A New “War of the Worlds”: The Evolution of Resistance

Why?

Antibiotics came into general use in the 1950’s and were heralded as a miracle drug. Diseases that were once feared because of their mortality rate could be easily treated and were no longer a threat to human population. However, throughout the subsequent years, the misuse of antibiotics has led to the evolution of new threats like MRSA and resistant TB. How could this have happened?

![Streptococcus bacteria](https://encarta.msn.com)

Fig. 1 Shows a photomicrograph of *Streptococcus* bacteria
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Learning Objectives

Students will:
- Identify sources of variation
- Identify selecting agents
- Describe how resistant organisms appear and increase within a population

Prerequisites & Resources

- Bacteria reproduce asexually
- Mutations cause changes in genetic material
- Living things have a tendency to reproduce and increase in number
- Through the process of natural selection, individuals within a population that have favorable traits tend to survive and pass on these traits to their offspring
- Pesticides are used to kill insects
- How to read a graph

Concepts/Vocabulary

- Adaptation
- Antibiotic (“anti”=against; “bios”=life)
- Environment
- Resistance
- Selecting Agent
- *Streptococcus* bacteria
Jane was babysitting her five-year old neighbor Saturday evening. The little girl had a fever and cough and could not go with her parents to a family party. Jane woke up Monday morning and began to get ready for school. As she got on the bus, she realized her throat felt a little scratchy when she swallowed. By lunchtime, she was running a fever and was barely able to swallow. Jane felt so sick that she went to the nurse. Her mother called and advised to take Jane to the doctor. Jane was examined by the doctor and exhibited the following symptoms: a fever of 101° F, white spots coating her throat and tonsils, and swollen lymph nodes in her neck. To find out whether Jane’s sore throat was caused by a bacteria or a virus, Jane was given a rapid Strep test. The test returned positive. Jane had strep throat. This meant Jane had the bacteria, *Streptococcus* growing in her throat! The doctor prescribed Penicillin V three times a day for 10 days to treat the infection. Penicillin V is an antibiotic designed to kill *Streptococcus* bacteria.

After taking the antibiotic for 24 hours, Jane felt much better and was able to return to school by the following day. She continued to take the Penicillin V as prescribed. However, by the following Sunday, Jane’s throat began to hurt again. By Sunday evening, she felt as sick as she did on Monday. Worried about her daughter, Jane’s mother took her back to the doctor early Monday morning. He informed Jane and her mother that Jane had contracted a form of strep that was penicillin resistant.

**Key Questions**

1. What is the name of the bacteria that caused Jane’s infection?

2. What are three symptoms of a strep infection?

3. How did the doctor treat the infection?

4. How do you think this strep infection was transmitted to Jane?
5. The following graph shows the number of bacteria (in millions) in Jane’s throat over time. Extend the line on the graph to show what happened to the number of bacteria in Jane’s throat on Sunday 11/10 and Monday 11/11.

![Number of Bacteria Per Day of Infection](image)

6. Jane’s strep infection was penicillin resistant. What do you think this means?

7. Why do you think it was important for the doctor to know if bacteria or viruses caused Jane’s infection?
Model 2

After Jane was exposed to the strep bacteria, they began to reproduce and populate the throat environment. Let’s take a look at what was happening in Jane’s throat during the week of her strep infection.

![Diagram showing bacterial reproduction]

**Key Questions**

1. What variation(s) exists in the population of strep bacteria found in Jane’s throat on Sunday 11/3?

2. Which variety of bacteria is found in her throat on Wednesday?

3. If all of the strep bacteria in Jane’s throat reproduce asexually, how did some of these bacteria become different from the rest?

4. Why weren’t all of the bacteria able to survive from Sunday – Wednesday?

**Key**

- Penicillin sensitive streptococcus
- Penicillin resistant streptococcus
5. In the third box above, draw what Jane’s throat would look like on Monday when she feels sick again and explain why.

