ACTIVITY WORKSHEET: 99.99%: The Problem With Antibacterial Products and the Simplicity of Natural Selection

Name:
Group:

Part A: Prediction
If you look at the label on a container of hand sanitizer, you'll see that it claims to kill 99.99% of germs (bacteria). What about the 0.01% that are not killed?

Predict: What will happen to the population of 0.01% of bacteria that are not killed by hand sanitizer, and how does this relate to evolution?

Part B: Background
In this lab, you will learn about the concept of natural selection as it applies to a current-day issue.
You should know the following:

1. A *population* is a group of the same kinds of organisms living in the same area.
2. In any population, there is variation in traits among the organisms due to mutation or the recombining of genes from egg and sperm cells.
3. Even bacteria, which reproduce by asexual reproduction (splitting in half), can have offspring that are not exactly the same due to mutations of the DNA or through exchanging DNA with another bacterium. A *mutation* is a permanent change in the DNA sequence of a gene.
4. Some traits help an organism survive and some do not help survival. Some traits, like being left- or right-handed, have no effect on survival. The environment determines which traits are favorable.
5. *Selective pressure* is something that changes the ability of an organism to survive in a particular environment. A selective pressure can be something that is living or something that is not living.
6. Organisms with favorable traits survive. We call the favorable trait an *adaptive advantage* because it helps the organism survive. Organisms with an adaptive advantage (favorable traits) pass the genes for those traits on to their offspring. By this mechanism, over time, more and more organisms in a population have the favorable traits. We say the population has evolved and that the organisms have adapted to the environment.

Part C: Modeling natural selection
Materials (per group of three students)
1 paper cup containing 20 white mini-marshmallows (or soft Styrofoam packing peanuts)
1 paper cup containing 8 skittles (or pebbles) of any color
1 toothpick
1 8" diameter paper plate
1 clock or stopwatch

(Note: Do not eat the candy or marshmallows.)

1. Put eight mini-marshmallows and two Skittles on the same plate in the middle of your group. The marshmallows and Skittles represent bacteria. Most of the bacteria (marshmallows) are the same (clones) due to asexual reproduction. They have a soft "shell," are white, and are cylindrical in shape. Two of the bacteria (the Skittles) are not like the other clones. They represent bacteria that had three mutations resulting in three different traits (colorful, hard shell, and disc shaped).
2. Look at how the beginning row in Table 1 is filled out.
3. The toothpick represents antimicrobial hand sanitizer. When you use the toothpick to catch the bacteria (marshmallows and Skittles), it is like bacteria being destroyed by the chemicals in the hand sanitizer.
4. First dose of hand sanitizer (D1): One student in the group uses the toothpick to pick up—one at a time—and set aside as many of the bacteria as possible in seven seconds.
5. The student then counts how many bacteria of each kind are left on the plate, and all students in the group fill in the second row on the table (D1).
6. The first student then lets the remaining bacteria "reproduce by fission" by making copies of them. In other words, the student doubles the number of any of the remaining bacteria. For example, if there are three marshmallows left, make six by adding three more marshmallows to the plate. If there are two Skittles left, make four by adding two more Skittles to the plate. This represents reproduction 1 (R1).

