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Paper Clip Bacteria – Modeling Evolution

Bacteria are single-celled, small, simple organisms. They do not have specialized organelles inside their cells. Bacteria are often used to model evolution because they go through many generations in a relatively short time. In this activity, you will model how a bacteria population is affected by exposure to an antibiotic.

Bacteria normally die when exposed to an antibiotic, such as penicillin. However, some bacteria have developed inheritable traits that make them resistant to antibiotics. The primary cause of antibiotic resistance in bacteria is genetic mutation. When a mutation allows a bacterium to survive in the presence of an antibiotic, the surviving bacteria pass on their antibiotic resistance mutation to their offspring when they reproduce.

In this activity, the starting bacteria population includes (1) **typical bacteria** that die when exposed to antibiotics and (2) **mutated bacteria** that are antibiotic resistant. The mutated bacteria have a higher chance of survival when exposed to an antibiotic. The paper clips in this activity represent bacteria. **The color paper clips** represent the typical bacteria phenotype, and the **silver paper clips** represent bacteria that have undergone a mutation that gives them antibiotic resistance.

Assumptions

- Typical bacteria have a 1-in-6 chance of surviving exposure to an antibiotic.
- Mutated bacteria have a 5-in-6 chance of surviving exposure to an antibiotic.
- Both typical and mutated bacteria produce offspring of the same type. This means that typical bacteria will produce typical bacteria and mutated bacteria will produce mutated bacteria.

Procedure

1. Start with a population of 20 bacteria, 18 typical and 2 mutated. Record the starting bacteria population for both typical and mutated bacteria in the table in the column labeled “Start of Generation.”

2. The entire population of bacteria will be exposed to an antibiotic. You will simulate this event by rolling the die for *each* individual bacterium (paper clip) to see if the bacterium survives antibiotic treatment.
    a. **For typical bacteria**, which have a 1-in-6 chance of surviving exposure to an antibiotic, **survival and reproduction happen only when a 1 is rolled**. Any other roll will lead to death.
    b. **For mutated bacteria,** which have a 5-in-6 chance of surviving exposure to an **antibiotic, survival and reproduction occurs in rolls of 1–5.** Death only occurs when a **6** is rolled.

3. For each individual bacterium, roll the die.
    a. Determine if the bacterium survives by consulting the laminated table (dice roll determining bacteria survival)

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b. When a bacterium dies, remove it from the population by setting it aside.
c. Record the number of bacteria that died after antibiotic treatment in the "Dead" column in the table.
d. Record the number of bacteria that survived after antibiotic treatment in the "Survivors" column in the table.

4. The surviving bacteria reproduce. Bacteria divide in half when they reproduce, in a process called **binary fission**. Each surviving bacteria becomes two bacteria. In the Table, use the number of survivors from Generation 1 to calculate and record the total number of bacteria after each surviving bacteria reproduces in the "Reproduction" column in (Hint: Multiply the number of surviving bacteria by two.)
   a. Write the number of bacteria in your "Reproduction" column at the end of Generation 1 in the column "At start of Generation" for Generation 2.

5. Repeat steps 2–4, filling in the table for another two generations.

Bacteria Survival Over Generations					
		Number of Bacteria			
Generation	**Bacteria**	**Start of Generation**	**Dead** (at end of generation)	**Survivors** (end of generation)	**Reproduction** (survivors x 2)
1	Typical (Color paper clip)				
	Mutated (Silver paper clip)				
2	Typical (Color paper clip)				
	Mutated (Silver paper clip)				
3	Typical (Color paper clip)				
	Mutated (Silver paper clip)				
4	Typical (Color paper clip)				
	Mutated (Silver paper clip)				

START # FOR NEXT GENERATION.