6. Why would it be dangerous for the bacteria to have no variations within its population?

7. In this environment, penicillin is considered a “selecting agent”. Describe how penicillin is acting as the selecting agent.

8. Imagine and describe a specific adaptation (structure or function) that the resistant bacteria may have that has allowed them to survive exposure to the antibiotic.

9. Explain how this model is an example of natural selection.

10. An antibiotic does not create resistant bacteria, it selects for resistant individuals in the population. Using the model above, explain this statement in your own words.

11. Scientists are concerned about the evolution of antibiotic resistant bacteria. What are some ways you can help prevent this increase?
Exercises

1. Complete the key for this graphic by drawing the appropriate insect next to each label.

2. What is the selecting agent in this environment?

3. How did some of these insects become different from the original population?

4. Why did some of the insects die while others survived the pesticide?

5. Why would it be dangerous for the insects to have no variation within their population?

Problems
1. Ming loved to buy antibacterial soaps from her local bath and body shop. These products have fast become a popular alternative to traditional cleaning products. These antibacterial products are so popular because they are intended to decrease bacteria thus breaking the cycle of infection. As a consumer, why might you be concerned about the over use of these new products?

2. In his organic gardening magazine, Jake read an advertisement for a company selling ladybugs as natural predators for insect pests. The ad stated that ladybugs are a potentially more effective method of controlling insect populations than using pesticides. Should Jake purchase the ladybugs to control pests in his garden? Why/Why not?
Standards Connections

Connections to the National Science Education Standards:

- Changes in DNA (mutations) occur spontaneously at low rates.
- Species evolve over time. Evolution is the consequence of the interactions of (1) the potential for a species to increase its numbers, (2) the genetic variability of offspring due to mutation and recombination of genes, (3) a finite supply of the resources required for life, and (4) the ensuing selection by the environment of those offspring better able to survive and leave offspring.

Connections to the New York State Living Environment Core Curriculum:

- 2.1d In asexually reproducing organisms, all the genes come from a single parent. Asexually produced offspring are normally genetically identical to the parent.
- 3.1b New inheritable characteristics can result from new combinations of existing genes or from mutations of genes in reproductive cells.
- 3.1f Species evolve over time. Evolution is the consequence of the interactions of (1) the potential for a species to increase its numbers, (2) the genetic variability of offspring due to mutation and recombination of genes, (3) a finite supply of the resources required for life, and (4) the ensuing selection by the environment of those offspring better able to survive and leave offspring.
- 3.1g Some characteristics give individuals an advantage over others in surviving and reproducing, and the advantaged offspring, in turn, are more likely than others to survive and reproduce. The proportion of individuals that have advantageous characteristics will increase.
- 3.1h The variation of organisms within a species increases the likelihood that at least some members of the species will survive under changed environmental conditions.
- The diversity of life on Earth today is the result of natural selection occurring over a vast amount of geologic time for most organisms, but over a short amount of time for organisms with short reproductive cycles such as pathogens in an antibiotic environment and insects in a pesticide environment.

Hints For Facilitation

Model 1: Teachers may suggest that students with learning difficulties read the model before class. This will allow these students ample time to understand the reading. Students may not bring answered questions into class.

Model 1 #5: The exact number of bacteria is not important, rather students should draw a general trend for an increase in the number of bacteria during Sunday and Monday.
Model 1 #7: Teachers might want to intervene and describe the differences between bacteria and viruses. Teacher should ensure that the basic differences between bacteria and viruses are apparent to the students when answering this question.

Model 2: Teachers should remind students that models might be incomplete. Students should also be reminded NOT to complete a model until told to do so.

Model 2 #5: Students drawings should show an increase in the number of penicillin resistant bacteria, and their explanation should show an understanding that the environment is selecting for the resistant bacteria.

Model 2 #8: Be prepared to accept bizarre answers. It is very important that students are given a chance to hypothesize about possible adaptations. Teacher should encourage listing all group ideas.

Model 2 #9: Teachers may want to direct students to the prerequisite list to review the process of natural selection.

