Some Similarities between the Spread of Infectious Disease and Population Growth

I. The Spread of Infectious Disease

1. An infectious disease is any disease caused by germs such as viruses or bacteria. What are some examples of infectious diseases?

To investigate the spread of an infectious disease, we will assume that:

- At the beginning, only one person is infected. In the figure below, Time 0 shows one infected person. Everyone else is not infected.
- The infectious disease spreads when an infected person interacts with a person who is not infected. During each round of interactions, each person interacts with one other person. Time 1 shows how the infection spread during the first round of interactions.

2a. Time 2 shows the results after the second round of interactions. Draw arrows to show how each person who was already infected spread the infection to a nearby newly infected person. For Times 3 and 4, draw arrows to show how the infection spread during the third and fourth rounds of interactions.

2b. Fill in the “Increase in # infected” blanks to show how many people became newly infected during each round of interactions.

2c. Explain why the number of newly infected people was smallest in the first round of interactions and biggest in the last round of interactions.

During each round of interactions, each infected person passed the infection to one uninfected person. Therefore, the total number of infected people doubled after each round of interactions. This is an example of exponential growth.

3. Graph the total number of infected people at each time. Connect the points to create a line graph. This graph will show exponential growth.

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1 By Drs. Ingrid Waldron and Jennifer Doherty, Dept Biology, Univ Pennsylvania, © 2018. This Student Handout (which may be copied for classroom use) and the Teacher Preparation Notes with instructional suggestions and biology background are available at http://serendip.brynmawr.edu/sci_edu/waldron/#infectious.
Next, your class will carry out a simulation of the spread of infectious disease. A simulation is a simplified demonstration of a real life process.

Procedure
A. This simulation requires an even number of participants. Each participant will get a data strip with a secret number for time 0. Write your secret number on one of the post-its on the back of your data strip. Watch the demonstration of how to do each interaction.
B. For each interaction, find a partner. Show each other your post-its with your secret numbers. Multiply these two numbers and record the product on your data strip as your secret number for this Time. Also, record the name of the person you interacted with. Go back to your seat. If your secret number has changed, use a new post-it to write your new secret number and put it on top of the old one.
C. Wait until your teacher tells you to begin each round of interactions. Each time, move to a different part of the room and interact with a different person. Follow the instructions in B.

After the simulation is complete, your teacher will explain the simulation and collect your data to determine the number of infected people at each time in the simulation.

4a. Enter the data from your simulation in this table.

<table>
<thead>
<tr>
<th>Time</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td># Infected people</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4b. How many people participated in your simulation? ____

5a. In this graph, draw a horizontal line that shows the number of people who participated in your simulation. This indicates the maximum number of infected people for your simulation.

5b. The squares in this graph show exponential growth where the number of infected people has doubled at each time. Explain why exponential growth could not continue for the second half of your simulation.

6a. Graph the data from your simulation. (Use dots.)

6b. Use an * to mark the first simulation data point that is lower than the square that indicates exponential growth. What happened during the simulation that prevented the number of infected people from doubling?

7. In your simulation the infection spread very rapidly. In real life, infections do not spread this rapidly. What are some reasons why the spread of infectious disease is slower in real life?
II. Exponential and Logistic Population Growth

In this section you will learn about some of the similarities between population growth and the spread of infectious disease.

Suppose that a single bacterium is placed in a container with a lot of food. Every 30 minutes, each bacterium in the container divides into two bacteria, so population size doubles every 30 minutes.

8a. Add to this figure to show how population size doubles from 60 minutes to 90 minutes.

8b. How many bacteria do you think there will be after five hours?

9a. Complete this table to show how many bacteria there will be at each time if the number of bacteria doubles every 30 minutes.