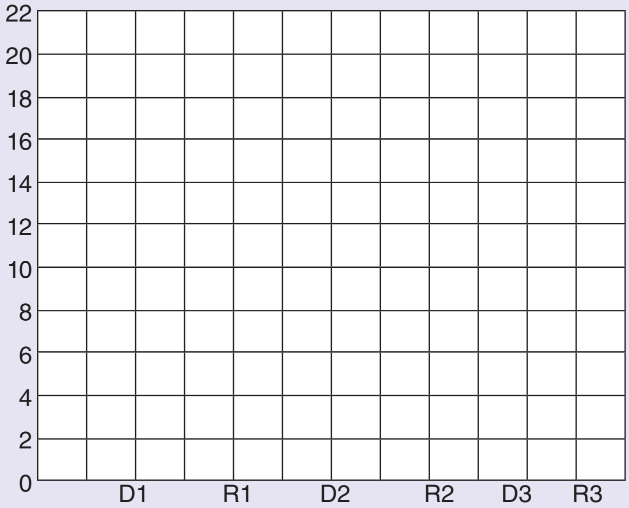
7. The first student then counts the number of each kind of bacteria on the plate after reproducing and all students in the group fill in the third row on the table (R1).
8. The second student in the group repeats steps 4 and 5 for the second dose of hand sanitizer (D2), catching bacteria—one a time—with the toothpick in seven seconds and counting the remaining bacteria. All group members fill in the fourth row of the data table (D2).
9. The second student repeats steps 6 and 7 for the second reproduction (R2).
10. The third student in the group repeats steps 4 and 5 for the third dose of hand sanitizer (D3) and steps 6 and 7 for the third reproduction (R3); all students record the data.

Part D: Data collection
Table: The effect of hand sanitizer on the number of normal and mutated bacteria

Time	Number of normal (marshmallow) bacteria	Number of mutated (Skittle) bacteria
Beginning (step 0)	8	2=
After step 4 (first dose of hand sanitizer, D1)		
Remaining bacteria reproduce (first reproduction, R1)		
After step 8 (second dose of hand sanitizer, D2)		
Remaining bacteria reproduce (R2)		
After step 10 (D3)		
Remaining bacteria reproduce (R3)		

Make a graph of your data showing the change in the number of each kind of bacteria over time.

Title: The effect of hand sanitizer on the number of normal and mutated bacteria over time



Number of bacteria from the table

Part E: Follow-up discussion questions *(answers in italics)*

1. If hand sanitizer were actually effective in killing 8 out of 10 bacteria, what percentage should be on the label? (*80%*)
2. How many "normal" bacteria, out of 10 total, would you have in this lab to bring the percentage closer to 99.99%? (*9*)
3. 99.99% equals 99.99 out of 100. Because you cannot have fractions of bacteria, in order for this activity to simulate real numbers, you would need a total of how many bacteria? (*10,000*) How many should be marshmallows? (*9,999*) How many should be Skittles? (*1*)
4. If you did this simulation with 10,000 bacteria to start, about how long do you think it would take for the population of resistant bacteria to become greater than the population of normal bacteria population? (*Answers will vary, but students should recognize that it would take a far longer time for the resistance to happen due to the sheer numbers of bacteria. Reinforce with students that using low numbers is a weakness of the simulation and that, in reality, resistance takes a while.*)

Part F: Homework questions *(answers in italics)*

1. When you used a toothpick to pick up and remove bacteria, that step represented the hand sanitizer killing the bacteria. Use numbers from your data to describe which kind of bacteria, normal or mutated, were killed most easily with every dose of hand

sanitizer. Circle your numbers in your answer. (*Answers will vary, but usually numbers show that the normal bacteria are killed most easily because their numbers go down; see Figure 3.*)

2. Describe the selective pressure that determined which bacterial trait was favorable. (*The selective pressure that determined which trait was favorable was the toothpick, which represented hand sanitizer; see Figure 3.*)

3. In the table below, list each of the traits in the category in which it belongs.

	Normal bacteria: White, cylindrical, soft bodied	Mutated bacteria: Colorful, disc shaped, hard bodied
Adaptive advantage (helped survival)	*(Answers vary, but usually none of the traits was favorable.)*	*(Disc shaped and hard bodied)*
Unfavorable trait (hurt survival)	*(Soft bodied)*	*(None)*
Unaffected traits (neither helped nor hurt)	*(White, cylinder)*	*(Colorful)*

4. Choose one trait from above that was an adaptive advantage. Explain how the trait was an adaptive advantage. (*Answers will vary. The hard body of the mutated bacteria was an adaptive advantage in that it made it very difficult for the toothpick to "catch" it.*)