Misconception alerts: Students often think that the antibiotic or pesticide causes the mutation. Students need to understand that the mutation existed before the introduction of the selecting agent. The selecting agent simply selects those pre-existing individuals that can survive. Additionally, students want to use the word “immune” or “immuned”. Teachers need to make sure that these words are not used because the immune system is not part of this process.

**Why?**

Antibiotics came into general use in the 1950’s and were heralded as a miracle drug. Diseases that were once feared because of their mortality rate could be easily treated and were no longer a threat to human population. However, throughout the subsequent years, the misuse of antibiotics has led to the evolution of new threats like MRSA and resistant TB. How could this have happened?

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- Through the process of natural selection, individuals within a population that have favorable traits tend to survive and pass on these traits to their offspring
- Pesticides are used to kill insects
- How to read a graph
Concepts/Vocabulary

- Adaptation
- Antibiotic ("anti"=against; "bios"=life)
- Environment
- Resistance
- Selecting Agent
- *Streptococcus* bacteria

Model 1

Jane was babysitting her five-year old neighbor Saturday evening. The little girl had a fever and cough and could not go with her parents to a family party. Jane woke up Monday morning and began to get ready for school. As she got on the bus, she realized that her throat felt a little scratchy when she swallowed. By lunchtime, she was running a fever and was barely able to swallow. Jane felt so sick that she went to the nurse. Her mother was called and advised to take Jane to the doctor. Jane was examined by the doctor and exhibited the following symptoms: a fever of 101° F, white spots coating her throat and tonsils, and swollen lymph nodes in her neck. To find out whether Jane’s sore throat was caused by a bacteria or a virus, Jane was given a rapid Strep test. The test returned positive. Jane had strep throat. This meant Jane had the bacteria, *Streptococcus* growing in her throat! The doctor prescribed Penicillin V three times a day for 10 days to treat the infection. Penicillin V is an antibiotic designed to kill *Streptococcus* bacteria.

After taking the antibiotic for 24 hours, Jane felt much better and was able to return to school by the following day. She continued to take the Penicillin V as prescribed. However, by the following Sunday, Jane’s throat began to hurt again. By Sunday evening, she felt as sick as she did on Monday. Worried about her daughter, Jane’s mother took her back to the doctor early Monday morning. He informed Jane and her mother that Jane had contracted a form of strep that was penicillin resistant.

Key Questions

1. What is the name of the bacteria that caused Jane’s infection?

   *Streptococcus*

2. What are three symptoms of a strep infection?

   * Scratchy throat when swallowing
   * Fever
   * Trouble Swallowing
   * Spots coating throat and tonsils
   * Swollen lymph nodes in neck
3. How did the doctor treat the infection?

*Penicillin V, an antibiotic (dosage may be included)*

4. How do you think this strep infection was transmitted to Jane?

*Transmitted from the girl she babysat by coughing*
5. The following graph shows the number of bacteria (in millions) in Jane’s throat over time. Extend the line on the graph to show what happened to the number of bacteria in Jane’s throat on Sunday 11/10 and Monday 11/11.

Students’ drawings should show an increase in the number of bacteria. The exact numbers of bacteria are not

![Graph showing number of bacteria per day of infection]

6. Jane’s strep infection was penicillin resistant. What do you think this means?

The strep bacteria are not killed by penicillin.

7. Why do you think it was important for the doctor to know if bacteria or viruses caused Jane’s infection?

The doctor needs to choose a drug that will kill the bacteria.
Antibiotics only work on living things. Viruses are not alive and can not be killed by antibiotics.
Model 2

After Jane was exposed to the strep bacteria, they began to reproduce and populate the throat environment. Let’s take a look at what was happening in Jane’s throat during the week of her strep infection.

Key Questions

1. What variation(s) exists in the population of strep bacteria found in Jane’s throat on Sunday 11/3?

Some bacteria are resistant and some are sensitive to penicillin.

