Endeavor
STEM Teaching Certificate Project

Understanding antibiotic resistance

Grade: High school

AP Biology

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BIG IDEAS

KEY CONCEPTS in this lesson

1) Antibiotics are chemicals that kill bacteria or stop them from growing.
2) Some bacteria have genes that confer resistance to antibiotics. Bacteria may acquire these genes through mutations (less likely), transformation or through bacterial conjugation.
3) Bacteria undergo rapid growth in optimal conditions, such as when they have ample food or space, or when they are not treated with antibiotics.
4) When treated with an antibiotic, bacteria with genes that confer resistance to that antibiotic are more likely to survive, reproduce, and pass on their genes to offspring than bacteria without those genes are. If this process repeats over many generations, most or all bacteria in the population will become resistant to the antibiotic. This is an example of evolution by natural selection.

EDUCATION STANDARDS

NGSS, Common Core, or related State standards. Write out (or copy and paste) standards completely. Please identify the point when each standard is addressed in the 5E template below.

NGSS Performance Expectation(s)

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts:
Asking Questions and Defining Problems Asking questions and defining problems in 9-12 builds on K-8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and design problems using models and simulations. ● Ask questions that arise from examining models or a theory to clarify relationships. (HS-LS3-1) *Analyzing data in 9–12 builds on K–8 experiences and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.* ● *Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible. (HS-LS4-3)* ***Obtaining, Evaluating, and Communicating Information*** *Obtaining, evaluating, and communicating information in 9–12 builds on K–8 experiences and progresses to evaluating the validity and reliability of the claims, methods, and designs.* ● *Communicate scientific information (e.g., about phenomena and/or the*	***LS3.B: Variation of Traits*** **Environmental factors also affect expression of traits, and hence affect the probability of occurrences of traits in a population. Thus the variation and distribution of traits observed depends on both genetic and environmental factors. (HS-LS3-2),(HS-LS3-3)** **LS4.C: Adaptation** ● Evolution is a consequence of the interaction of four factors: (1) the potential for a species to increase in number, (2) the genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for an environment's limited supply of the resources that individuals need in order to survive and reproduce, and (4) the ensuing proliferation of those organisms that are better able to survive and reproduce in that environment. (HS-LS4-2) ● Natural selection leads to adaptation, that is, to a population dominated by organisms that are anatomically, behaviorally, and	*2. Cause and effect: Mechanism and explanation. Events have causes, sometimes simple, sometimes multifaceted. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated. Such mechanisms can then be tested across given contexts and used to predict and explain events in new contexts.*

process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically). (HS-LS4-1)	physiologically well suited to survive and reproduce in a specific environment. That is, the differential survival and reproduction of organisms in a population that have an advantageous heritable trait leads to an increase in the proportion of individuals in future generations that have the trait and to a decrease in the proportion of individuals that do not. (HS-LS4-3),(HS-LS4-4) • Adaptation also means that the distribution of traits in a population can change when conditions change. (HS-LS4-3) • Changes in the physical environment, whether naturally occurring or human induced, have thus contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline–and sometimes the extinction–of some species. (HS-LS4-5),(HS-LS4-6) • Species become extinct because they can no longer survive and reproduce in their altered environment. If members cannot adjust to change that is too fast or drastic, the opportunity for the species' evolution is lost. (HS-LS4-5)	

Common Core State Standards: *Use your state standards if Common Core is not applicable in your state. You are encouraged to list the CCSS and your state standards.* Math: *If applicable* ELA: *If applicable*
ITEEA Standards *(If applicable)*
Other Standards *(as needed)*

MEASURABLE STUDENT LEARNING OBJECTIVES

Students will be able to understand the concept of antibiotic resistance and how bacteria can acquire antibiotic resistance from either their environment or from other bacteria that have resistance (explaining horizontal gene transfer). Students can explain the concept of a plasmid and how it contains genes that can protect the bacteria from antibiotics. Students will also be able to explain how bacteria with the antibiotic resistant gene will populate and that the bacterial population will change over time to now have bacteria with plasmids that can break down a particular antibiotic. This is an example of evolution by natural selection.

