LSLC Virtual Field Trip – Teacher Guide

Antibiotic-Resistant Bacteria

Virtual Field Trip Summary:

Students follow the story of Ajay, a 15-year-old boy who has a life-threatening case of food poisoning caused by antibiotic-resistant *Salmonella* bacteria. The virtual field trip investigation will guide students to explore complex questions: How did the bacteria become multidrug-resistant? How could the bacteria spread to humans, animals, plants, and the environment?

Core Concepts:

- Antibiotic use (for people, animals, or crops) can lead to bacteria that are resistant to multiple antibiotics.
- Illnesses caused by antibiotic-resistant bacteria are dangerous because they are difficult to treat.
- Bacteria can acquire new antibiotic resistance genes through mutation or through gene transfer from the environment, from other bacteria, and from viruses.
- Natural selection occurs when bacteria with genes for antibiotic resistance survive and become more common.
- A One Health approach would identify and seek solutions to the spread of antibiotic-resistant bacteria between people, animals, and the environment (e.g., water, soil, and plants).

Suggested Grade Levels: Grades 9 – 12

Time Required (approximately 135 – 145 minutes):

<u>Introduction</u>

Home Page Content – Video Introduction and Digital Lab Notebook downloads **15 minutes**

<u>Content</u>

Part 1: A dangerous *Salmonella* infection **15 - 20 minutes**

Part 2: The source of the outbreak **15 -20 minutes**

Part 3: How do bacteria become resistant to multiple antibiotics? **20 minutes**

Part 4: Natural selection and antibiotic-resistant bacteria **20 minutes**

Part 5: The spread of antibiotic-resistant bacteria **30-40 minutes**

Part 6: One Health and antibiotic-resistant bacteria **20-30 minutes**

<u>Extension Content</u>

Extension Activity – Mini Project to reinforce One Health concepts. **Time will vary.**

 This lesson was developed with support from the National Institutes of Health under Award Number R25GM132758. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.

Teacher Preparation:

Simulations of laboratory techniques are used. Consider discussing the importance of laboratory safety. Use this as an opportunity to review your school's Chemical Hygiene Plan and reinforce relevant laboratory safety procedures with your students. Online videos can be used as a visual review. Here is a link to an example: https://youtu.be/MEIXRLcC6RA

Materials/Supplies Overview:

1. Electronic devices for accessing the internet individually or in groups. Provide access to:
    - Google (Docs, Google Slides, Jamboard, etc.). If needed, convert these programs into another platform such as Microsoft products (Word, PowerPoint, etc.)
    - PowerPoint or similar digital program for making slides, or poster paper and markers.
2. Confirm that you have access to the **Antibiotic-Resistant Bacteria Virtual Field Trip** website. Click the link below to preview the virtual field trip to become familiar with the website:

    https://sites.google.com/view/outreachprogramsvft03/home
3. Link for **Digital Lab Notebook** that serves as an answer sheet, data collection tool, and record of their virtual lab activities. The Digital Lab Notebook can also be used for extra credit assignments. **Each student will need to make their own copy of the Digital Lab Notebook**:

    https://docs.google.com/presentation/d/1vujRfBD4VDSOWqadwqq_BIOWq8pSVcsCjuPuTR4AxEQ/copy

    Note: Provide the PowerPoint version of the **Digital Lab Notebook** for students who do not have access to Google Slides.

General Information:

1. Read Suggested Procedures section of this guide for each part.
2. Some parts of the virtual field trip have multiple videos embedded within the website. Play each video to preview information and content before use with students.
3. Answer Keys have been included in this Teacher Guide. Review the answer keys.
4. Share the link for the **Antibiotic-Resistant Bacteria Virtual Field Trip** with each student.
5. Share the link or provide printed copies of the **Digital Lab Notebook**.
6. Students can work individually or in pairs to complete this virtual field trip.
7. The virtual field trip can be completed within the time schedule preferred by the teacher. It should be completed in sequential order - Part 1, before Part 2, and so on.

(Optional) Parking Lot Suggestion:

The topic of this virtual field trip is rich enough to trigger conversations and questions that go beyond the immediate content in this lesson. Teachers may set up a "Parking Lot" for collecting student questions or ideas for additional connections/research. If participation in the virtual field trip is done with video conferencing formats, breakout rooms or a Google Jamboard can also be used for this Parking Lot Strategy in place of using sticky notes and poster paper.

Parking Lot Strategy

- Make a large poster paper or bulletin board area in the classroom as your Parking Lot.
- When students have a question or additional connection, have them write it on a sticky note and hand it to you or put it in the Parking Lot.
- Only answer questions immediately if they are essential for completing the lesson.
- Put sticky notes with other questions or connections in the Parking Lot.
- At the end of the lesson, review the Parking Lot questions.
- Remove questions that were answered by the lesson.
- Ask students which remaining questions and connections they would like to discuss.

(Optional) Team Science Suggestion:

Teachers can introduce the concept of **Team Science** if students will be working in groups. **Team Science** is a popular approach in research where large projects are divided among individuals as they work in one or more groups to solve problems. For more on team science: https://www.apa.org/science/about/psa/2013/04/team-science.

To promote additional student engagement during each part of the virtual field trip, a different set of students can volunteer or be assigned to the roles below. Alternatively, a set of students working in a small group can be assigned or given a role for their group. *If you identify additional roles for promoting student engagement, describe them in your Teacher Evaluation feedback.*

1. **Timekeeper:** Student who will keep track of time allowed and spend on each part. The teacher will provide the Timekeeper with the time limit for the virtual field trip part. The Timekeeper is given a physical timer to monitor time or is provided access to a clock. The Timekeeper should be given a printed copy of the Antibiotic-Resistant Bacteria Virtual Field Trip Log (see page xvii) and pencil or pen to record the actual time spent on the part. If more time is needed than allotted, the teacher can choose to provide more class time to finish, or direct students to complete the rest during out of school time. Timekeeper then announces to the class the total time that will be provided for the "Part" of the virtual field trip. For example, this can be done by saying,
    - *I am the Timekeeper for Part 1. Our 20 minutes for Part 1 begins now!*
    - *We have 5 minutes left in Part 1,*
    - *We have 1 minute left in Part 1,*
    - *Part 1 is finished, click the "Next Page" button on the bottom of your screen.*

2. **Recordkeeper:** Student who will remind the class to record their responses in their Digital Lab Notebooks following each question/activity. When the Timekeeper announces 5 minutes left, the Recordkeeper can follow the announcement by saying,

    - *Remember to record your data and observations in your Digital Lab notebook.*

    When the Timekeeper announces the end of Part 1, the Recordkeeper can say,

    - *Make you sure all Part 1 responses are in your Digital Lab Notebook.*

    Note: *For those using a Google Slide version, the Digital Lab Notebook is "autosaved" to the student account. If using a PowerPoint version of the Digital Lab Notebook, the Recordkeeper can also remind students to save the file. This will prevent loss of data. The following announcement can be made,*

    - *Click "save" in your Digital Lab Notebook before moving to the next part.*

Suggested Procedures (Parts 1-6):

<u>Homepage: Introduction</u>

1. Share the **Antibiotic-Resistant Bacteria Virtual Field Trip** website link with each student: https://sites.google.com/view/outreachprogramsvft03/home

    - Teachers can screen share to show students the website before the students work independently or in groups.
    - Teachers should direct students to watch the **Introduction Video** at the top of the **Homepage**. Dr. Alcéna-Stiner along with three Interns from the Life Sciences Learning Center, provide an overview for the field trip in the video. For this **Introduction Video** and all additional videos in the virtual field trip:
        - The teacher can play the video on a Smartboard or similar option to project the video for the entire class.
        - Make sure to turn audio on and adjust volume accordingly.
        - Students who are working independently have an option to read the text in the video and/or listen to the text being read aloud.
        - Students who do not want the audio in videos played can simply mute or adjust their audio volume.

