Meet the Lab

Antibiotic Hunters: Superpowered by Students

Educator Guide

PBS Wisconsin Education
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Project Background: *Meet the Lab* and STEAM Identity

Meet the Lab is a series of learning media resources designed to introduce middle school students to scientific research through a human lens. This makes it different from many online science education resources that focus solely on science content learning (the "what" and "how" of science learning). Instead, *Meet the Lab* was created to focus on the "why" and the "who" of science learning, addressing two specific challenges in the science classroom:

As a science teacher, how do I:

- Connect science learning to the community at-large and to real-world problems in a way that resonates with my students?

- Connect science learning to my students' identities, and illuminate possible academic and career pathways for them to pursue?

Meet the Lab offers media resources and activities that we hope will serve you as you dig into these challenges. Each lab starts with a context-setting video that describes real-world problems that are relevant to student lives. We follow that with a second video and two activities that introduce students to multiple real-life scientists (as well as real lab content and practices), with a goal for students to relate to the scientists personally and to consider the possibilities of STEAM in their future.

A student's STEAM identity ("Who do I think I am, who can I be, where do I belong, and how do others see me?" in context of Science, Technology, Engineering, Arts, and Math) starts to develop very early on. Middle school is a critical time for students to actively construct their identities, and identify directions and possibilities for their lives. The science classroom is one place for students to develop an internal drive for science, and to see science and career pathways in science as relevant and accessible.

Meet the Lab features lab teams (rather than only featuring individual scientists), showing how diverse groups of people work together across disciplines to pursue answers to questions about our world. We hope this will support a parallel vision for student groups in your science classroom to work together as they enact scientific practices to answer relevant scientific questions.

Learning Goals

By using *Meet the Lab* resources, students will:

Learning Goal	**Project Component**
Make connections between lab research and why it matters in real life.	*Why Research Matters*
Identify scientific practices researchers use and apply these same practices to classroom experiments.	*Science Practices*
Identify strengths in science, and relate to people in science careers.	*Meet the Scientists*

Meet *This* Lab: Tiny Earth Network

This set of education resources introduces students to the researchers from the Tiny Earth Network (founded by Jo Handelsman) and helps students uncover some of the patterns researchers use to find new treatments for antibiotic resistant bacteria infections. Researchers at the lab use microbiology culturing techniques to discover new antibiotics for bacterial infections that have become resistant to current antibiotics (including MRSA and Streptococcus Pneumoniae). They work with high school and college students around the world to help source antibiotics from soil samples, which are then analyzed to identify and test new antibiotics.

Before using these resources: Students should be familiar with the idea that bacteria are single celled organisms that can live in soil. They should know that bacteria produce antibiotics as a defense against other bacteria. Scientists can use these antibiotics to treat bacterial infections in humans.

Founder: Jo Handelsman

Jo's Education:

- Middle and High School in New York
- BS, Agronomy, Cornell University (Ithaca, NY)
- PhD, Molecular Biology, University of Wisconsin-Madison (Madison, WI)
- Post Doctorate, Plant Pathology, University of Wisconsin-Madison (Madison, WI)

Jo says, "I founded Tiny Earth because my mother unfortunately died of an antibiotic-resistant bacterial infection in her lungs. Her story, along with so many people getting infections with bacteria that are resistant to the known antibiotics have really fueled my passion for discovering new antibiotics."

Activating the *Why Research Matters* Content

This video is meant to draw students into one person's personal story of how an antibiotic resistant infection impacted her life and how that experience impacted her career path. The story is meant to elicit discussion about students' experience with antibiotics, prior knowledge and questions about research.

Watch the video, and then discuss it in small groups or as a class. Use the following questions (also featured next to the video) to guide your discussion, if helpful.

1. Jessi's experience with antibiotic resistant bacteria made her curious about microbiology, and ultimately inspired her to go into a career in science. What experiences have you had that make you curious about science?

2. Doctors and scientists often have to try new methods of treatments to find solutions for problems, and it took several tries over many years to find the right solution for Jessi's infection. Can you think of a time when your first solution didn't work and you had to try again?

Activating the *Science Practices* Content

This video focuses on the tools researchers at the Tiny Earth Network use, the practices used to conduct investigations, and the cross-cutting concept of finding patterns.

The accompanying slide deck activity allows students to closely examine the images that Amanda, one of the researchers, has taken to discover new antibiotics. The slide show starts with soil and prompts students to identify the different materials that soil contains. Students then begin to describe similarities and differences between bacteria colony growth. Next, they learn how bacteria living in soil can be grown and analyzed to identify ones that produce antibiotics from ones that do not. Students then examine petri dishes to identify the presence of zones of inhibition. After, they examine bacteria from three different soil samples that the lab is investigating to determine which show the most promise for discovering antibiotics. The images shared are involved in real research products, but aspects have been artificially assigned to serve as a teaching model.

