About the Lesson

In this activity you will examine some data about bacteria, graph the data and draw some conclusions based on the data and the graph.

Vocabulary

- prokaryotes

- eukaryotes

- line of best fit

- regression

Teacher Preparation and Notes

- Students should know how to input data into lists and graph linear equations.

- You may want to further explain the terms bacteria, prokaryotes and eukaryotes.

Activity Materials

- Compatible TI Technologies:

    TI-84 Plus*
    TI-84 Plus Silver Edition*
    🔴TI-84 Plus C Silver Edition
    🔴TI-84 Plus CE

* with the latest operating system (2.55MP) featuring MathPrint^{TM} functionality.
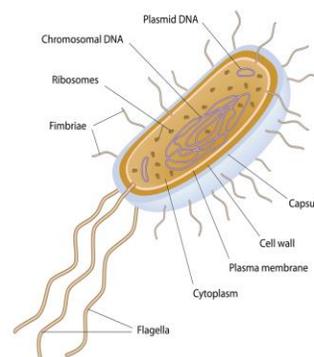
©Alila07 | Dreamstime.com

Tech Tips:

- This activity includes screen captures taken from the TI-84 Plus CE. It is also appropriate for use with the rest of the TI-84 Plus family. Slight variations to these directions may be required if using other calculator models.

- Watch for additional Tech Tips throughout the activity for the specific technology you are using.

- Access free tutorials at http://education.ti.com/calculators/pd/US/Online-Learning/Tutorials

- Any required calculator files can be distributed to students via handheld-to-handheld transfer.

Lesson Files:

- Is_There_a_Limit_Student.pdf
- Is_There_a_Limit _Student.doc

Introduction

Of all the organisms in the world, few could compete with bacteria for the title of "Fastest Reproducer." Bacteria are unicellular, like lots of other organisms, but the unique characteristic they possess is the absence of a true nucleus. Organisms that do not have a nucleus are called prokaryotes. Because the cells of a tree, a frog, a mushroom, and even an amoeba do have a nucleus, they are called eukaryotes.

Problem

Which group do you think you fit into—the prokaryotes or the eukaryotes? Below is a table that shows the reproductive capability of bacteria. After looking at the table, you will graph the data to get an idea of the type of population growth the bacteria can accomplish. These bacteria were grown in a flask in a laboratory setting, and kept in the same container throughout the experiment.

Time in minutes	Number of bacteria
30	4,000
60	4,500
90	5,200
120	6,100
150	7,200
180	8,500
210	10,000
240	11,700

Entering the Data

Enter the data from the table above into your TI-84 Plus CE.

1. Press [stat] [enter].

2. Press [▲] to move to the heading **L1**. Press [clear] [enter].

3. Follow the same procedure to clear **L2**, if needed.

4. Navigate back to **L1**, making sure that your cursor is in the first row of the list, and not at the very top. Using the data table, enter the data from the first column (Time in Minutes) in **L1**. Type in the number and then press [enter] or [▼]. Repeat this until you have entered all of the data in **L1**.

5. Enter the data from the Number of Bacteria column in the data table into **L2**. Make sure you have the same number of data entries in **L1** as you do in **L2**.

6. Press [2nd] [stat plot] to define the plot.

7. Press [enter] to select **1:Plot1**. Set your TI-84 Plus CE as shown at right.

8. Press [2nd] [format] and make sure the defaults are set.

9. Press [mode] and make sure the defaults are set there as well..

```
NORMAL FLOAT AUTO REAL RADIAN MP
Plot1 Plot2 Plot3
On Off
Type:▦ ⟋ ⣀ ⊞⋯ ⊞⊞ ⟋
Xlist:L₁
Ylist:L₂
Mark :▣ + ·  .
Color: RED
```
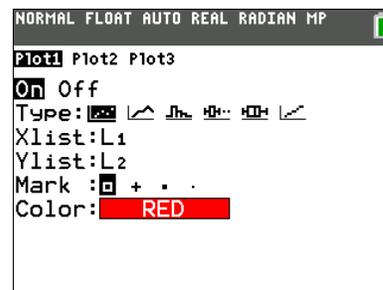
10. Press [window] and set an appropriate window for the data you have entered. Which of the variables (time or number of bacteria) is dependent on the other? Set **Xmin** and **Xmax** appropriately, according to your data, then choose whatever **Xscl** (scale along the X-axis) you would like. Set **Ymin** and **Ymax** appropriately, and choose a **Yscl** (scale along the Y-axis).

11. Press [y=]. If there are any equations on this screen, press [▼] to place the cursor next to **Y1=**, and then press [clear] to clear the equation. Repeat this sequence to clear all equations.