    Note: some pages have an optional audio player that can be used for students to hear the text on the page or in a diagram read aloud.

2. Teachers should explain that the virtual field trip has **six parts**. Students are about to participate in **Part 1: <u>A dangerous Salmonella infection?</u>**
3. The virtual field trip can be completed within the time schedule preferred by the teacher. However, they should be completed in sequential order, Part 1, before Part 2, and so on.
4. The website will guide students through each part of the **An Outbreak of Antibiotic-Resistant Bacteria Virtual Field Trip**
    - If students are using a mobile device and not a computer, they may need to scroll downward or across to view content based on the size of their screen.
5. Students are given a link to download their own **Digital Lab Notebook** (see bottom of Homepage): https://docs.google.com/presentation/d/1vujRfBD4VDSOWqadwqq_BIOWq8pSVcsCjuPuTR4AxEQ/copy
    - Teachers can have students share their individual **Digital Lab Notebook** links for grading or extra credit for participating in the activities.

Part 1: A dangerous Salmonella infection (15 - 20minutes)

1. Teachers should explain that the virtual field trip has **six parts**. Students are about to participate in **Part 1: A dangerous Salmonella infection**
2. Students work individually or with their partner to complete Part 1.
3. Direct students to scroll down to read through the science comic and answer questions 1-4 in their Digital Lab Notebooks. If working with a partner or within groups, considering asking for student volunteers to read aloud to their partner(s).
4. Teacher or Recordkeeper reminds students to use their Digital Lab Notebook to record responses.
5. When Part 1 time ends or students have completed Part 1 responses to questions 1-4 in their Digital Lab Notebook, the teacher or Timekeeper reminds students to click "Next Page" at the bottom of the screen.
6. At the top of the new page, students are informed that they will start **Part 2** when their teacher gives access.
7. Students who finish Part 1 ahead of the class can keep learning on their own using the link(s) provided on this page.
    - **Centers for Disease Control and Prevention (CDC)** - One Health https://www.cdc.gov/onehealth/index.html
    - Teacher should tell students that this virtual field trip is based on a CDC investigation: **Outbreak of Multidrug-Resistant *Salmonella* Infections Linked to Raw Chicken Products** https://www.cdc.gov/salmonella/infantis-10-18/index.html

   Note: Exploring content from the link(s) provided will add additional time for the virtual field trip. Teachers with limited time can have students explore the link(s) outside of school time.

8. To begin Part 2, simply have student click "Next Page" at the bottom of the screen.

Part 2: The source of the outbreak (15 - 20 minutes)

1. Direct students to access Part 2 of the **Antibiotic-Resistant Bacteria Virtual Field Trip** website. Students can click "Next Page at the bottom of the current page or if they are returning to the website homepage have them select "Part 2" from the sidebar/dropdown menu on the left.
2. Direct students to scroll down to read through the science comic then answer questions 5-8 in their Digital Lab Notebooks. If working with a partner or within groups, considering asking for student volunteers to read aloud to their partner(s).
3. Tell students that they will need to use the information in the news article to complete the questions.
4. Students work individually to read the simulated news article. Using the instructions in their Digital Lab Notebook, they underline information that would help Ajay understand how he was exposed to the *Salmonella* that made him sick.
5. Next students should use the circle, box, or line to highlight the important information. Then answer the questions.
6. If they are working with a partner, consider:
    - Assigning one student in each pair to underline information that would help Ajay and the other student use the circle, box, or line to highlight the important information.
    - Having both students work individually. Then partners compare/discuss what they have underlined, highlighted, circled, or put in a box.
7. Teacher or Recordkeeper reminds students to use their Digital Lab Notebook to record responses.
8. When Part 2 time ends or students have completed Part 2 responses in their Digital Lab Notebook, the teacher or Timekeeper reminds students to click "Next Page" at the bottom of the screen.
9. At the top of the new page, students are informed that they will start **Part 3** when their teacher gives access.
10. Students who finish Part 2 ahead of the class can keep learning on their own using the link(s) provided on this page.
    - **Centers for Disease Control and Prevention (CDC) - One Health**
      https://www.cdc.gov/onehealth/index.html
    - **Video summary of a similar case**
      https://www.cdc.gov/foodsafety/patient-stories/AJ-salmonella.html
    - **Additional patient story videos**
      https://www.cdc.gov/foodsafety/patient-stories.html
    - **Centers for Disease Control and Prevention (CDC): Salmonella**
      https://www.cdc.gov/salmonella/index.html
11. To begin Part 3 simply have student click "Next Page" at the bottom of the screen.
12. After students have recorded all data in their Digital Lab Notebooks, they are directed to click "Next Page" on the bottom right of the screen.

<u>Part 3: How do bacteria become resistant to multiple antibiotics?</u> (20 minutes)

Note: The focus of this part should be on the concept that mutation is not the only way bacteria can become resistant to antibiotics. Bacteria can acquire antibiotic resistance genes from their environment, from viruses, and from gene exchange with other bacteria.

1. Direct students to access Part 3 of the **Antibiotic-Resistant Bacteria Virtual Field Trip** website. Students can click "Next Page at the bottom of the current page or if they are returning to the website homepage have them select "Part 3" from the sidebar/dropdown menu on the left.
2. Emphasize that the purpose of the modeling activity in Part 3 is to show how bacteria could become resistant to many types of antibiotics.
3. Explain that the cartoon illustrations in "The Story" and interactive "Activity" provide information that they will need to answer the questions (9-12) in their Digital Lab Notebooks.
4. Students can be encouraged to work with one or more partners to complete Part 3.
5. Direct students to read "The Story" cartoon first.
    - Ask students to volunteer to read the information in each text box of the cartoon aloud to the class, within their group or individually.
6. Student will use visual simulations in the "Mutation Roulette" activity. Some students may need additional assistance with the features requiring them to spin the wheel. Teacher should practice using a computer and handheld electronic device for Part 1 and Part 2 of the activity, if students will have access to both.
7. After reading "The Story" direct students to identify the following:
    - **Color Wheel**
    - **Key for Color Wheel**
    - Virtual **Dice (die)**
    - **Key for Dice Roll**
    - **Simulated *Salmonella* Bacteria Cell in Chicken Intestine** that contains **colored beads**.
8. Explain that the beads represent genes that make bacteria resistant to specific antibiotics.
9. Students can use Part 1 or Part 2 to make their models.
10. Using the mutations identified in Part 1 and or Part 2, students must drag and drop the resistance genes they got into their Simulated *Salmonella* bacteria cell. *Note: Each colored bead represents a resistance gene mutation.*
11. If students are working in a group, ask the group to select the model that represents the most dangerous *Salmonella* bacteria. They should explain their selection.
12. Encourage students to discuss the model with the following prompts: Do you think this model is an accurate way to represent what happens in the intestines of chickens, other animals, and humans? Why or why not? What questions do you have about the model?
13. Teacher or Recordkeeper reminds students to use their Digital Lab Notebook to record answers.
14. Teacher or Timekeeper reminds students to click "Next Page" at the bottom of the screen.