The companion data sheet allows students to record their answers to questions posed by Amanda, the researcher, before they move on to the next slide, where she reveals her answers. Encourage students,, especially in the discovery section of the activity, to defend their own interpretation of the model and use evidence they see in the model patterns to decide which bacteria produces the best antibiotic and ultimately, which soil type should be used to find more antibiotics. Different interpretations of these models that might lead to productive disagreements and discussions over which soil types look most promising.

The focus is for students to participate with Amanda as she identifies ways she uses patterns in her research. This is an NGSS cross-cutting concept that should be made explicit as students are participating in the activity; they are engaging in the same practice of identifying and classifying patterns that a scientist does.

Harmful bacteria Amanda used in the activity to test effectiveness of antibiotics:

- **Bacteria X:** A species of Acinetobacter (AH-sin-neto-bacter), which has been causing drug resistant infections in soldiers in the Middle East. It's Gram Negative.*
  Go to PBS LearningMedia and search for "Killer Microbe" to find a *NOVA scienceNOW* video that describes how this bacteria has become so deadly.

- **Bacteria Y:** A species of Bacillus (Buh-SILL-us), which represents Gram Positive bacteria (a thick layer of cell wall around the cell). Testing against Bacillus helps find potential alternatives to penicillin and methicillin to fight MRSA.

- **Bacteria Z:** A species of Pseudomonas (Sue-duh-MOAN-us), which represents a Gram Negative* potential pathogen for humans and plants.

*Gram Negatives are typically harder to kill! They have TWO membranes the drugs have to penetrate.

Common words and phrases from Amanda (the scientist):

- **Antibiotics:** Chemicals produced by bacteria that scientists design into medicines that can treat certain bacterial infections like strep throat, pink eye, pneumonia, and many others. Antibiotics stop bacteria from growing.

- **Antibiotic resistant infection:** Populations of bacteria often evolve resistance to antibiotics over time, which makes the antibiotics less effective at treating infections.

- **Bacteria colonies:** When single-celled bacteria multiply, they form large bacteria colonies.

- **Media:** Bacteria food that helps certain bacteria to grow and replicate into bacteria colonies.

Answer Key for the *Science Practices* Activity

Slide 3: What kinds of things can you find in soil?
Water, minerals, air, and organisms are all found in soil.

Slide 9: What patterns do you recognize? What similarities do you see among the bacteria colonies? What differences do you see? Are there any colonies that stand out to you?
All of the bacteria colonies are circles. Some even have smaller circles inside of them. Some are small while others are larger. There are several groups of colonies that are the same color. A few colonies may stand out. These are bacteria colonies that have properties that may be new or different. One colony has two colors and another is black!

Slide 27: What do you notice about the space around the different test bacteria? Is there empty space around the test bacteria?

Test Bacteria #	Empty Space?	Test Bacteria #	Empty Space?
1	No	7	Yes, empty space
2	No	8	Yes, although it is thinner than other spaces
3	No	9	No
4	No	10	No
5	Yes, empty space	11	No
6	No		

Slide 34: How many different types of bacteria colonies do you see? What similarities and differences do you notice?
All of the bacteria colonies in soil A are spherical or circular. Three bacteria colony types (small white, tiny yellow, white or offish white colonies with circles inside of them).

All of the bacteria colonies in soil B are spherical or circular. Three bacteria colony types (small whtie, large yellow, really large off-white colony that is a bit shiny). Most of the bacteria colonies in soil C are spherical or circular, but one colony is irregular in shape. Four bacteria colony types (tiny yellow, small white, white or offish white colonies with circles inside of them, and the irregularly shaped white one).

Slide 40: Which test bacteria are producing the best antibiotics? How can you tell?
All three bacteria in Soil A create good zones of inhibition. Only two bacteria in Soil B are working. Two bacteria in Soil C also create zones of inhibition, but they are smaller than the ones created by bacteria in Soils A and B.

Slide 47: Which test bacteria are producing the best antibiotics? How can you tell?

Bacteria Y		**Bacteria Z**	
Test Bacteria #	**Zone of inhibition?**	**Test Bacteria #**	**Zone of inhibition?**
1	Yes	1	Yes
2	Yes	2	Yes (thin)
3	Yes	3	Yes (thin)
4	Yes (large)	4	No
5	No	5	No
6	Yes	6	Yes
7	Yes	7	Yes (thin)
8	Yes (large)	8	Yes
9	Yes	9	Yes (thin)

Slide 50: What if we looked at all three petri dishes together? Are there any patterns between the soils that you notice? Which soil do you think we should study if we want to find more antibiotics?
All bacteria in Soil A made antibiotics against all three harmful bacteria types X, Y, and Z. All bacteria in Soil B made antibiotics against harmful Bacteria X, Y, and Z. But not all bacteria were effective all the time. Bacteria in Soil C made antibiotics against harmful Bacteria Y and Z. However, these bacteria were only a bit effective against Bacteria X.