5. Choose one unfavorable trait from above. Explain how the trait was unfavorable. (*Answers will vary. The soft body of the normal bacteria was unfavorable in that it made it very easy for the toothpick to catch it.*)

6. Revisit your prediction from part A. After completing this simulation, describe what happens to the bacteria that are not killed by hand sanitizer and explain how this relates to evolution. (*Answers will vary. The bacteria that are not killed by hand sanitizer reproduce and pass on to their offspring the genes that enable them to survive. Over time, the population of bacteria contains large numbers of the resistant bacteria.*)

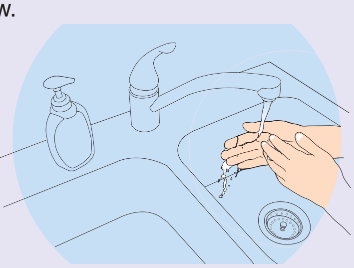
7. When a doctor prescribes an antibiotic, the doctor instructs you to take all of the medication until it is gone. This advice should be taken very seriously. If you stop taking the antibiotics too early, what happens to the bacteria that, by chance, have a trait that prevents them from being killed very quickly by the antibiotic? Explain how your response relates to this activity on hand sanitizers. *(Answers will vary, but strong responses should reflect a solid conceptual understanding that organisms with favorable traits survive and reproduce. By this mechanism, over time, a population evolves so that most organisms have the favorable trait. In this example, the favorable trait is antibiotic resistance. See Figure 3.)*

8. Challenge: When a population of bacteria becomes resistant to an antibacterial chemical, a new chemical needs to be created. Think of a new kind of chemical (another other kind of "weapon," utensil, or object such as a pencil or spoon) that would be effective on the mutated bacteria. In other words, describe a new selective pressure that would reduce the number of mutated bacteria. Describe your new antibacterial chemical and explain how and why it would be effective on the mutated bacteria. (*Students construct their response to this based on the candy bacteria and the fact that the mutated ones have a hard shell. Answers will vary. See Figure 3.*)

9. Choose any two from the choices below.

   A. Over time, the population of bacteria went from mostly ____________(*normal*)____________ to mostly ________(*mutated*)__________________. How does the change in the bacteria population illustrate the concept of evolution (change over time) by natural selection? You may answer with labeled illustrations or with a written response.

   B. Hand sanitizers are used everywhere: homes, libraries, schools, grocery stores, hospitals, etc. Washing with regular soap and water also helps get rid of bacteria as shown in the picture below.



There are advantages and disadvantages to using hand sanitizers over washing with soap and water. Describe two reasons why hand sanitizers should be used instead of soap and water. Describe two reasons why hand sanitizers should not be used. Use evidence from this activity to support your reasons. (*Answers will vary; see Figure 3*.)

C. In the same way that hand sanitizer creates resistant bacteria, overuse of antibiotics creates resistant strains of bacteria, as well. Doctors are becoming more and more hesitant to prescribe antibiotics to people if they are sick, especially if the doctor does not know if the sickness is caused by a virus or a bacterium. Why do you think it is a good idea for doctors to be cautious about prescribing antibiotics? Use data from this lab to support your response. (*Answers will vary. A strong response would include a conceptual understanding that prescribing an antibiotic for someone who may not have a bacterial infection still results in killing bacteria in the body. These "helpful" bacteria offer competition to harmful, potentially resistant bacteria and, if their numbers dwindle, it provides an opportunity for harmful resistant bacteria to flourish. See Figure 3.*)

D. Many people argue that evolution should not be taught, yet others argue that it is relevant to our everyday lives. What argument would you give for teaching evolution? You may find it helpful to connect this question to the activity you just did. (*Answers will vary. A strong student response would explain that antibiotic-resistant bacteria are the result of evolution by natural selection. Strains of antibiotic bacteria are becoming more common. Plants and insects that are resistant to pesticides and insecticides are also increasing. Knowledge of how and why these organisms become resistant to the substances that are designed to control them helps people make educated decisions about the use of antibiotic products, insecticides, and pesticides. See Figure 3.*)