Write the learning objectives as "students will be able to" statements. Be sure that your objectives are measurable and connect to the standards listed above. You are encouraged to use Webb's Depth of Knowledge to create action oriented objectives.

STEM INTEGRATION

The three subject areas this lesson plan will focus on is Science, Engineering and Math. The study of evolution by natural selection is an important concept for students to understand and applying it using the real-world application of antibiotic resistance will make this more relatable especially since bacteria reproduce quickly and generation times are shorter (making evolution take place in only as few as 1 generation). Students will model how antibiotic resistance can take place in the environment by simulating a mini-bag bacterial population that acquires different plasmids through different means of horizontal gene transfer (transformation, transduction or conjugation). Students will also plot their results and explore the concept of probability via the dice roll. They will also see how the probability of mutations causing bacterial resistance to antibiotics is much lower than horizontal gene transfer methods.

*Choose at least **TWO** of the following subject areas- Science, Technology, Engineering, or Math to address. Along with those subjects, please choose **at least one** other subject to integrate (any of the S- T- E -M- subjects, Art, Literacy, Social Studies, P.E., Music, etc.), for a total of **at least** three different subject areas. Please list them here.*

Clearly explain how each subject is integrated and how integration enhances students' understanding in each subject. Substantiate how practices will be developed within subjects. Why is the integration logical?

MATERIALS NEEDED

Hook activity

White board; markers; several different colored sticky notes (depending on how many groups assigned as each group should have their own color)

KWL handout or electronic version/student

Modeling how bacteria acquire antibiotic resistance activity

- 2 mini-plastic bags (1.5x1.5 bags)/student (60 for a class of 30)
- 2-3 mini-plastic bag (1.5x1.5) –this will be for the bacterial set-up (conjugation)
- 100 beads of each color: blue, green, red
    - 1 clear cup filled with ~20 blue beads/group
    - 2-3 mini-bags filled with green beads/group (represents conjugation)
    - about 20 red beads will be spread out on each group's table
- ~10 pink beads (it is unlikely you will need this many)
- 1-2 dice/group
- 1 Key dice roll handout/group

Simulating antibiotic resistance

- 1 inch hole puncher: found here at amazon: to make yellow and green circles. Alternatively you can use small circular chips (poker chips or even bingo chips as long as you sort it into two different colors)
    - Yellow construction paper
    - Green colored construction paper (or you can use any color except yellow)
- 1 paper bag/student
- Student handout “Arms race for a superbug” w/ tracking sheet

ENGAGING CONTEXT/PHENOMENON

Using the Harvard MEGA-plate antibiotic resistance model to show how antibiotic resistance can take place in a matter of only a few generations. Students will also look at another video (FRONTLINE) that introduced antibiotic resistance through the context of salmonella poisoning in chicken.

What are your engaging phenomena or your “hook” for the lesson? Be sure whatever you choose is appropriate for the subject area and grade level you are addressing. Several example phenomena are shared in course. Consider how observations of the natural world serve as phenomena to engage students in the content.

DATA INTEGRATION

Students are collecting data from their model as well as analyzing data from the CDC. They will examine the rate of antibiotic resistance that can arise in a given bacterial population. They will also compare their data with other students data in the class as well as the data they examined from the CDC.

What data is being used in this lesson? Are students analyzing or collecting data? What are they doing with the data? This would be a great place to include all the different NASA data made available to you. If NASA data is not appropriate for your lesson, speak to your course instructor to identify another source of data that is appropriate. It *may be publicly available, collected by students, or accessible to you with permission through other projects.*

TEACHER BACKGROUND KNOWLEDGE

Teachers should have a good background knowledge of what a plasmid is and why it is important for bacteria as well as the types of horizontal gene-transfer, the concept of antibiotic resistance and how evolution by natural selection can take place within only a few (or sometimes 1) generation.

What background information does the teacher need to effectively teach this lesson? If you can provide links to resources, please do so.

DIFFERENTIATION OF INSTRUCTION

Students will be able to use their personal computers at certain points in the lesson to take notes or to view (or rewatch) any of the posted videos for this lesson. Students will also be able to access the student handout that explains the background information and details of the Harvard Mega-plate experiment.

