Super Bugs — Bacterial Drug Resistance

Secrets of the Sequence Video Series on the Life Sciences • Grades 9 – 12

Teaching materials developed by VCU Life Sciences.

Virginia Commonwealth University

Classroom Tested Lesson

Video Description

"Secrets of the Sequence", Show 119, Episode 1

"Super Bugs" – approximately 8 minutes viewing time

We are under attack – by germs. Drug-resistant bacteria are invading organisms, and hospitals are their favorite breeding ground. Scientists are studying the genetics of bacteria and trying to find out how to stop the invasion.

Ward Television
Producer: Paul Malkie
Associate Producer: Laura Bramon
Featuring: Dr. Gordon Archer, Infectious Diseases, Virginia Commonwealth University; Dr. Richard Wenzel, Internal Medicine, Virginia Commonwealth University; and Thomas J. Huff, Ph.D., Life Sciences at Virginia Commonwealth University
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National and State Science Standards of Learning

National Science Education Standards Connection

Content Standard C: Life Sciences

As the result of their activities in grades 9-12, all students should develop an understanding of

- the cell,
- molecular basis of heredity,
- biological evolution,
- interdependence of organisms, and
- behavior of organisms.

Content Standard F: Science in Personal and Social Perspectives

As a result of activities in grades 9-12, all students should develop an understanding of

- personal and community health,
- science and technology in local, national, and global challenges.

Content Standard G: History and Nature of Science

As a result of activities in grades 9-12, all students should develop an understanding of

- science as a human endeavor and
- historical perspectives.

Selected State Science Standards Connection

Use http://www.eduhound.com (click on "Standards by State") or a search engine to access additional state science standards.

Illinois

Standard 11A. Know and apply the concepts, principles, and processes of scientific inquiry.
Standard 12.A Know and apply concepts that explain how living things function, adapt, and change.
Standard 12.B Know and apply concepts that describe how living things interact with each other and with their environment.
Standard 13. B Know and apply concepts that describe the interaction between science, technology, and society.

North Carolina

Competency Goal 1: The learner will develop an understanding of the physical, chemical, and cellular basis of life.
Describe the structure and function of enzymes and explain their importance in biological systems.
Competency Goal 2: The learner will develop an understanding of the physical, chemical, and cellular basis of life.

- Analyze the molecular basis of heredity/DNA.
- Assess the application of DNA technology to forensics, medicine, and agriculture.
- Analyze and explain the role of genetics and environment in health and disease.

Competency Goal 3: The learner will develop an understanding of the unity and diversity of life.
Determine the internal and external factors that influence the growth and development in organisms.
Competency Goal 5: The learner will develop an understanding of the behavior of organisms, resulting from a combination of heredity and environment.
Evaluate and explain the evolution of behavioral adaptations and survival of populations.

Overview

Bacteria were most likely the first forms of life on earth; they have always been a part of our lives. While there are beneficial bacteria – those which help in the formation of cheese, yogurt, and vaccines – we tend to focus on the pathogenic or disease-causing species. And well we should. *Yersinia pestis*, the bacterium responsible for the Black Plague, killed nearly half the population of Europe in the 14th century. Also, prior to the availability of antibiotics, 40 percent of all patients who contracted pneumonia died.
In 1864, Louis Pasteur determined a relationship between bacteria (which he called "animalcules") and disease. Until this point, it was safer to give birth at home than in hospitals: bed linens weren't changed, medical equipment was passed from one surgery to the next without sterilization, doctors and nurses moved from one patient to the next without disinfecting their hands or changing clothes. Influenced by Pasteur's work, English surgeon Joseph Lister found that washing hands in between treating patients decreased the mortality rate of his patients. More importantly, hand washing between delivering babies prompted a dramatic decrease in maternal mortality. Bacteria, also called germs, had been identified as a source of infection; doctors and scientist could now begin the long process of finding medicines to fight bacteria, known as antibiotics.

Today we can determine the shape, grouping, physiology, and metabolism of a bacterium in order to classify it as one of the 5,000 known species of bacteria (this represents between 1-10% of the actual number of bacterial species on Earth.) Most bacteria are not pathogenic, but the ones that are pathogenic cause everything from tooth decay to typhoid. The introduction of antibiotics in 1944 was one of the greatest advancements in modern medicine. Initially intended for use on the battlefields of World War II, over the course of 50 years antibiotics became the most commonly prescribed medicine in history. As a result, antibiotic-resistant bacteria were seen as early as 1952. The combination of over-prescribing (for infections that could run their course), improper prescribing (for viruses, which cannot be killed by antibiotics), and improper use (patients not finishing prescriptions), has caused bacteria to become stronger than the medicines we use to fight them. We are running out of adequate antibiotics, and researchers estimate it may be 20 more years before scientists develop a new, effective broad-spectrum antibiotic.

In this lesson students learn the concept of bacterial drug resistance, methods bacteria use to fight the influences of antibiotics, transmission of resistance from one type of bacteria to another, and problems that arise when trying to control or eradicate antibiotic resistant (AR) bacteria.