15. At the top of the new page, students are informed that they will start **Part 4** when given access from their teacher.
16. Students who finish Part 3 ahead of the class can keep learning on their own using the link(s) provided on this page.
    - **Centers for Disease Control and Prevention (CDC)** - One Health
      https://www.cdc.gov/onehealth/index.html
    - **Report: Antibiotic Resistance Threats in the United States 2019**
      https://www.cdc.gov/drugresistance/pdf/threats-report/2019-ar-threats-report-508.pdf
    - **CDC: Food Safety Videos**
      https://www.cdc.gov/foodsafety/communication/food-safety-videos.html#patient-stories
17. To begin Part 4 simply have student click "Next Page" at the bottom of the screen.
18. **IMPORTANT:** Data/answers from Part 3 will be used in Part 4. Remind students to check that they recorded the colors of the beads that were in the bacterial cell and what antibiotic resistance genes they represent.

<u>Part 4: Natural selection and antibiotic-resistant bacteria</u> (20 minutes)

1. Direct students to access Part 4 of the **Antibiotic-Resistant Bacteria Virtual Field Trip** website. Students can click "Next Page at the bottom of the current page or if they are returning to the website homepage have them select "Part 4" from the sidebar/dropdown menu on the left.
2. Students will use Digital Lab Notebook data from Part 3. They need to know to what antibiotics their bead model is resistant. Specifically, they need to recall the antibiotic resistance that was modeled using their simulated bacterial cell and colored beads.
3. Explain that the text boxes and illustrations in Part 4 provide information that they will need to answer the questions (13-19) in their Digital Lab Notebooks. They may read the questions first and then go back to the text boxes to look for the answers.
4. Emphasize that the purpose of the model in Part 4 is to show how the use of antibiotics can lead to natural selection bacteria that are resistant to many types of antibiotics.
5. To make Part 4 more active, have all students stand up. As the questions describe the introduction of antibiotics, students whose model would <u>not</u> survive exposure to that antibiotic should sit down. Alternatively, students may "raise hand" and "lower hand" in place of standing and sitting when using video conference programs during remote learning.
6. Students work individually or with a partner to complete Part 4.
7. If students are working in a class, ask the class to select the model that represents the *Salmonella* bacteria that will become most common if additional antibiotics are used on the farm. They should explain their selection.
8. Discuss the model. 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?
9. Teacher or Recordkeeper reminds students to use their Digital Lab Notebook to record responses.
10. Teacher or Timekeeper reminds students to click "Next Page" at the bottom of the screen.
11. The last page directs students to learn more using the links provided.
12. Students are informed that they will start **Part 5** when given access from their teacher.

Part 5: The spread of antibiotic-resistant bacteria **(30 minutes)**

1. Direct students to access Part 5 of the **Antibiotic-Resistant Bacteria Virtual Field Trip** website. Students can click "Next Page at the bottom of the current page or if they are returning to the website homepage have them select "Part 5" from the sidebar/dropdown menu on the left.
2. Explain that the cartoons in Part 5 provide information that they will need to answer the questions (20-22) in their Digital Lab Notebooks. They may read the questions first and then go back to the cartoons to look for the answers.
3. Ask a student to read the first cartoon aloud. Then ask an additional student to read the second cartoon aloud. Alternatively have students read both cartoons individually or within their groups.
4. Students must use the information in both cartoons to answer question 20.
5. Have students read the remaining cartoons using the same approach.
6. Questions 24 and 25 are interactive and must be completed using the **How Antibiotic-Resistant Bacteria Spread** picture in the Digital Lab Notebook.
7. Direct students to their Digital Lab Notebooks to answer questions 21 and 22.
8. Students must use the directions and tools in their Digital Lab Notebooks to draw arrows on the **How Antibiotic-Resistant Bacteria Spread** picture to represent each of the six statements (A-F) provided.
9. Have students label the arrow with the letter of the statement that it represents. As an example, the first statement has been shown on the picture using a red arrow and red "A".
10. Students work individually or with their partner to complete Part 5. Encourage them to ask you to check their work if they are not sure what they have done is correct.
11. Call on several students to share their answers to questions 20-22.
12. Teacher or Recordkeeper reminds students to use their Digital Lab Notebook to record responses.
13. Teacher or Timekeeper reminds students to click "Next Page" at the bottom of the screen.
14. The last page directs students to learn more using the links provided.
15. Students are informed that they will start **Part 6** when given access from their teacher.

<u>Part 6: One Health and antibiotic-resistant bacteria</u> (20 - 30 minutes)

1. Direct students to access Part 6 of the **Antibiotic-Resistant Bacteria Virtual Field Trip** website. Students can click "Next Page at the bottom of the current page or if they are returning to the website homepage have them select "Part 6" from the sidebar/dropdown menu on the left.

2. Explain that the cartoons and textboxes in Part 6 provide information that students will need to answer questions 23 and 24.

2. Direct students to read the cartoon at the top of the page followed by the information in the "**One Health**" box.
   - Ask a student to read aloud to the class. Alternatively, ask students to read the information individually or within a group.

3. Students may work with their partner(s) to complete question 23.
   - Direct students to review all data collected in their Digital Lab Notebooks throughout the virtual field trip to look for answers.

4. Have several students share their answer to question 23. It is important for students to have the correct answer before moving on to question 24.

5. Direct students to read the next cartoon followed by the information in the "**Community Resources**" box.
   - Ask a student to read aloud to the class. Alternatively, ask students to read the information individually or within a group.

6. Students may work with their partner(s) to complete question 24.

7. Direct students to the Digital Slide template in their Digital Lab Notebooks. Alternatively, students can create their own designs.

8. Students work with their partner(s) to design a Digital Slide. Consider modeling how to complete the Digital Slide by showing the students how they can insert data and information into the templates provided in their Digital Lab Notebooks.

9. Suggestion – Collect digital slides into one slide deck. Share this slide deck with the class. If you have ample class time, you may consider having students present and explain their slide.

10. Students receive full credit if their slide links Antibiotic-resistance to the health of humans, animals, and the environment.
    - Optional extension: Have students identify another example of a One Health problem. Have students use their idea to create a similar digital slide that explains why their example is a One Health problem.
    - After students have recorded all responses in their lab notebooks, they are directed to click Next Page on the bottom right of the screen.

11. The last page asks students to provide their feedback on this virtual field trip, using the **Antibiotic-Resistant Bacteria Virtual Field Trip Student Evaluation** form. Guide students to complete and submit the evaluation form.