2. Which variety of bacteria is found in her throat on Wednesday?

Penicillin resistant streptococcus.

3. If all of the strep bacteria in Jane’s throat reproduce asexually, how did some of these bacteria become different from the rest?
There was a mutation.

4. Why weren’t all of the bacteria able to survive from Sunday – Wednesday?

   Penicillin was able to kill the penicillin sensitive bacteria.

5. In the third box above, draw what Jane’s throat would look like on Monday when she feels sick again and explain why.

Student’s drawings should show an increase in the number of penicillin resistant bacteria, and their explanation should show an understanding that the environment is selecting for the resistant bacteria. It is OK to have some penicillin sensitive bacteria in their drawing if the students say that there may be sensitive bacteria nearby and they have moved into the view of the diagram.

6. Why would it be dangerous for the bacteria to have no variations within its population?

Without variation, all of the bacteria would die when the antibiotic is introduced into the environment.

7. In this environment, penicillin is considered a “selecting agent”. Describe how penicillin is acting as the selecting agent.

   The penicillin did not cause the resistance. It killed the sensitive bacteria and selected for the resistant bacteria.

8. Imagine and describe a specific adaptation (structure or function) that the resistant bacteria may have that has allowed them to survive exposure to the antibiotic.

   Be prepared to accept bizarre answers. It is very important that students are given a chance to hypothesize about possible adaptations. Teacher should encourage listing all group ideas. Some ideas may include a specialized structure on the cell wall or membrane, special enzymes that hydrolyze the antibiotic, or maybe a behavior like creation of biofilms.

9. Explain how this model is an example of natural selection.
The original bacterial population of bacteria contained variation. When the penicillin was introduced, the bacteria with the favorable trait (resistance) survived and reproduced. The resistance was passed onto the offspring of the bacteria thus increasing the number of resistant bacteria within the population.

10. An antibiotic does not create resistant bacteria, it selects for resistant individuals in the population. Using the model above, explain this statement in your own words.

*The variation for resistance existed in the population before the penicillin was introduced into the environment. The penicillin killed off all other bacteria that was not resistant, leaving only the resistant ones.*

11. Scientists are concerned about the evolution of antibiotic resistant bacteria. What are some ways you can help prevent this increase?

Take all of my antibiotic, don’t stop because you feel better, only use antibiotics for bacterial infections, do not use antibacterial soap, etc. Do not take an antibiotic prescribed to someone else

**Exercises**

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Key

- Pesticide sensitive insects
- Pesticide resistant insects
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1. Complete the key for this graphic by drawing the appropriate insect next to each label.

2. What is the selecting agent in this environment?

   *The pesticide*

3. How did some of these insects become different from the original population?

   *A mutation or recombination of genes because of sexual reproduction*

4. Why did some of the insects die while others survived the pesticide?

   *Those that are sensitive to the pesticide are killed after the pesticide is sprayed.*
   *Those that are resistant to the pesticide survived.*

5. Why would it be dangerous for the insects to have no variation within their population?

   *Without variation, all of the insects would die when the pesticide is introduced into the environment.*

**Problems**

1. Ming loved to buy antibacterial soaps from her local bath and body shop. These products have fast become a popular alternative to traditional cleaning products. These antibacterial products are so popular because they are intended to decrease bacteria thus breaking the cycle of infection. As a consumer, why might you be concerned about the over use of these new products?

   *Students may suggest that these products may lead to resistant bacteria*

2. In his organic gardening magazine, Jake read an advertisement for a company selling ladybugs as natural predators for insect pests. The ad stated that ladybugs are a potentially more effective method of
controlling insect populations than using pesticides. Should Jake purchase the ladybugs to control pests in his garden? Why/Why not?

Students who choose to purchase the ladybugs may suggest that they offer a safer alternative to pesticides because they will not lead to pesticide resistance, and will not pollute the environment.

Students who choose not to purchase the ladybugs may suggest that the ladybugs may be imported (exotic) and will disrupt the food chain.