Testing: A sample related multiple choice item from State Standardized Exams

Since the 1940's, people have been using antibiotics to kill disease-causing bacteria. What has been one of the consequences?

- Viruses are genetically combining with bacteria.
- Most disease-causing bacteria are becoming extinct.
- Bacteria that are less resistance to antibiotics have evolved.
- Bacteria that are more resistant to antibiotics have evolved.*

Source: Illinois State Board of Education, ISAT, Grade 11: Science

Video Preparation

Preview the video and make note of the locations at which you will later pause the video for discussion.

Before Viewing

1. Have the students work in pairs to generate a list of the roles bacteria play in our lives.
   Then have the students respond to the following questions and combine their answers on the board or on an overhead transparency.
   - How would life be different without them (positives and negatives)?
   - Why do we need them?
   - In what ways do we rely on bacteria?

2. Lead a discussion on the student's responses. Explain that while bacteria serve us in many positive ways (decomposition, fermentation, nitrogen fixation, cheese and yogurt production; bacteria are even used to 'eat' oil spills), we tend to think of their negative impact. They make us sick. They can even kill us; sometimes in a matter of hours. Due to the over-prescription of broad-spectrum antibiotics in the last several decades, many bacteria are so antibiotic-resistant that they are practically impossible to kill. The ability of bacteria to trade bits and pieces of their genes (known as a plasmid, or circular ring of DNA) helps bacteria spread their resistance to other bacteria, regardless of species.

During Viewing

1. START the video.

2. PAUSE the video (1:45 minutes into the video) after the first "guide to the genome" explanation

   Ask the following questions:
   - "What is a plasmid?"
     A circular piece of DNA found in bacteria.

   - "What are two ways bacteria can fight the effect of antibiotics?"
     Efflux pumps that pump out the drugs, or the production of enzymes to degrade or inactivate the antibiotic.

3. RESUME the video

4. PAUSE the video (5:01 minutes into the video) after the statement…very effective in evading our latest antibiotics."

   Discuss the concept of "survival of the fittest."
   Students should understand that those bacteria with genes that allow them to resist the effects of strong antibiotics survive and pass those genes on to their offspring.

5. RESUME the video and view to the end.

After Viewing

1. Ask: "How can you help prevent antibiotic resistance?"
   Take personal responsibility by not insisting on an antibiotic for a viral disease, such as a cold; take all the pills in the prescription and don't stop when you start to feel better; don't use leftover antibiotics to treat another infection.

2. Ask: "What are the two ways antibiotics work to destroy bacteria?"
   Destroy the cell wall, interfere with the production of proteins.

3. Ask: "What factors make hospitals a breeding ground for antibiotic resistance?"
   An increased density of bacterial infections; low resistance among patients due to illness or treatment; intense, often overuse of antibiotics.

4. Lead a discussion on the dilemma of FDA regulations and the time frame it takes for a drug to get approved versus the time it takes for a bacterium to change.

5. Conduct the Student Activity: Exchanging DNA - It's just that easy.
   This activity gives students a hands-on experience with the ease in which antibacterial resistance is passed from one bacterium to another. Time: approximately 15 minutes.

Teacher Notes for Student Activity: Exchanging DNA - It's just that easy.

This activity is intended to mimic the transfer of pieces of bacterial DNA (plasmids) between bacteria. It is important to stress to the students that they are not all the same type of bacteria; one might be streptococcus, another might be a bacillus. Any type of bacteria can pass on its antibiotic resistance to any other type of bacteria.

Materials

- Paper lunch bag for each student
- Yellow construction paper to make 1" squares
- Two other colors of construction paper such as blue and green to make 1" squares

Preparation

1. Each student will need a paper bag with "bacterial DNA".
2. Prepare most bags to have 10 one-inch squares of green construction paper.
3. Prepare **five** bags to have 5 blue squares and 5 yellow squares. The yellow squares represent bacteria with pieces of DNA that code for antibiotic resistance; the blue squares represent another kind of bacteria different from the green bacteria.

4. Display the following table on an overhead projector or draw it on the board.

	Number of students with yellow squares	Number of students with NO yellow squares
Before Exchanges	*5*	
First Exchange Round		
Second Exchange Round		
Third Exchange Round		

5. Discuss the Activity Analysis after students have completed the activity (see separate student handout):

Activity Analysis (with answers)

1. When the activity began, 5 students had bags containing "infectious" yellow bacteria that carried DNA for antibiotic resistance (AR-DNA).
   - How many students were "infected" with yellow squares (AR-DNA) after the first exchange round? _____
   - The second exchange round? ____
   - And finally, after the third exchange round? ____

2. If you are bacteria without a yellow square, what will happen to you if you are in a patient who takes an antibiotic?

   You will die and not reproduce; other bacteria with antibiotic resistance [AR] will survive and reproduce, thus passing along the AR genes.

3. Suppose we continued to do this activity for eight or nine exchange rounds, what would you expect to happen?

   Yellow squares would become more evenly distributed.

4. Speculate on what the results would have been if you weren't allowed to give away a new yellow square once it was put in your bag - excluding the bags with initial "infectious" bacteria.