    Student evaluation form:
    https://redcap.urmc.rochester.edu/redcap/surveys/?s=8EADKAW8XYHWRWA9

    Note: Students will be asked to "Enter your teacher's school email address." Provide students with the teacher's email address. Make sure students use and enter the correct email address.

12. The bottom of the last page directs students to learn more about One Health using the links provided as Online Resources.

13. Teachers are encouraged to provide feedback using the **LSLC Virtual Field Trip Teacher Evaluation** form.

    Teacher evaluation form: https://redcap.link/2022-LSLC-VFT-Teacher_Feedback

Suggested Online Resources:

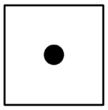
Links to additional resources are added after some parts of the virtual field trip. If you would like to, you could use them for additional asynchronous time for information discovery and reflection on concepts. Below is a full list of the ***Suggested Online Resources:***

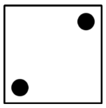
- This lesson is based on a CDC investigation.
  - **Outbreak of Multidrug-Resistant *Salmonella* Infections Linked to Raw Chicken Products**
    https://www.cdc.gov/salmonella/infantis-10-18/index.html
  - **CDC: Food Safety Videos**
    https://www.cdc.gov/foodsafety/communication/food-safety-videos.html#patient-stories
  - **CDC: Antibiotic Resistance**
    https://www.cdc.gov/drugresistance/index.html
  - **CDC: Salmonella**
    https://www.cdc.gov/salmonella/index.html
- **CDC: One Health**
  https://www.cdc.gov/onehealth/index.html

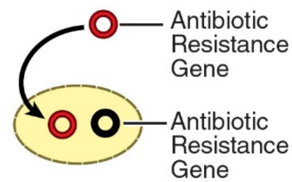
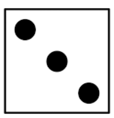
Scan the QR code with your smartphone or tablet camera app to link to a file with all the One Health websites.

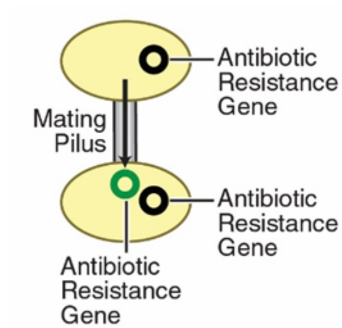
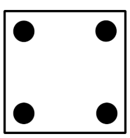
- **Antimicrobial Resistance & Multidrug Resistant Salmonella**
  https://cahfs.umn.edu/antimicrobial-resistance-multidrug-resistant-salmonella
- **Scientific American: How Drug-Resistant Bacteria Travel from the Farm to Your Table**
  https://www.scientificamerican.com/article/how-drug-resistant-bacteria-travel-from-the-farm-to-your-table/
- **New York Times: Deadly Germs, Lost Cures**
  https://www.nytimes.com/series/deadly-germs-lost-cures
- **FRONTLINE: The Trouble with Antibiotics**
  Consider showing these videos after students have completed this lesson.
  https://www.pbs.org/wgbh/frontline/film/trouble-with-antibiotics/
- **About AMR (Antimicrobial Resistance)**
  https://amr.biomerieux.com/en/about-amr/
- **Report: Antibiotic Resistance Threats in the United States 2019**
  https://www.cdc.gov/drugresistance/pdf/threats-report/2019-ar-threats-report-508.pdf
- **Questions and answers about Antibiotics in Chicken Production**
  https://www.nationalchickencouncil.org/questions-answers-antibiotics-chicken-production/
- **Answers to Common Questions about the Use of Antibiotics in Animal Agriculture**
  https://www.pewtrusts.org/en/research-and-analysis/articles/2017/11/answers-to-common-questions-about-the-use-of-antibiotics-in-animal-agriculture
- **American Psychological Association- Team Science**
  https://www.apa.org/science/about/psa/2013/04/team-science.

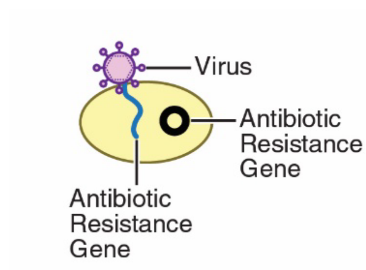
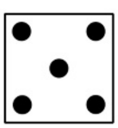
Key for Dice Roll: How Bacteria Get New Antibiotic Resistance Genes

<table>
<tr><td></td><td>Your Salmonella does <u>not</u> gain any new antibiotic resistance genes.

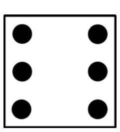
Do <u>not</u> add any new antibiotic genes to your Salmonella.</td></tr>
<tr><td></td><td>During transformation, bacteria take up "free floating" genes that have been released from dead bacteria in their environment. Your Salmonella takes up a “free floating” cephalosporin resistance gene from the contents of the chicken’s intestine. Add a red cephalosporin antibiotic resistance gene to your Salmonella.


</td></tr>
<tr><td></td><td>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.


</td></tr>
<tr><td></td><td>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.