How can you adjust this lesson to meet the unique needs of students in your classes? What needs should be addressed? Think about and make these modifications PRIOR to the lesson so all students have the greatest ability to participate.

REAL-WORLD CONNECTIONS FOR STUDENTS

Students have all taken antibiotics at some point in their life. There is a real-life connection in that students are familiar with taking medicine and that antibiotics should be taken to its entirety–students have probably wondered why this is and this lesson addresses this issue.

Is the lesson culturally responsive? What teaching practices do you suggest? How will students connect to the lesson in their everyday lives?

INTEGRATION POSSIBLE MISCONCEPTIONS

Students might not understand how evolution by natural selection can take place and may think that an individual can evolve rather than populations evolving. Although on a microscale this can take place, I worry that this might confuse students when they are learning about macroevolution. One bacteria could technically evolve by acquiring genes via horizontal gene transfer. This is not how multicellular organisms acquire their own genes and therefore a multicellular organism cannot itself evolve. Rather, the organisms with the desired trait will survive and reproduce; causing the population itself to evolve. Making this concept clear throughout the lesson, as well as at the end of the lesson is important.

Are there any previous ideas or thoughts you anticipate students having about this concept? List them here as it will help you consider ideas to include in your lesson.

LESSON PROCEDURE

This is where you include each phase of the 5E. They should be extremely clear, well organized, and ready to be used by another educator. Be sure that each learning experience meets the guidelines for each "E". The template below will help you.

5E	Details of 5E Lesson Implementation
Engage *Introduce the lesson with an anchoring phenomenon. Facilitate student questions, discussion, etc. as appropriate. Learn about what students*	**Procedure:** show students the video of a giant petri dish and how antibiotic resistance evolved: https://www.youtube.com/watch?v=yybsSqcB7mE During this phase students are watching the video together as a class. The teacher will only show the first 45 seconds together and stop the video. The teacher will clarify the experimental setup and ask students if they have questions about the setup. Next, the teacher will ask students to make predictions as to what they are going to see by the end of the video. Then I want them to have a brief discussion with their partner/group member about their prediction and if they have any questions so far into the experiment. After this discussion, the teacher will show the remaining portion of the video. When the video is complete the

<table>
<tr>
<td>already know and want to know.</td>
<td>teacher will have students go back to their predictions and have a group discussion as to what they observed and if they found anything surprising. Students will next make a prediction as to why they think the results happened the way they did. This will then segue into a class discussion that is teacher facilitated. Giving a MEGA plate student handout (here is the google doc) to all students for background information may help some students who are not familiar with antibiotic resistance or who might need additional support in understanding the experiment.

Next students (in groups with their own color) will fill out a KWL chart and follow directions on this chart. Students will be given 3 minutes to address the first question and then the teacher opens up the discussion to the entire class. Next another 3 minutes are used to address Q2 and another 3 minutes for Q3.

1. What do I already know about antibiotic resistance:

2. What I wonder about antibiotic resistance:

3. What I learned about antibiotic resistance:

Teacher can also ask for a show of hands, how many students have either taken an antibiotic themselves or known someone who has? What was it for? Did it work? a. Note that students may not understand the differences between antibiotics, and vaccines. If time allows, briefly discuss these differences.

Next hook: show the first 6 minutes of “the Trouble with Chicken” https://www.youtube.com/watch?v=tlY7jxd7GAY

Have students write down any questions/comments they have after seeing this Frontline video.</td>
</tr>
</table>