Best soil to study to find more antibiotics: Since we found the most antibiotics in Soil A, that might be the best one to look at. However, we found at least one decent antibiotic in every soil type, so there might be other options as well.

Slide 59: What do you think we should do next?
- We could try the same antibiotic on other bacteria colonies to see if it helps. We ask: How do patterns compare across different bacteria? Biologists on our team look at this!

- We could find out what the antibiotic that is preventing bacteria growth looks like. We ask: How do patterns compare across different antibiotics? Chemists on our team look at this!

- We could find out which genes in the bacteria are making the antibiotic. We ask: How do patterns compare across different genomes? Computer scientists on our team look at this!

- Eventually, after many years of testing, when we have more evidence to support our work, we might pass on our work to doctors to test in people with bacterial infections.

Activating the *Meet the Scientists* Cards

The researcher trading cards are meant to foster students' own STEAM identity by making a connection between themselves and a featured researcher.

Encourage students to review the trading cards from the scientists from the lab, keeping in mind the question "Who do you relate to the most and why?" and then have them discuss what they learned and their own answers to the question in small groups or as a class.

To extend the activity, share the list of superpowers (below) with your class, and ask students to identify which superpower(s) they have. Do they share a superpower with any of the scientists?

Sample superpowers:
Ambition
Compassion
Creativity and Originality
Deep Investigation
Dependability and Follow Through
Endurance and Perseverance
Enthusiasm
Flexibility
Heart and Passion
Imagination and Curiosity
Inclusive Communication
Organization and Order
Outgoing Optimism
Planning and Strategy
Precision and Attention to Detail
Sensitivity and Intuition
Spontaneity and Risk-taking
Super Helper Skills
Terrific Troubleshooting
Vision and Leadership

As an additional extension to the activity, invite students to create their own trading card using the downloadable PDF on the website.

To use the fillable PDF in the browser: Select "View" to open the PDF, fill in the text boxes, and use the "print" function to save as a new PDF (or to make a physical copy). To annotate the PDF in the browser you will need an extension (like Kami for Google Chrome), or you can download and print a physical copy to write on directly.

To use the fillable PDF in an application like Adobe Acrobat: Select the "Download" option. Open the file in your preferred program, fill in the text boxes, and use the "Save As..." function to save as a new PDF.

To use the PDF as a physical worksheet: Just download and print!

Curricular Connections

Are you learning about bacteria growth, medicine, antibiotics, or life sciences? Consider one of these activities:

Candy Antibiotic Resistance Activity
This activity involves using marshmallows, hard candies, a toothpick, and tweezers to simulate how antibiotic resistance occurs.

Directions

1. Have students split into at least two teams.

2. Give each team two toothpicks and two tweezers.

3. Spread hard candies around a large table and teams to gather around the table.

4. Establish this analogy with the students before the activity begins:
    a. The marshmallows represent a harmful bacteria.
    b. The hard candy represents a harmful bacteria that is antibiotic resistant.
    c. The toothpick represents the antibiotic.
    d. The tweezers represent a newly developed antibiotic.

5. Have students complete two rounds:
    a. Round 1. Have students spend 10 second trying to pick up all of the marshmallows and candies with only the first antibiotic (toothpick). Students will quickly learn that the toothpick is an ineffective antibiotic for the hard candy.
    b. Round 2. Have students spend 10 second trying to pick up all of the marshmallows and candies with only the second antibiotic (tweezers). The only solution is the new antibiotic. It will be an effective antibiotic for all bacteria.

6. Consider asking students follow up questions:
    a. Why did one tool work better than the other?
    b. How could we repeat this activity to determine its accuracy?
    c. What do you think this tells us about antibiotic resistance?

At the end of this activity, students should understand that the marshmallows and the hard candies are models of two different bacteria colonies - one that is effectively treated by the first toothpick antibiotic (marshmallows) and the other that is antibiotic resistant (hard candies). Scientists like those in the Handelsman Lab study bacteria in order to discover new antibiotics that may be effective against harmful bacteria that have become resistant to current antibiotics.

Bacteria Simulation

This online simulation walks students through the basics of bacteria and demonstrates how bacteria respond to antibiotics and can become resistant over time.

1. Ask students about their knowledge of simulations, if they've ever used one and why.

2. Allow students to go to this website: https://theyardgames.org/game/bacteria, read through the prompts, and start exploring the simulation.