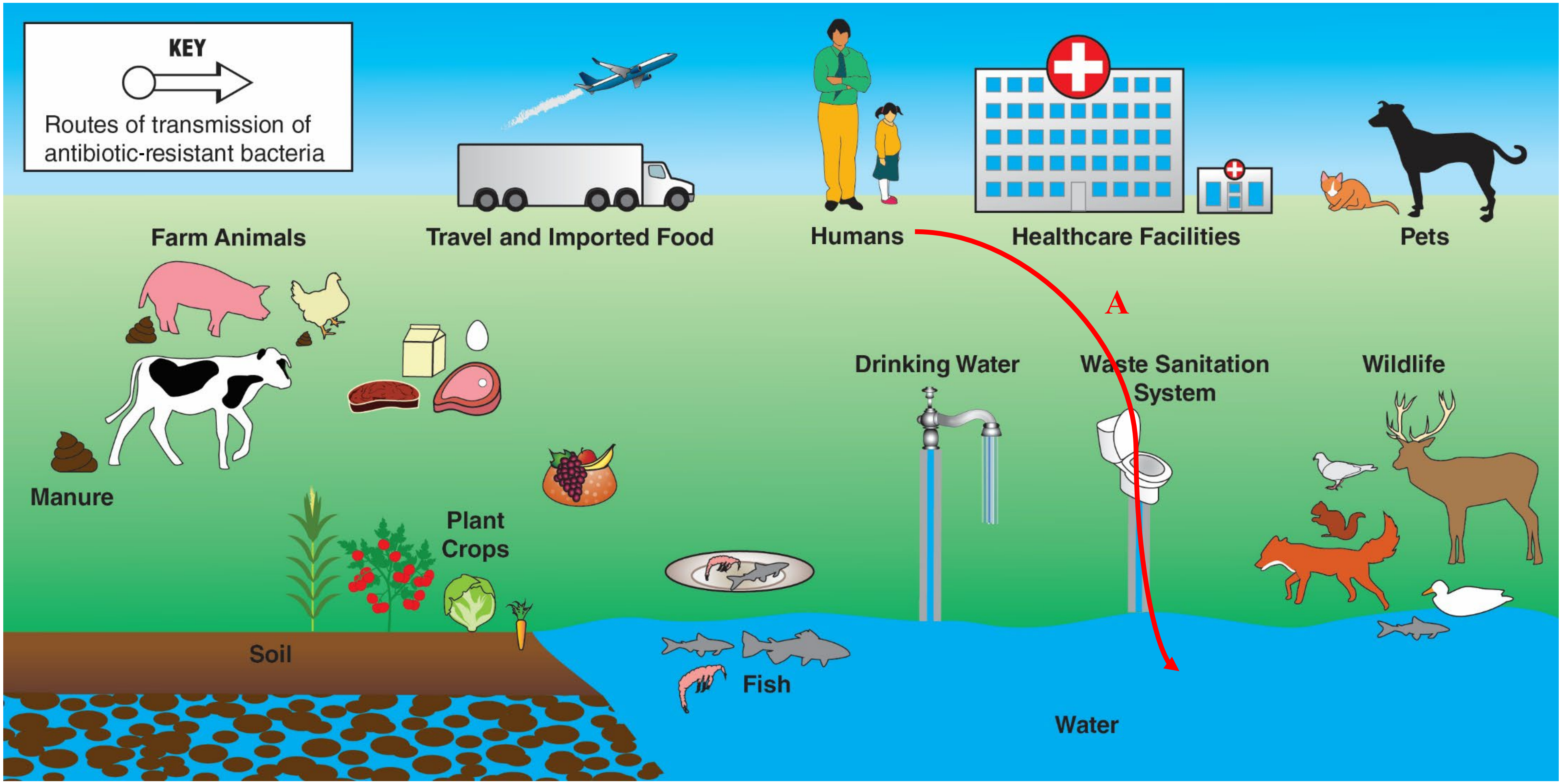

</td></tr>
<tr><td></td><td>Mutations that create new antibiotic resistance genes are extremely rare.

If you roll a 5 on the dice, roll the dice nine more times. If you roll 5’s on all ten rolls of the dice, add a pink penicillin resistance gene to your Salmonella.

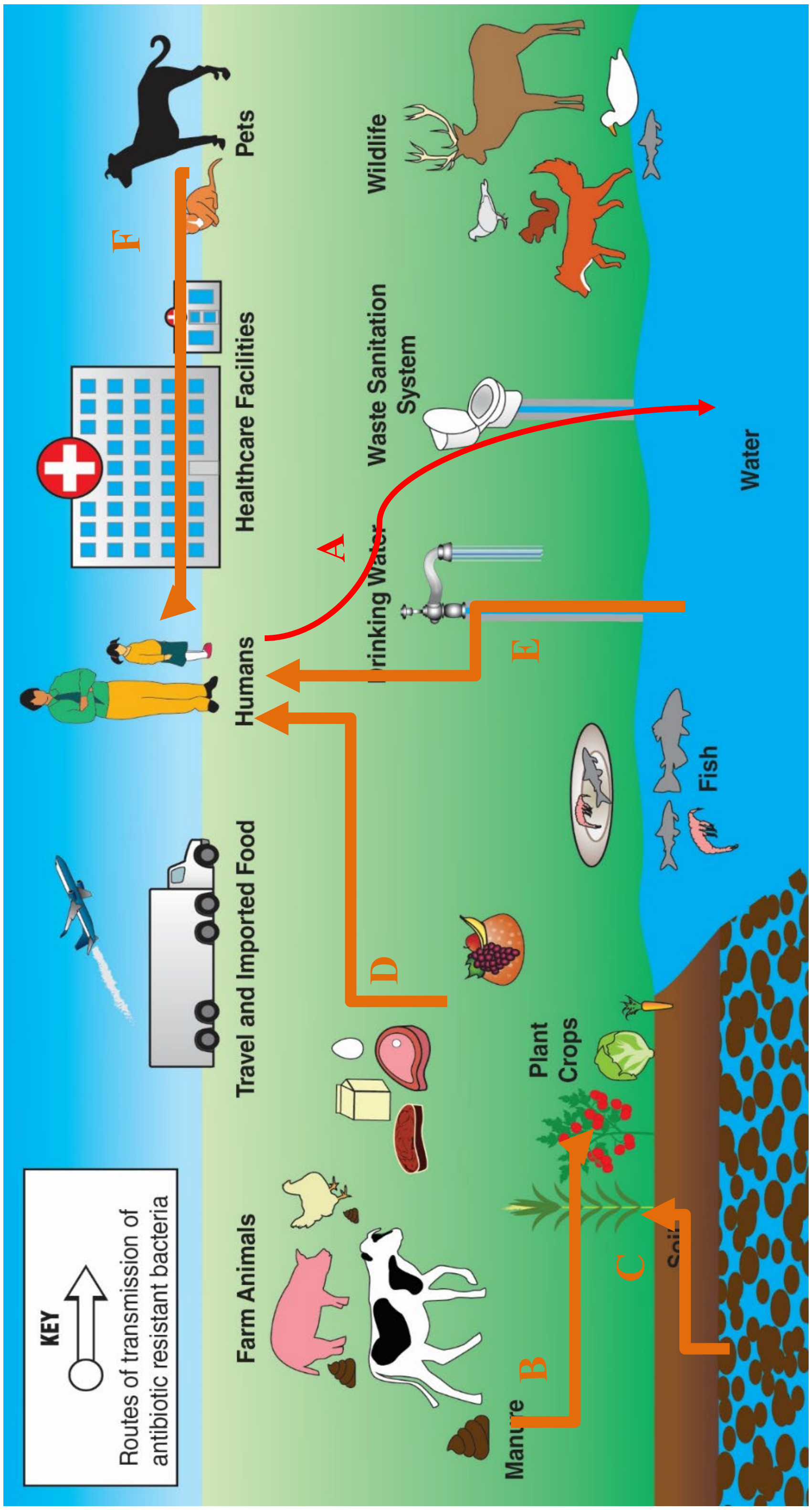
Mutations are <u>random</u> changes in genes. Mutations are not caused by exposure to antibiotics. They rarely lead to antibiotic resistance genes.</td></tr>
<tr><td></td><td>Your Salmonella does <u>not</u> gain any new antibiotic resistance genes.

Do <u>not</u> add any new antibiotic genes to your Salmonella.</td></tr>
</table>

How Antibiotic-Resistant Bacteria Spread



Teacher KEY for Part 5 Question 2



NGSS Correlation:

Working Towards Performance Expectations		
HS-LS4-3. Apply concepts of statistics and probability to support explanations that organisms with an advantageous heritable trait tend to increase in proportion to organisms lacking this trait. [Clarification Statement: Emphasis is on analyzing shifts in numerical distribution of traits and using these shifts as evidence to support explanations.] [*Assessment Boundary: Assessment is limited to basic statistical and graphical analysis. Assessment does not include allele frequency calculations.*]		
Science and Engineering Practices	**Disciplinary Core Ideas**	**Crosscutting Concepts**
1. 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.	• Natural selection occurs only if there is variation in the genes and traits between organisms in a population. Traits that positively affect survival can become more common in a population. • Natural selection leads to adaptation, that is, to a population dominated by organisms that are anatomically, behaviorally, and 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. • Adaptation also means that the distribution of traits in a population can change when conditions change.	• Students observe patterns in systems at different scales and cite patterns as empirical evidence for causality in supporting their explanations of phenomena. They recognize classifications or explanations used at one scale may not be useful or need revision using a different scale; thus requiring improved investigations and experiments. They use mathematical representations to identify certain patterns and analyze patterns of performance in order to reengineer and improve a designed system.