	Modifications *S*tudents can use their own personal computer to watch the video at their own pace if needed. They can also take notes on their own personal device as well. The KWL chart can be provided electronically or it can be done on three sections of the board. Sticky notes can be provided; one for each group. **Standards Addressed** **Formative/Summative Assessments** *(How will you assess in each phase?)* **Resources** https://www.youtube.com/watch?v=yybsSqcB7mE *Resource for KWL chart* *MEGA Plate student background handout*
Explore *Plan for students to engage in hands-on activities that are designed to facilitate conceptual change.*	**Procedure:** Students will explore how resistance takes place in bacteria–this exploration will help students understand that mutations are not the only means that enable bacteria to acquire antibacterial resistance. They will also see how this plays a role in the evolution of bacteria with antibiotic resistant genes. **Part 1: Students will do independent exploration on the concept of antibiotic resistance and horizontal gene transfer** –prior to this lesson, students should know the differences between bacterial DNA and eukaryotic DNA (as well as cells). 1) They will watch this TedED video And take notes in their notebook. https://www.youtube.com/watch?v=znnp-Ivj2ek 2) Students will watch this video on horizontal gene transfer and take notes on the three major types: https://www.youtube.com/watch?v=8HDwayuWH0E 3) They will visit HHMI biointeractive on bacterial conjugation and take notes in their notebooks

	Part 2: Modeling how bacteria acquire antibiotic resistance.
	
	1. Distribute to each group a tray that contains the following:
	    a. 1 dice (die)
	    b. Copy of the key for Dice toss
	    c. 1 plastic cup containing blue beads inside (~10 or so)
	    d. 3-4 mini bags with green beads inside (~5 in each)
	    e. Approximately 10 loose red beads on each table. Each color bead represents a unique plasmid. The cup represents viral transmission of DNA (transduction), the mini-bag bacteria with green beads will represent conjugation and the loose red beads represent transformation. These colored beads are all plasmids that have genes that enable resistance to different antibiotics.
	    f. 2 mini-ziplock bags for each student
	2. Class is divided into several groups (3-5 people/group depending on the class size). Each group table will represent a community that the bacteria inhabit and each person will have 2 mini ziplock bags that each represent a bacteria. To start off, these bacteria will be empty of plasmids.
	
	good to note that bacteria already come equipped with their own unique plasmids however for simplicity we cannot show this for every mini-bag bacteria. This can be a discussion the teacher has before starting the activity. If the teacher wants to show this they can have a few white beads in the bags already to represent plasmids that do not carry genes for antibacterial resistance.
	
	3. Explain to students that beads represent plasmids (circular DNA) and that the colored beads are plasmids that contain genes that break down different antibiotics.
	4. Students now work as a group (can be individual if you have more dice) and each student rolls the die. Using the key for dice toss, they will modify their bacteria (they can choose to modify 1 or both of their bacteria with each toss). If they roll a 2 for example, they must select a red bead from off the table and place it in at least one of their mini-bacteria bags.

The 2 demonstrates transformation and that bacteria are picking DNA from their surroundings (you can ask students where they think this DNA might have come from in a real-world scenario).

5. If students get a pink bead tell them to raise their hand and the teacher can give this to them. The pink bead is hard to get and demonstrates that acquiring antibiotic resistance via mutation is also rare.
6. Teacher will also go around the room with a mini-bacteria bag filled with black beads; the teacher will randomly select a handful of students and give them a black bead. This black bead represents a different antibiotic resistant gene.
7. Students should continue this activity taking turns rolling the dice for at least 4 dice rolls (if time permits you can do more) and tell them to save their mini-bacteria bags after they are finished as it will be used for the next part.

Part 2: Natural Selection

1. Students will have their two mini-bacteria bags and using the key, they need to know what antibiotic(s) their bacteria is(are) resistant to.
2. Emphasize that the purpose of the model in Part 2 is to show how the use of antibiotics can lead to natural selection bacteria that are resistant to many types of antibiotics.
3. The teacher should read the Natural Selection textbox. To make Part 2 more active, have all students hold their mini-bacteria bags with beads and stand up. As the antibiotics are being introduced in each scenario, students whose model would not survive exposure to that antibiotic should sit down.
4. Have students work individually or as a group on Part 2.
5. Discuss the bacteria model they created. Do you think the model is an accurate way to represent what happens when antibiotics are used in chickens, other animals, and humans? What questions do you have about the model?

Part 3: Data integration

Have students use the sample size of their group to now plot on a graph the rate of antibiotic resistance genes that have been acquired through 4 rounds.What is the rate of antibiotic resistance for each antibiotic? What types of trends can students observe here?

