

COMPLETE ESTEEM

Grades 9 - 12

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An exponential expression defines a rate of change, such as growth or decay in a way that allows for calculation of how much growth has occurred after a given amount of time. For example, a simple bacteria which grows at a rate of k every hour would be expressed by $P(t) = P_0e^{kt}$, where P_0 is the initial population and t is the number of hours that have passed.

Interacting with Math

Exploring Exponential Growth in Nature

Bacteria describe a group of microorganisms that can be found distributed through the air, soil, water, and on a variety of surfaces handled by human beings. Some bacteria have been known to cause disease. To further study these unicellular organisms, laboratory cultures are made and measured for activity and growth. Bacterial growth occurs at an exponential rate; e.g. some bacteria doubles every 20 minutes. This means reproduction occurs rapidly, and the rate of growth can be calculated by recording the number of bacteria over short intervals of time. When grown in a Petri dish, bacteria can be seen in small colonies, and the area of these colonies can be recorded as a representation of the growth.

Purpose

Bacteria can be used as a model to understand exponential growth. By graphing the total area of bacterial colonies over time, an exponential curve can be fitted to the data and a rate of growth can be calculated.

Materials

- Petri Dishes (35 mm dia)
- Cotton Swabs
- Agar with Broth for Nutrient Source
- Transparencies
- Tape
- Permanent Marker
- Incubation Set-up

In order to reproduce quickly in the Petri dish, the bacteria are swabbed onto an agar base that is prepared with a nutrient source such as a meat broth. This is prepared well in advance to collection, as follows:

Try swabbing doorknobs, elevator buttons, or even the bottom of your shoes!

1. Place 50 mL of water into a beaker and allow water to near boiling.
2. After adding stirring stones, add 1 gram of Agar-agar and 1.5 grams of a broth bouillon.
3. Allow everything to dissolve. Pour into prepared Petri dishes and allow to cool.

In this experiment, the incubation setup is a box placed under a heat-providing desk lamp. The box controls the humid environment while the desk controls the temperature to allow optimal growth.

Activity 1: Growing Exponential Bacteria

The agar is prepared with 1.5g of bouillon, with enough water to reach 50 mL, and 1 g of agar-agar powder. This is stirred constantly over medium heat until dissolved and poured into dishes. Allow setting.

Procedure

1. With the cotton swab, collect sample from a location that is in frequent use.
2. Gently rub swab back and forth on the surface of the agar in a petri dish.
3. Label the lid with the time and date
4. Tape down the lid with two pieces of tape crossing over the top of the dish
5. Place in an incubation box with the desk lamp directly above.
6. Allow 24 hours for growth into visible colonies
7. After 24 hours have passed, observe the various colonies in the dish, taking care not to remove the lid
8. Lay a piece of transparency above the dish and trace out the shapes of the colonies
9. Calculate the are of the colonies by estimating with a piece of graph paper
10. Repeat steps 8-9 every 20 minutes, and record data below.

**Give each student
a copy of the
following Activity**

Page: Data

**Collection for each
colony cultured**

Activity 2

Data Collection: Growing Exponential Bacteria

Growing bacteria is simple! The important methodology to follow is to graph all collected data to create a trend line.

Record all data below, and create a graph in the space provided. Label all axes.