   The yellow squares/AR genes would be much more widely distributed after the second round, and even more so after the third round.

5. In what way is this activity similar to "real life" DNA exchange in bacteria?

   DNA exchange is random, and can occur between different species of bacteria – the blue and green bacteria.

6. In what way is this simulation activity not completely accurate?

   In this simulation there is no DNA replication. In real life, the bacteria would incorporate the AR-DNA into their plasmids, replicate, and then pass on bits of DNA. The infected bacterium could make 16 million copies of itself in a day, each one containing the AR gene. In our simulation, the bacteria could also take in an AR gene (a yellow square) and then lose it in the next exchange.

Student Handout: Exchanging DNA - It's just that easy.

Materials

- A paper bag containing 'bacterial DNA'

Procedure

1. At your teacher's direction, walk around the room and exchange bacterial DNA with other students. When you exchange with another student, take a paper square from his or her bag without looking and put it in your bag. Have him or her do the same. Continue doing this until you have made 10 exchanges. Be sure you don't look but keep track of the number of exchanges.
2. Return to your desk and sort your squares into two piles: yellow squares in one pile and all the others (blue and green) in another pile.
3. If you have yellow squares, let your teacher know so this data can be entered into the class data table on the board and in your table below:

	Number of students with yellow squares	Number of students with no yellow squares
Before Exchanges	*5*	
First Exchange Round		
Second Exchange Round		
Third Exchange Round		

4. Put all your squares back in the bag and repeat Steps 1 through 3 two more times, for total of three exchange rounds. Record the number of students with yellow squares from the class data table after each exchange round.

Activity Analysis

1. When the activity began, 5 students had bags containing "infectious" yellow bacteria that carried DNA for antibiotic resistance (AR).

2. How many students were "infected" with yellow squares (AR-DNA) after the first exchange round? _____

3. The second exchange round? ____

4. And finally, after the third exchange round? ____

5. If you are bacteria without a yellow square, what will happen to you if you are in a patient who takes an antibiotic?

____

____

6. Suppose we continued to do this activity for eight or nine exchange rounds, what would you expect to happen?

7. Speculate on what the results would have been if you weren't allowed to give away a new yellow square you received once it was put in your bag.

8. In what way is this activity similar to "real life" DNA exchange in bacteria?

9. In what way is this simulation activity not completely accurate?

Additional Resources

Because Web sites frequently change, some of these resources may no longer be available. Use a search engine and related key words to locate new Web sites.

Emerging and Re-emerging Infectious Disease

The National Institute of Health offers this free high-school curriculum supplement. Student activities include lab experiments with bacteria, accompanied by online video support for experiments.
http://science.education.nih.gov/customers.nsf/HSDiseases?OpenForm

Food Science

A free curriculum for middle or high school classrooms, with interactive video, manuals, and reference guides, which links food science and microbes; included is the overuse of antibiotics in animal feed.
http://www.nsta.org/fdacurriculum

"Microbes: What They Do and How Antibiotics Change Them" - Dr. Maura J. Meade-Callahan

Antibiotics and antibacterials can do more damage than good when they:

- kill good bacteria inside the human body
- destroy microbes that clean up pollution
- lead to antibiotic resistance in microorganisms
- make treatment of some diseases difficult when overused

http://www.actionbioscience.org/evolution/meade_callahan.html

Video: Intimate Strangers: Unseen Life on Earth

This PBS documentary provides an overview of the microbial world and offers a clear and exciting picture of the field of microbiology. Meet scientists across the globe working to investigate the microbial world in diverse locations from a termite's stomach to a hospital operating room to an African village — and even outer space. These programs increase the microbial literacy of students, the general public, and biotechnology workers.
http://www.learner.org/resources/series147.html

Bacteria & Drug Resistance

http://whyfiles.org/038badbugs/
http://www.fda.gov/oc/opacom/hottopics/anti_resist.html
http://www.fda.gov/fdac/features/795_antibio.html
http://www.cdc.gov/drugresistance/
http://www.cdc.gov/drugresistance/community/
http://www.ucsusa.org/food_and_environment/ antibiotic_resistance/index.cfm
http://people.ku.edu/~jbrown/resistance.htm

Bacteria: Information & Interests

http://microbes.info/
http://www.cdc.gov/ncidod/dbmd/diseaseinfo/
http://www.fda.gov/fdac/features/2002/402_bugs.html
http://www.bacteriamuseum.org/

Plague (The Black Death)

http://www.byu.edu/ipt/projects/middleages/ LifeTimes/Plague.html
http://www.eyewitnesstohistory.com/plague.htm (excellent)

Others
http://history1900s.about.com/library/weekly/aa062900a.htm (Typhoid Mary)
http://www.iditarod.com/serum_run.html (Iditarod dogsled race – diphtheria serum run)

Genomic Revolution
http://www.ornl.gov/sci/techresources/Human_Genome/education/education.shtmL
This Web site of the government-funded Human Genome Project has links about genomics, the history of the project, and more.

Secrets of the Sequence Videos and Lessons
This video and 49 others with their accompanying lessons are available *at no charge* from www.vcu.edu/lifesci/sosq