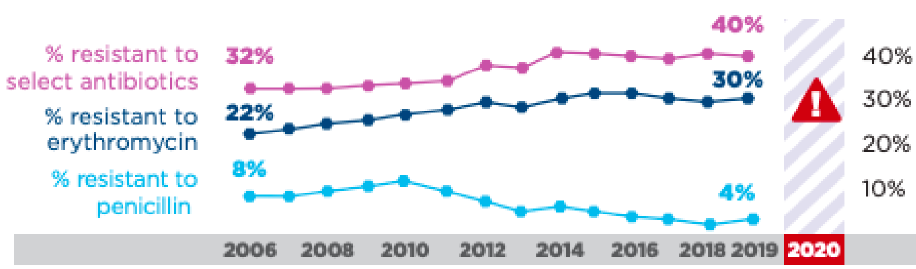
Next each group will access the CDC special 2022 report: https://www.cdc.gov/drugresistance/pdf/covid19-impact-report-508.pdf (or copies can be distributed to each group)

Each student will examine at least two graphs and come up with at least two questions they have about the graph. I will have each group examine the graph on page 24 and to note the trends they see. What questions do they have? I will have each group discuss the graphs each person selected and then open up the conversation to the class.

Resistance data for 2020 are not yet available because of delays in isolate submission and laboratory supply shortages, despite jurisdictions working tirelessly to maintain surveillance. The U.S. needs to continue building stronger public health infrastructure.

Drug-resistant *S. pneumoniae* is one of the only germs listed in this report with effective vaccines to prevent infections, including pneumococcal conjugate vaccines (PCVs). PCV has reduced pneumococcal infections caused by vaccine strains—most of which were resistant to antibiotics—by more than 90% in children and 60% in adults. Non-vaccine strains contribute to disease and resistance.

New vaccines will be critical for *S. pneumoniae* as resistance to some important antibiotics continues to increase.*



*Unable to compare data with 2019 report estimates, see Methods for details.

How does the data of their mini-bacteria bag activity differ from any of the trends they observe from the packet? Do they notice any similarities?

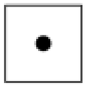
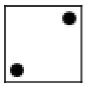
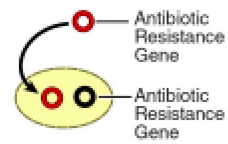
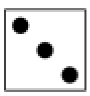
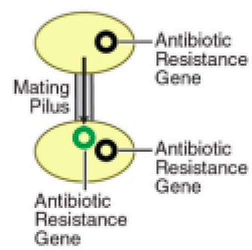
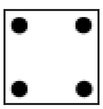
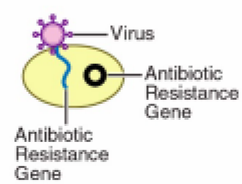
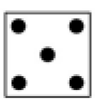
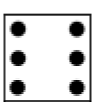
	—-- Ideas to add to this lesson plan (not finished here) *Part 4: structure and function of the prokaryotic vs eukaryotic cell* *Using microscopes students will examine prokaryotic and eukaryotic fixed slides and record their observations. At this time students will finish a Venn diagram that demonstrates the differences and similarities between these two cell types.* *Students will be exploring the very first antibiotic discovered: penicillin. Students are expected to take notes during their exploration. This will help reinforce their learning on osmosis and diffusion lesson* *Part 5: diffusion & osmosis activity and how it relates to penicillin. Modify (Not) sorry to burst your bubble* *(What happens during this phase? What is the teacher doing? What is the student doing?)* **Modifications** *(What student needs must be addressed? How can you make each experience accessible for ALL learners?)* **Standards Addressed** *(Which standards are being explicitly taught in this section?)* **Formative/Summative Assessments** *(How will you assess in each phase?)* **Resources** *(List all resources and materials used in this part of the lesson.)*