Antibiotic-Resistant Bacteria
ANSWER KEYS

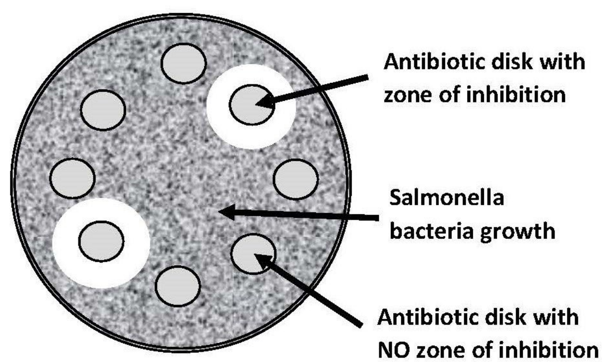
Part 1: A dangerous *Salmonella* infection

Base your answers to questions 1 through 4 on the information in the text box below.

For 15-year-old Ajay, a case of food poisoning caused by *Salmonella* bacteria became life threatening. Some of the *Salmonella* bacteria escaped from his intestine and caused a serious infection in his circulatory and urinary systems. Ajay was treated with azithromycin, a type of antibiotic that doctors usually prescribe for *Salmonella* infections. Unfortunately, that antibiotic did not work, and Ajay kept getting sicker.

Ajay's doctors ordered laboratory tests to determine which type of antibiotics might be effective in treating his bacterial infection. For these tests, disks with different antibiotics were placed on a growth medium in a lab dish. Then, a sample of *Salmonella* bacteria from Ajay was grown on the growth medium. The results of the tests are shown in the diagram below.

- If the *Salmonella* bacteria are killed by the antibiotic on the disk, a clear ring, called a zone of inhibition, will appear around the disk.
- If the *Salmonella* bacteria are resistant to (not killed by) the antibiotic on a disk, there is not a zone of inhibition around the disk.



1. Each disk contains a different type of antibiotic. Why do six of the antibiotic disks not have a zone of inhibition around them?

   Those disks have antibiotics that do not kill the bacteria.

2. How many of the antibiotics tested would be effective in treating Ajay's *Salmonella* infection? Support your answer with information from the diagram above.

   Only two of the antibiotic disks have zones of inhibition around them and could be used to treat Ajay's infection.

3. How can you tell that the *Salmonella* that infected Ajay are antibiotic-resistant *Salmonella*?

   Antibiotic resistant bacteria are bacteria that are not killed by one or more antibiotics. Most of the antibiotic disks had no zone of inhibition indicating that the bacteria are not killed by those antibiotics.

4. Explain why the lab report from Ajay's tests described the *Salmonella* that affected him as "multidrug-resistant" bacteria.

   There were only two antibiotic disks with zones of inhibition. That means that the bacteria are multi-drug resistant because they are resistant to the antibiotics in all of the other disks.

Part 2: The source of the outbreak

Luckily, doctors found two antibiotics that were effective in killing the *Salmonella* bacteria that made Ajay so sick. After Ajay was treated with these antibiotics, he slowly recovered and was released from the hospital. Ajay asked his doctors if they knew how he was exposed to the *Salmonella* that made him so sick. The doctors said that epidemiologists were working to identify the source of the outbreak. About a month after Ajay recovered, his father noticed a news article about a *Salmonella* outbreak.

Read the news article below. As you read, underline information that would help Ajay understand how he was exposed to the *Salmonella* that made him sick. Use the circle, box, or line to highlight the important information.

Student annotations may vary using the tools below.

Salmonella Outbreak Linked to Contaminated Chicken

An outbreak of food poisoning caused by antibiotic resistant *Salmonella* bacteria has sickened at least 129 people. The *Salmonella* outbreak is a serious health threat because the antibiotics usually used to treat *Salmonella* infections are not effective for treating this outbreak.

Epidemiologists from the CDC (Centers for Disease Control and Prevention) conducted interviews with ill people. Most remembered eating different types and brands of chicken products purchased from many different locations.

CDC laboratory scientists conducted tests that identified the multidrug-resistant *Salmonella* in samples taken from affected humans, affected pets, some live chickens, some raw chicken products, and some raw pet food that contains chicken.

The CDC provided advice to physicians who are selecting antibiotic treatment for suspected cases of *Salmonella* infection. The CDC also shared this information with veterinarians, farmers, and food processors from the chicken industry. The CDC requested that they take steps to reduce *Salmonella* contamination.

Because not all chicken was contaminated, the CDC did not advise consumers to avoid eating chicken. They also have not recalled chicken products or advised stores to stop selling or recall chicken products. The CDC recommended that consumers avoid exposure to *Salmonella* bacteria by handling raw chicken carefully.

Base your answers to questions 5 through 8 on the information in the news article on the previous page.

5. Explain why "multidrug-resistant" bacteria are dangerous.

   They cause illnesses that are difficult to treat because only some antibiotics will kill the bacteria.

6. The news article claims that chickens were the source of *Salmonella* that caused the outbreak. State two pieces of evidence to support this claim.

   - ***Ill people who reported eating different types and brands of chicken products purchased from many different locations.***
   - ***Tests identified the multi-drug resistant Salmonella in samples taken from affected humans, affected pets, live chickens, raw chicken products, and raw pet food that contains chicken.***

7. The CDC did not recommend that people stop selling or buying chicken. State two pieces of evidence that support this decision by the CDC.

   - ***Not all chicken was contaminated.***
   - ***There are things that people can do to protect themselves from exposure to Salmonella bacteria.***

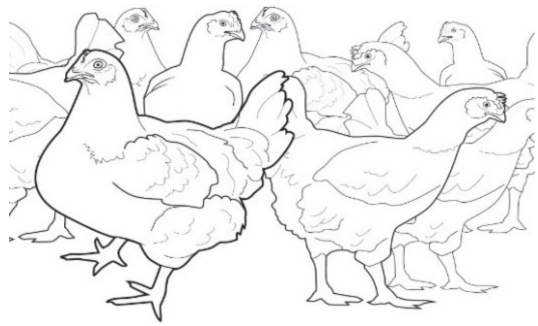
8. Explain why the CDC provided information about the *Salmonella* outbreak to veterinarians, farmers, and food processors.

   These people could take actions to prevent Salmonella contamination of animals and foods.

Part 3: How do bacteria become resistant to multiple antibiotics?

Ajay knows that mutations could cause new traits to appear. However, he also knows that mutations are rare and random events. He asked his biology teacher "**How could *Salmonella* bacteria become resistant to many different antibiotics**?"

You and your classmates will model how *Salmonella* living in the intestines of a chicken may acquire antibiotic resistance genes from other bacteria around it.



The intestines of a chicken are crowded with millions of bacteria that may contain different antibiotic resistance genes—genes that enable them to survive exposure to specific antibiotics.

The simulated bacterial cell represents a *Salmonella* bacteria cell living in the intestine of a chicken. On the **Key for Beads**, to the right, identify the antibiotic resistance gene that is present in your model bacteria.