<table>
<thead>
<tr>
<th>Time</th>
<th>0 min.</th>
<th>30 min.</th>
<th>1 hr.</th>
<th>1 hr. 30 min.</th>
<th>2 hr.</th>
<th>2 hr. 30 min.</th>
<th>3 hr.</th>
<th>3 hr. 30 min.</th>
<th>4 hr.</th>
<th>4 hr. 30 min.</th>
<th>5 hr.</th>
</tr>
</thead>
<tbody>
<tr>
<td># Bacteria</td>
<td>1</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Increase in # bacteria ___  ___  ___  ___  ___  ___  ___  ___  ___  ___

9b. Fill in the “Increase in # bacteria” blanks.

10. Why did population size increase slowly at the beginning and more rapidly at later times?

11. Graph the number of bacteria at each time. Connect the points to show the population growth curve.

12. In this example, population size doubled every 30 minutes. This type of population growth is called ___________________________ growth.

13. A real population of bacteria cannot keep increasing exponentially forever. Why not?
14. Each individual in a population needs resources like food and water. Competition for resources increases as a population gets bigger. Increased competition results in increased mortality and/or decreased reproduction, so the rate of population growth (slows down / speeds up). Eventually, the population will reach a maximum size which is called the **carrying capacity** of the environment. The carrying capacity depends on the amount of resources available in the environment. This type of population growth is called **logistic population growth**.

15a. One curve in this figure shows logistic population growth in an environment with carrying capacity = K. The other curve shows exponential population growth. Label the curve that shows logistic population growth.

15b. Which population growth curve includes the effects of competition?

- exponential ___  logistic ___  both ___  neither ___

15c. Explain why the difference between the exponential and logistic population growth curves is small at the beginning and bigger at later times.

The graph on the left below shows approximately logistic growth for a laboratory population of Paramecia. The graph on the right below shows approximately logistic growth in the total number of people infected during an Ebola epidemic in Guinea.

16. For each graph, match each letter to the correct item in the list below the graph.

<table>
<thead>
<tr>
<th>Population Growth</th>
<th>Spread of an Infectious Disease</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Graph" /></td>
<td><img src="image" alt="Graph" /></td>
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</tbody>
</table>

- Population growth was slow because few individuals were reproducing.
- Population growth stopped because competition for food had increased mortality and/or reduced reproduction.
- Population growth was faster because there were quite a few reproducing individuals and not too much competition for food.
- Spread of infection was slow because few people had Ebola and could pass on the infection.
- Spread of infection stopped because effective sanitary precautions prevented new infections.
- Spread of infection was faster because there were quite a few infected individuals and not enough sanitary precautions.

Notice the similarities in the processes responsible for both types of logistic growth.
III. Population Growth Models vs. Complex Reality

A model is a simplified representation of reality that can help us to understand a real-world phenomenon. However, a model may be too simple to accurately describe a complex real-world situation. For example, exponential and logistic population growth are two useful models of changes in population size, but these models cannot explain the following examples.

17a. Researchers measured population size four times a year for a population of rabbits that lived in Ohio. How did population size change from October to January each year?

17b. What happened at this time of year to cause this change in population size?

A real world population is part of a complex ecosystem that includes the physical environment and communities of different types of organisms. This figure shows the food chain for three species in a marine ecosystem off the coast of Alaska.

18a. As a result of human hunting, sea otters were rare at the beginning of the twentieth century. Then, hunting was restricted, and sea otters became abundant. When the number of sea otters increased, the sea urchin population size _______________. Explain your reasoning.

18b. As a result of the change in sea urchin population size, the kelp population size _______________. Explain your reasoning.

19a. In the exponential and logistic population growth models, does population size ever decrease?

19b. What would need to be added to the exponential and logistic population growth models in order to predict the decreases in population size in the examples you have just analyzed?

20. To summarize what you have learned, fill in one match per blank. (You may use each match more than once.)

   The exponential population growth model includes _____
   The logistic population growth model includes _____  _____
   In the real world, population size can be affected by _____  _____  _____
       a. increases in population size as a result of reproduction
       b. the effects of changes in the environment
       c. the effects of competition for limited resources