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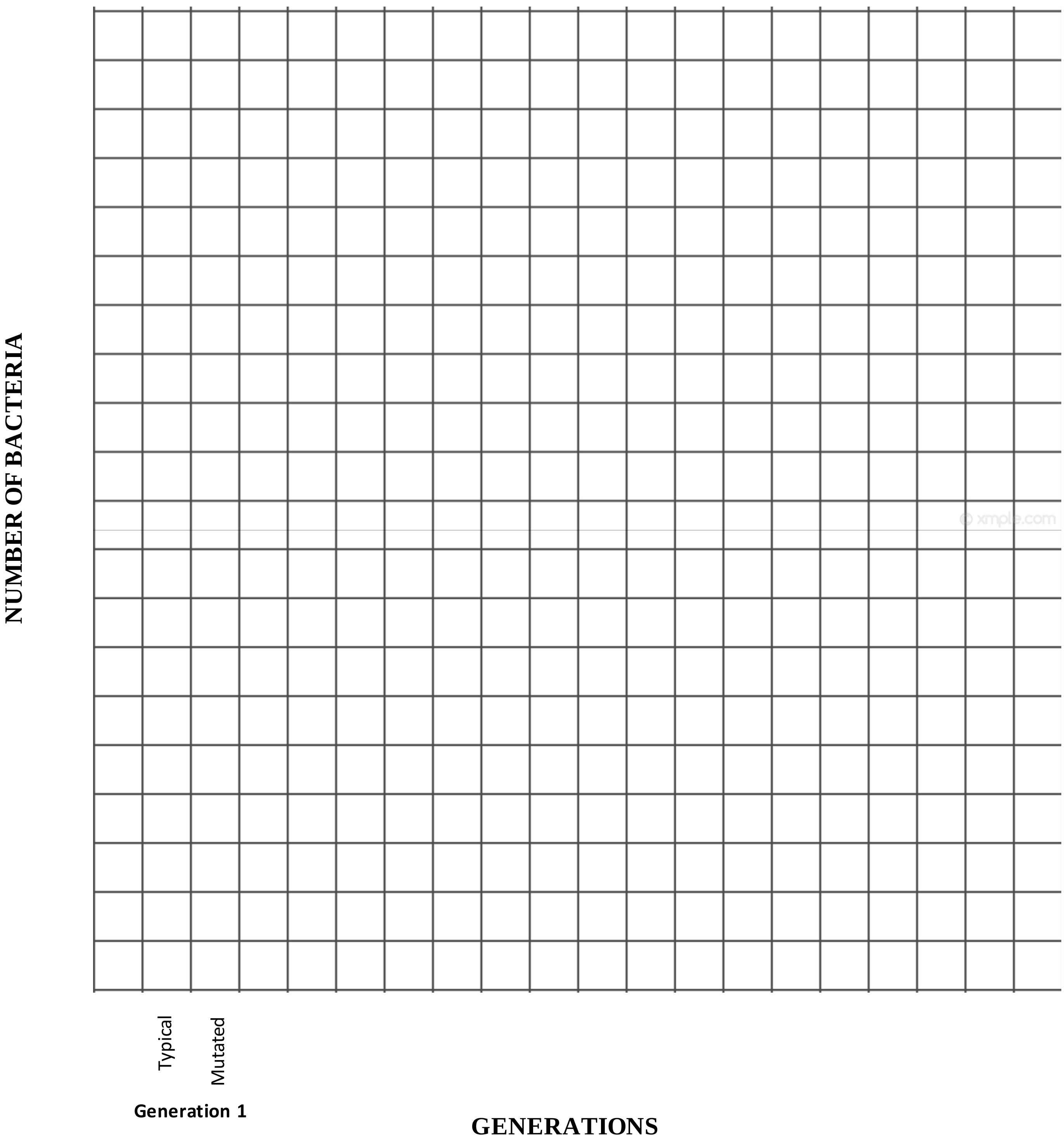
Data Analysis

Graph your results for both typical and mutated bacteria. Use the numbers from the "At start of Generation" column. Use a different color for each type of bacteria. There should be **8 bars total** – one for each of the four generations, for both typical and mutated bacteria. The first generation has been set up for you.



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Activity Questions:

1. On average, how do the proportions of typical and mutated bacteria change in the population over time?

2. What was necessary to model evolution? (Hint: Think about how the game would work if all the paper clip bacteria looked the same.)

3. Explain why evolution happens to a whole population rather than to a single individual.

4. Animals can develop illnesses from bacterial infections. Antibiotic medications are sometimes prescribed to treat these infections. What do you think might happen to a population of bacteria that is exposed frequently to such antibiotics?

5. Before the widespread use of antibiotics, there were only low levels of antibacterial resistance. As antibiotic use has grown, so has the number of antibiotic resistant bacteria. Why do you think this has occurred?

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6. During a bacterial infection, exposure to antibiotics helps kill off bacteria. However, the antibiotic must be administered for a relatively long period of time. What might happen if someone was prescribed antibiotics but did not complete their full course?

7. This activity simulated a selective process that resulted in a shift of gene variation within a population over a short time scale. How do you think a shift in the proportion of genes in a population could lead to the evolution of a new species?