Key for Beads

Blue bead = Tetracycline resistance gene

Black bead = Erythromycin resistance gene

Green bead = Ciprofloxacin resistance gene

Pink bead = Penicillin resistance gene

Red bead = Cephalosporin resistance gene

You will use either dice rolls or a color wheel along with beads to model how bacteria can become resistant to multiple antibiotics.
To identify the resistance genes you can roll dice and follow the steps below or spin the color wheel with the **Key for Color Wheel** to make a model of your own to show the randomness of having a resistant gene. The **Simulated *Salmonella* Bacterial Cell in Chicken Intestines** contains beads that represent antibiotic resistance genes from other bacteria that live in the chicken's intestines.

Step 1: Roll the dice. Follow the instructions on the **Key for Dice Roll** to determine what happens to the *Salmonella* bacteria. Did the *Salmonella* bacteria get a new antibiotic resistance gene, if so, what resistance gene did the Salmonella receive?

NO - Go to Step 2

YES - Answer the next two bullets:

- On the **Key for Beads** above, identify the name of the antibiotic resistance gene that is now present in your model bacteria.

- What process was used to acquire this resistance gene? Describe the process by which the bacteria obtained the new gene.

Answers will vary

Step 2: Roll the dice again. Follow the instructions on the **Key for Dice Roll** to determine what happens to the *Salmonella* bacteria. Did the *Salmonella* bacteria get a new antibiotic resistance gene, if so what resistance gene did the Salmonella receive?

NO - Go to Step 3.

YES - Answer the next two bullets:

- On the **Key for Beads**, identify the name of the antibiotic resistance gene that is now present in your model bacteria.

- What process was used to acquire this resistance gene? Describe the process by which the bacteria obtained the new gene.

Answers will vary

Step 3: Roll the dice again. Follow the instructions on the **Key for Dice Roll** to determine what happens to the *Salmonella* bacteria. Did the *Salmonella* bacteria get a new antibiotic resistance gene, if so what resistance gene did the Salmonella receive?

NO - Go to Step 4

YES - Answer the next two bullets:

- On the **Key for Beads**, identify the name of the antibiotic resistance gene that is now present in your model bacteria.

- What process was used to acquire this resistance gene? Describe the process by which the bacteria obtained the new gene.

Answers will vary

Step 4: Roll the dice again. Follow the instructions on the **Key for Dice Roll** to determine what happens to the *Salmonella* bacteria. Did the *Salmonella* bacteria get a new antibiotic resistance gene, if so what resistance gene did the Salmonella receive?

NO - Go to Question 9

YES - Answer the next two bullets:

- On the **Key for Beads**, identify the name of the antibiotic resistance gene that is now present in your model bacteria.

- What process was used to acquire this resistance gene? Describe the process by which the bacteria obtained the new gene.

Answers will vary

9. Multidrug-resistant bacteria are resistant to more than one antibiotic. Is your *Salmonella* bacteria model multidrug-resistant? If so, list the antibiotics that it is resistant to.

    Student answers will vary depending on the antibiotic resistance genes in their bacteria.

10. If a person becomes infected with *Salmonella* bacteria like the one that you modelled, what kinds of antibiotics would be effective for treating the infection? Explain how you can tell. *Note: Refer to the* ***Key for Beads****.*

    Student answers will vary depending on the antibiotic resistance genes in their bacteria. Their explanation should include the idea that their model did <u>not</u> contain a bead or beads to represent the antibiotics in their answer.

11. If you are working with other students who have made *Salmonella* bacteria models, explain how you would identify the *Salmonella* bacteria model that would be most likely to survive and reproduce in an environment where multiple antibiotics are present.

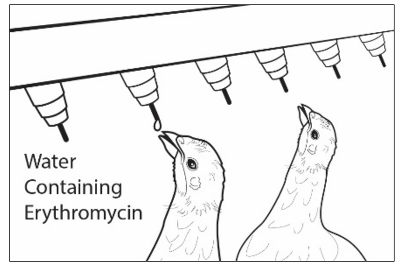
    The bacteria cell with the most different types of antibiotic resistance genes would be most likely to survive and reproduce.

12. Ajay wanted to know how *Salmonella* bacteria could become resistant to many different antibiotics. Explain how it is possible for bacteria to acquire resistance to multiple antibiotics without relying on the rare and random process of mutations.

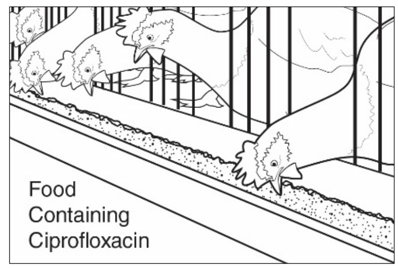
    They can get antibiotic resistance genes from other bacteria, from viruses, or from their environment. Students may list the processes of transformation, transduction, or conjugation.

Part 4: Natural selection and antibiotic-resistant bacteria

To prevent respiratory diseases in young chickens on his farm, farmers add an antibiotic called **erythromycin** to the water that the chickens drink. When the antibiotic erythromycin is used, only bacteria that have erythromycin resistance genes will survive.



To prevent intestinal diseases in young chickens on the farm, the farmer uses chicken feed that contains an antibiotic called **ciprofloxacin**. When ciprofloxacin is used, only bacteria that have ciprofloxacin resistance genes will survive.



13. What antibiotic resistance genes need to be present in *Salmonella* bacteria to enable them to survive and reproduce in the chickens that live on this farm?

    Erythromycin and ciprofloxacin resistance genes

14. Could the *Salmonella* bacteria that you modelled survive and reproduce in the intestines of chickens that live on this farm? *Look at the cup with beads and the key from Part 3.* Explain why or why not.

    Student answers will vary depending on what antibiotic resistance genes are present in their model. They will only survive if they have erythromycin and ciprofloxacin resistance genes.

15. Did the use of antibiotics on the farm cause your *Salmonella* bacteria to become antibiotic resistant OR was your *Salmonella* bacteria resistant to antibiotics before the antibiotics were used on the farm? Support your answer with evidence from the model.

    No, my bacteria had antibiotic resistance genes before it was exposed to the antibiotic.

16. Natural selection occurs when genes for antibiotic resistance become more common in a population because they increase organisms' abilities to survive and reproduce. What genes are likely to become more common in the population of *Salmonella* bacteria that live on the chicken farm?

    Resistance to erythromycin and ciprofloxacin

17. The statements below describe events in the natural selection of bacteria that are resistant to the antibiotic penicillin. Indicate the order in which the events occurred by writing numbers (2, 3 or 4) in front of the statements.

___1___ Bacteria in the chickens' intestines naturally have a variety of antibiotic resistance genes.

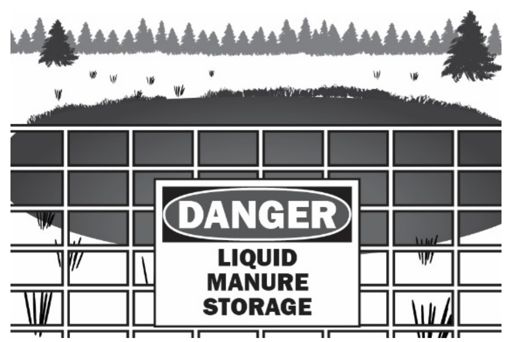
___***2***__ The bacteria are exposed to erythromycin when chickens drink their water.

