Contents

- 1 Sharpie
- 2 1.5 mL tubes
- 1 tube subcultured cells
- 1 pack transfer pipettes
- 1 mL 1XTSS*
- 1 tube of plasmid* (each tube contains 8 μ L)
- 1 mL LB broth**
- 1 LB or LB/X-gal plate**
- 1 LB/amp or LB/X-gal/amp plate**
- 4 sterile swabs

Notes

* Keep in freezer or on ice until ready for use.

** Keep refrigerated until ready for use, for best results pre-warm plates and LB broth in an incubator prior to use.

Plasmid Maps