12. Press [graph].

Data Analysis

1. What will you plot along the X-axis (the independent variable)?
   Sample Response: X-axis: Time

2. What will you plot along the Y-axis (the dependent variable)?
   Sample Response: Y-axis: Number of bacteria

3. Is there a constant difference between consecutive values in the Time in Minutes data list (the X list)? If so, what is that difference? If not, explain.

   Sample Response: There is a constant difference of 30 between the data points.

4. Look at the graph of your data. Does the graph look linear? Explain.

   Sample Response: The graph is not linear. The graph is curved.

5. Press [trace] and move from point to point on your graph by using [◄] or [►]. Estimate how many bacteria you would expect to find after 300 minutes.

   Sample Response: The estimate should be close to 15,700.

6. Without using the [trace] button, estimate how many you would have expected to find after 100 minutes.

   Sample Response: The estimate should be close to 5,500.

7. Now use ⟨trace⟩ to estimate the number of bacteria you would have after 100 minutes. How does your answer compare to the one you estimated in #6?

    Sample Response: Approximately 5,586 bacteria.

8. Estimate how many bacteria you would expect to find after 12 hours.
   Hint: you will need to change your ⟨window⟩ settings!

    Sample Response: Approximately 150,000 bacteria.

9. Estimate how many you would expect to find after 24 hours.

    Sample Response: Approximately 5 to 6 million bacteria.

10. In reality, can this rate of growth in bacterial numbers continue forever?
    Explain.

    Student answers will vary.

    Sample Response: No, this rate of growth in bacterial numbers cannot continue forever. The population will reach a limit because of limited space, food, and so on.

11. Populations of organisms can only grow as large as their environments allow them to grow. Natural population controls are called limiting factors, and the number of organisms of a particular species that can be supported by the environment is called the environment's carrying capacity for that species. You may want to consider these things as you look again at your answer to #10. What are some limiting factors influencing the population sizes of plants and animals in a deciduous forest?

    Student answers will vary.

    Sample Response: Some limiting factors influencing the population sizes of plants and animals in a deciduous forest include food supply, sunlight, water, weather, predation, competition, and so on.

12. What are some limiting factors at work in the desert? In the arctic? In the tropical rain forest?

    Student answers will vary.

    Sample Response: Some limiting factors at work in the desert include lack of water and extreme temperatures. Some limiting factors in the arctic include cold, lack of water, and limited sunlight. Some limiting factors in the tropical rain forest include nutrients in the soil, space, light, and so on.

13. Go back into the lists of your TI-84 Plus CE (press [stat][enter]) and extend your list of times in L1 to 600 minutes, using increments of 30. In L2, enter what you think would be realistic population data to correspond with the new times you entered in L1. Remember this data is not linear. Before you press [graph], make sure you take a look at your [window] and make necessary adjustments. How long do you think the bacteria population can grow at an unrestricted rate? Then what happens?

    Student answers will vary.

    Sample Response: Answers will vary for how long the bacteria population can grow at an unrestricted rate. The bacteria will start to die off because they will have reached the carrying capacity of the environment.

14. What do you think is the carrying capacity of your classroom for people? On what did you base your answer?

    Student answers will vary.

    Sample Response Answers will vary, and they should be based on space, air supply, and so on.

Going Further

Now, let's build a best-fit (regression) model for the data in your graph.

1. Go to the **Home** screen by pressing [2nd] [quit].

2. Press [stat], and then press [▶] to highlight **CALC**. You will see a list of regression models from which to choose. Press [▲] a few times until **0:ExpReg** is highlighted, and then press [enter].

3. Press [enter] to accept the **L1** and **L2** values. Press [vars] [▶] [enter] [enter], to place the equation into **Y1**.

4. Highlight **Calculate** and press [enter] to paste the correct syntax to the Home screen. You just told the TI-84 to build an exponential regression model based on the data in **L1** (time) and **L2** (number of bacteria), and then write the regression equation in **Y1**. To check this, press [y=]. You should see an equation next to **Y1**=.

5. Record the equation for Y1= **3315.89*1.005^x**

6. Press [graph] to see your original data points and observe the best-fit line being drawn.

7. Press [trace] and then press [▲] or [▼].

    a. Where do you see the cursor?

    Sample Response: The cursor will be on the data points.

8. Press [▶] and [◀] and notice what is displayed at the bottom of the screen.

    a. What do these numbers mean?

    Student answers will vary.

    Sample Response: The numbers represent the time in minutes and the number of bacteria.