___***4***___ Erythromycin-resistant bacteria become more common on the chicken farm.

___***3***___ Bacteria that are resistant to erythromycin survive and reproduce.

Animals in large industrial farms produce large quantities of manure - liquid (urine) and solid (feces) wastes. These wastes contain many different kinds of bacteria and viruses. Animal manure is often stored in open pits called "manure lagoons."

Manure lagoons are ideal places for bacteria reproduction. As the bacteria reproduce, they are exposed to low levels of antibiotics from the feces of animals that were treated with antibiotics. They are also surrounded by sources of antibiotic resistance genes such as viruses, free-floating antibiotic resistance genes, and other types of bacteria that are antibiotic resistant. This can result in new bacteria that are resistant to many different kinds of antibiotics. Wastes from manure lagoons may be used to fertilize fields or may be accidentally released into nearby water sources.



18. Describe what conditions in a manure lagoon are likely to result in the evolution (natural selection) of new antibiotic-resistant bacteria.

There are many bacteria mixed with many sources of antibiotic resistance genes.
There are low levels of antibiotics that allow resistant bacteria to survive and reproduce more rapidly that non-resistant bacteria.

19. Describe two ways that people might be exposed to antibiotic-resistant bacteria from manure lagoons.

By walking through fields fertilized with wastes. By eating plants grown in fields fertilized with wastes. By drinking water contaminated by wastes.

Part 5: The spread of antibiotic-resistant bacteria

Ajay claims that banning the sale of animal products from large farms is the best way to prevent outbreaks of diseases caused by antibiotic-resistant *Salmonella.* One of Ajay's friends whose parents own a large dairy farm asked him to consider the chart below and rethink his claim.

Some Sources of *Salmonella* Outbreaks

Animal Products	Pets and Pet Products	Plant Products
Poultry	Birds	Bean sprouts
Beef	Reptiles such as turtles	Melons
Pork	Amphibians such as frogs	Lettuce
Fish	Dogs	Onions
Milk	Cats	Tomatoes
Cheese	Hedgehogs	Peppers
Eggs	Pet food	Spinach
Ice cream	Pet treats	Cucumbers
		Cereal
		Rice
		Nuts
		Spices

Modified from: https://www.researchgate.net/figure/Some-sources-of-Salmonella-outbreaks_tbl1_278793722

20. Does the information on the chart support Ajay's claim that outbreaks of *Salmonella* could be prevented by banning the sale of animal products from farms that use antibiotics? Support your answer with information from the chart.

No because people could be exposed to antibiotic resistant Salmonella by eating plant products or coming in contact with pets or pet foods.

There are many ways that *Salmonella* can spread between humans, animals, and the environment. The six statements (A-F) listed below describe some of the ways that antibiotic-resistant bacteria such as *Salmonella* can spread between humans, animals, and the environment.

A. Antibiotic-resistant bacteria from humans can enter waterways if they are not completely removed by waste sanitation systems.

B. Farm animal manure applied to fields spreads antibiotic-resistant bacteria to soil and water.

C. Crops can be contaminated by antibiotic-resistant bacteria in soil and water.

D. Foodborne transmission of antibiotic-resistant bacteria to humans is a common route the spread to humans.

E. Antibiotic-resistant bacteria enter humans when they drink contaminated water.

F. Contact with pets and wildlife can transmit antibiotic-resistant bacteria to humans.

21. On the next slide, **Drag arrows** from the KEY on to the **How Antibiotic-Resistant Bacteria Spread** picture to represent each of the six statements (A-F). Then, drag letters B-F on to the picture to **label the arrow** with the letter of the statement that it represents.

    Note: As an example, the first statement has been shown on the picture using a red arrow and red "A".

22. Look at the arrows you drew on the **How Antibiotic-Resistant Bacteria Spread** picture. These arrows represent processes/routes that spread antibiotic-resistant bacteria. Suggest one way to block a process/route and prevent the spread of antibiotic-resistant bacteria to each of the following:

    - Humans:

    - Animals (pets or wildlife):

    - The environment (soil, water, plants, or air):

    Student answers will vary. Allow time for students to share their answers.

Part 6: One Health and antibiotic-resistant bacteria

One Health

A university is suggesting that the local government take a One Health approach to solving complex local problems, such antibiotic-resistant bacteria. A One Health approach uses the idea that complex problems often involve the health of people, animals, and the environment. Therefore, solutions to One Health problems must be designed to protect the health of people, animals, and the environment.

23. Use the information in the textbox above to explain what must be involved in a complex problem for it to be considered a One Health problem.

    ***It must involve humans, animals, and the environment*.**

To support adoption of a One Health approach, the university officials want to create a series of One Health digital slides to share with community members. Your team has been hired to create the first slide for this presentation. They want you to use antibiotic-resistant bacteria as an example of a One Health problem. The slide you produce should answer the question, "**Why are antibiotic-resistant bacteria a One Health problem?"**

Community members often get most of their information from this first slide – they tend to lose interest once in-depth discussion of the issue begins. Therefore, that first slide needs to give information in a way that people will remember. Using examples and pictures will help people understand and remember what the One Health approach involves.

24. Use the information in the text box above and what you learned about antibiotic-resistant bacteria to develop your digital slide. The following template may help you organize your digital slide:

Why are antibiotic-resistant bacteria a One Health problem?	
Credit given for providing 1-2 sentences that respond /answer the question	**Credit given for providing a picture with brief caption**
Credit given for providing a picture with brief caption	**Credit given for providing a picture with brief caption**

Optional Extension Activity and Questions:

1. Ask students to identify their own One Health Problem. They can use the table provided.

One Health Problem		
Environment	**Animals**	**People**
 ***Credit given for responses that include "environment." Answers will vary and be specific to each student.***	 ***Credit given for responses that include "animals." Answers will vary and be specific to each student.***	 ***Credit given for responses that include "people." Answers will vary and be specific to each student.***

2. Ask students to identify their own One Health Solutions. Have students complete and compare the **Possible One Health Solutions** in the chart below. Brainstorm ideas for actions that could be taken to "solve" parts of problem that you described in question 4. Be sure to include actions that would improve the health of humans, animals, and the environment.

One Health Solutions		
Environment	**Animals**	**People**
 ***Credit given for responding. Answers will vary and be specific to each student***	 ***Credit given for responding. Answers will vary and be specific to each student.***	 ***Credit given for responding. Answers will vary and be specific to each student.***

3. Which One Health solution would be easiest for <u>you</u> to implement? Explain why you chose that solution.

    Credit given for responding. Answers will vary and be specific to each student.

4. Which One Health solution would be easiest for <u>local communities</u> to implement? Explain why you chose that solution.

    Credit given for responding. Answers will vary and be specific to each student.

5. Which One Health solution would have <u>the greatest impact</u> on solving the One Health problem caused by the invasion of ticks? Explain why you chose that solution.

    Credit given for responding. Answers will vary and be specific to each student.