Data

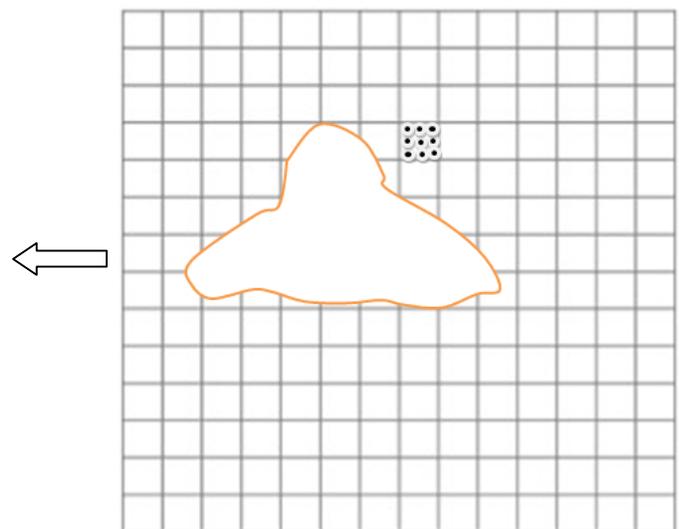
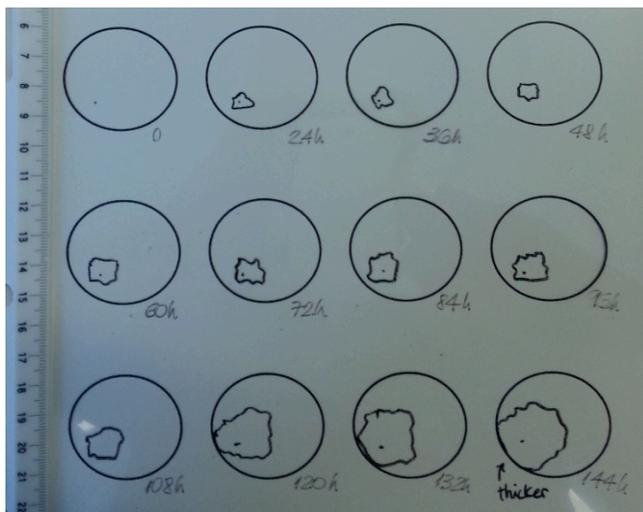
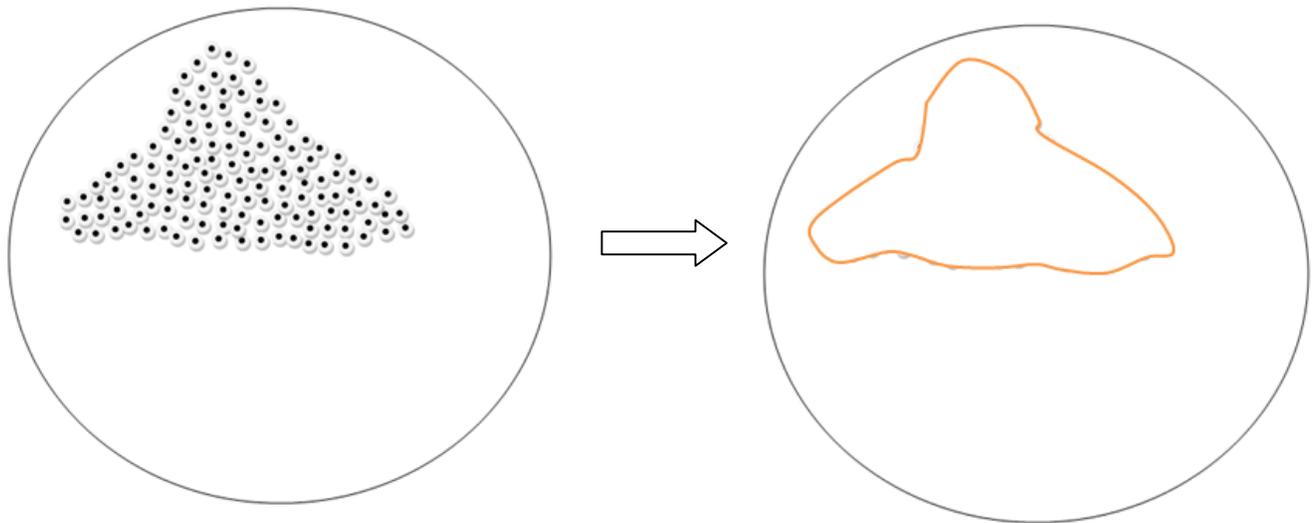
Time (hours)	Area (mm ²)		
	S1	S2	S3
0	0	0	0
24			
...			
...			
48			

Graph

Plot all data points to see a trend. Is it exponential? What does an exponential curve look like?

Activity 3

Measuring Area of Bacterial Density



Activity 3

Measuring Area of Bacterial Density through Technology

Spectrophotometer



Spectrophotometer is a photometer that can measure the intensity as a function of the light source wavelength. The device measures absorbance using the following mathematical relationship:

$$\text{Absorbance} = -\log_{10} \frac{I_t}{I_0}$$

Assessment

Exit Pass: Growing Exponential Bacteria

Reflect on and answer the following questions:

1. Why is bacteria ideal for exponential growth studies?

2. How could bacteria be used to observe exponential decay?

3. How soon does bacteria reach full saturation in a 35 mm dish? Using the same rate as seen in the activity, when would the saturation point be achieved in a 50 mm dish? (Assume nutrition is sufficient for growth to continue to saturation)

STEAM

Real-World Connections

Insert a description of the STEAM connections in each frame.