3. Consider asking students some of the questions as they play around with the simulation:
    a. What happens if you let the bacteria grow for a long time? Do they become better or worse?
    b. How many doses does it take to remove a small amount of bacteria? How many doses does it take to remove a larger amount of bacteria?
    c. What happens to the average resistance as time goes on? Why do you think this is?
    d. What happens to the average resistance once you dose an antibiotic?

Standards Supported

Next Generation Science Standards (NGSS)

Disciplinary Core Ideas (DCI):

1. LS2.B: Cycles of Matter and Energy Transfer in Ecosystems Food webs are models that demonstrate how matter and energy is transferred between producers, consumers, and decomposers as the three groups interact within an ecosystem. Transfers of matter into and out of the physical environment occur at every level. Decomposers recycle nutrients from dead plant or animal matter back to the soil in terrestrial environments or to the water in aquatic environments. The atoms that make up the organisms in an ecosystem are cycled repeatedly between the living and nonliving parts of the ecosystem. (MS-LS2-3)

2. LS4.B: Natural Selection Natural selection leads to the predominance of certain traits in a population, and the suppression of others. In artificial selection, humans have the capacity to influence certain characteristics of organisms by selective breeding. (MS-LS4-4) One can choose desired parental traits determined by genes, which are then passed onto offspring. (MS-LS4-5)

3. LS4.C: Adaptation Adaptation by natural selection acting over generations is one important process by which species change over time in response to changes in environmental conditions. Traits that support successful survival and reproduction in the new environment become more common; those that do not become less common. Thus, the distribution of traits in a population changes. (MS-LS4-6)

NGSS Practice Standards

4. SCI.ETS1: Students use science and engineering practices, crosscutting concepts, and an understanding of engineering design to make sense of phenomena and solve problems.

5. SCI.ETS3: Students use science and engineering practices, crosscutting concepts, and an understanding of the nature of science and engineering to make sense of phenomena and solve problems.

Wisconsin Science Standards (WSS)

Disciplinary Core Ideas (DCI) — Life Science:

1. Learning Priority SCI.LS2.B.m: Cycles of Matter and Energy Transfer in Ecosystems The atoms that make up the organisms in an ecosystem are cycled repeatedly between the living and nonliving parts of the ecosystem. Food webs model how matter and energy are transferred among producers, consumers, and decomposers as the three groups interact within an ecosystem.
    a. Example Three-Dimensional Performance Indicators: Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem (MS-LS2-3).

2. Learning Priority SCI.LS4.B.m: Natural Selection Both natural and artificial selection result from certain traits giving some individuals an advantage in surviving and reproducing, leading to predominance of certain traits in a population.
    a. Example Three-Dimensional Performance Indicators: Construct an explanation based on evidence that describes how genetic variations of traits in a population increase some individuals' probability of surviving and reproducing in a specific environment. (MS-LS4-4). Gather and synthesize information about the technologies that have changed the way humans influence the inheritance of desired traits in organisms (MS-LS4-5).

3. Learning Priority SCI.LS4.C.m: Adaptation Species can change over time in response to changes in environmental conditions through adaptation by natural selection acting over generations. Traits that support successful survival and reproduction in the new environment become more common.
    a. Example Three-Dimensional Performance Indicators: Use mathematical representations to support explanations of how natural selection may lead to increases and decreases of specific traits in populations over time (MS-LS4-6).

Disciplinary Core Ideas (DCI) — Engineering, Technology, and the Application of Science:

4. Standard SCI.ETS1: Students use science and engineering practices, crosscutting concepts, and an understanding of engineering design to make sense of phenomena and solve problems.

5. Standard SCI.ETS3: Students use science and engineering practices, crosscutting concepts, and an understanding of the nature of science and engineering to make sense of phenomena and solve problems.

Meet the Lab resources will work with a Claims Evidence Reasoning (CER) and/or Conceptual Modeling approach to teaching. Support for implementing these frameworks can be found through the National Science Teaching Association.

Resources for More Information

On Modeling, Bacteria, Infections and Antibiotics Resistance:
For information on the practice of modeling, go to the Wisconsin Department of Public Instruction website and search for "Science and Engineering Practices."
Link: https://dpi.wi.gov/science/standards/practices#model

For information on how bacteria can become antibiotic resistant check out PBS LearningMedia and search for "Killer Microbe" to find a *NOVA scienceNOW* video where one scientist describes how a type of bacteria became resistant to even the most powerful antibiotics.

For news reporting about the problem of antibiotic resistance: Go to PBS LearningMedia and search for "Antibiotics" to find resources from a *Frontline* series about antibiotic resistance.

For more information about what makes up soil: Go to PBS LearningMedia and Search for "The Ingredients for Soil" to find a *NOVA: Making North America* video where geologist Dave Montgomery describes the ingredients in soil.

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