Explain *Facilitate opportunities for students to explain their understanding of concepts and processes and make sense of new concepts.*	**Procedure:** Each student will work on their Explain questions after completing the activity. Have students think-pair-share to identify the conditions necessary for natural selection in the model. Next each group will draw their graph on the whiteboard so that the class can see the different graphs that have been generated. This can be done on a large graph paper and posted around the class. Each group will present their findings as well as similarities/differences they observed from the CDC special report packet. **Modifications** *(What student needs must be addressed? How can you make each experience accessible for ALL learners?)* **Standards Addressed** *(Which standards are being explicitly taught in this section?)* **Formative/Summative Assessments** *(How will you assess in each phase?)* **Resources** *(List all resources and materials used in this part of the lesson.)*
Elaborate *Provide applications of concepts and opportunities to challenge and deep ideas; build on or extend understanding*	**Students will now demonstrate how antibiotic resistance can take place via a simulation using the entire class** **Procedure:** *See teacher handout* *and* *student handout* **Modifications** *students will be working individually and teacher will be present at all times to make sure to give the signal that round 1 begins. Teacher must be very active during this activity and making sure students are following directions* **Standards Addressed** *evolution by natural selection is being*

and skills.	*reinforced in this lesson* **Formative/Summative Assessments** *Students are working on the activity table as well as the post activity questions that directly address student understanding of the material* **Resources** *see handouts linked above*
Evaluate *Assess students knowledge, skills and abilities.*	**Procedure:** *Revisiting the KWL chart at the beginning of the lesson, students will fill out the "what I have learned" section of this chart. Next students will act as a newscaster/reporter and attempt to address all of the 'wonder' questions they had in a short 1 page report as well as what they learned from this lesson. This report will be written in the style of a newspaper and they are going to write the front page headline and story. The story will be based on what they have learned in this lesson (in particular the antibiotic resistance and how bacteria can acquire this). They should also mention the public health crisis that we are currently facing with AR bacteria.* *Teacher will address student questions as each student writes this report.* *When reports are finished, it will be copied and distributed as a packet for students to read.* **Modifications** *(What student needs must be addressed? How can you make each experience accessible for ALL learners?)* **Standards Addressed** *(Which standards are being explicitly taught in this section?)* **Formative/Summative Assessments** *(How will you assess in each phase?)* **Resources** *(List all resources and materials used in this part of the lesson.)*

Dice Roll handout

Key for Dice Roll: How Bacteria Get New Antibiotic Resistance Genes

	Your *Salmonella* does <u>not</u> gain any new antibiotic resistance genes. Do <u>not</u> add any new antibiotic genes to your *Salmonella*.
	During **transformation**, bacteria take up "free floating" genes that have been released from dead bacteria in their environment. Your *Salmonella* takes up a "free floating" **cephalosporin resistance gene** from the contents of the chicken's intestine. Add a red cephalosporin antibiotic resistance gene to your *Salmonella*. 
	During a simple mating process called **conjugation**, antibiotic resistance genes can be transferred from one bacterium to another. Your *Salmonella* mates with another bacteria that is living in the intestine of the chicken. That bacteria cell gives your *Salmonella* a **ciprofloxacin resistance gene**. Add a green ciprofloxacin resistance gene to your *Salmonella*. 
	During **transduction**, antibiotic resistance genes are transferred from one bacterium to another by a virus. A virus picks up an antibiotic resistance gene from bacteria that contain a **tetracycline resistance gene**. The virus then injects the gene into your *Salmonella*. Add a blue tetracycline resistance gene to your *Salmonella*. 
	**Mutations** that create new antibiotic resistance genes are extremely rare. If you roll a 5 on the dice, roll the dice three more times. If you roll 5's on all four rolls of the dice, add a pink **penicillin resistance gene** to your *Salmonella*. Mutations are <u>random</u> changes in genes. Mutations are not caused by exposure to antibiotics. They rarely lead to antibiotic resistance genes.
	Your *Salmonella* does <u>not</u> gain any new antibiotic resistance genes. Do <u>not</u> add any new antibiotic genes to your *Salmonella*.

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REFERENCES

University fo Rochester
https://www.urmc.rochester.edu/MediaLibraries/URMCMedia/life-sciences-learning-center/documents/TEACHER-Antibiotic-Resistant-Bacteria-6-22-22.pdf