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Lab 1: Modeling bacterial growth rates

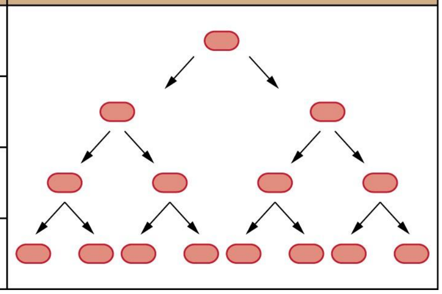
Overview: In this lab, you will again use the relationship between exponential and logarithmic functions to transform biological data. Here we will obtain growth rates for bacterial populations using two models, by using logarithmic transformations and calculating an average rate of change between data points. The goals are to (1) derive bacterial growth rates from your data and (2) produce graphical representations of your lab data for presentation.

Objectives:

- Apply logarithmic data transformations to find both the continuous growth rate and the bacterial growth rate.
- Determine the relationship between growth rate and temperature.
- Produce presentation-quality graphs of experimental data.

Bacteria experience exponential growth for a limited time, depending on availability of resources. During this exponential growth phase, there is a doubling of bacteria in each generation as shown in the figure at right.

Number of generations (*n*)	Number of cells	Each division adds two new cells
0	1	
1	2	
2	4	
3	8	



Notice that the population size of bacteria, P, at time $t = 0$, is $P(0) = 1 = 2^0$. Further, $P(1) = 2 = 2^1$, $P(2) = 4 = 2^2$, and $P(3) = 8 = 2^3$.

Because bacteria reproduce by doubling, we typically use an exponential model with base 2 for bacterial populations

$$P(t) = P_0 2^{Rt} \qquad (1)$$

where R is the **bacterial growth rate**. The units of the bacterial growth rate are generations per hour. The **doubling time** (number of hours per generation) is the reciprocal of the bacterial growth rate.

So in order to compute the doubling time of a bacteria population, we need to find the bacterial growth rate R, which is contained in the exponent of the model equation. To do this, we use logarithms. Since the base of the exponential function is 2, we will use a logarithm base 2 transformation.

First, take the logarithm base 2, $\log_2$, of both sides of the model equation.

$$\log_2[P(t)] = \log_2[P_0 2^{Rt}]$$

One of the ``rules of logarithms" is that the log of a product is the sum of the logs so the operation on the right hand side becomes addition:

$$\log_2[P(t)] = \log_2[P_0] + \log_2[2^{Rt}]$$

Notice that in the term $\log_2[2^{Rt}]$ we are taking the logarithm base 2 of an exponential with base 2, and when the base of the logarithm and the base of the exponent are the same, the result is just the exponent:

$$\log_2[P(t)] = \log_2[P_0] + Rt.$$

Finally, notice the resemblance to a linear function

$$\underbrace{\log_2[P(t)]}_{y} = \underbrace{\log_2[P_0]}_{b} + \underbrace{R}_{m}\underbrace{t}_{x}$$

in the form y = mx+b. This shows that R, the bacterial growth rate, is the slope of the line fit to the log-transformed data points.

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1. **Make a group copy of the spreadsheet for your section**:
   - Pierce lab:
   https://docs.google.com/spreadsheets/d/1qwJD9QCO-DF2Z8frahDz-Rcp2YYCkuvJQPkz3Bro7Oc/edit?usp=sharing
   - Jones lab:
   https://docs.google.com/spreadsheets/d/1nzvs5xxn8hXzyN4rVWQQfcCHWkncuVsyZWEOModP-zM/edit?usp=sharing

   Each group will complete all of the following tasks for an assigned bacteria type and some temperatures, as shown in the first tab of the spreadsheet. **Title and label all graphs that you produce.**

   - [x] ~~First, notice that for the data you collected, time is measured in *minutes*. Usually, we think of bacterial growth rates in generations per *hour*. For your assigned data, change the time units accordingly.~~

- [x] ~~For each of your group's assigned bacteria type and temperature, **create a scatterplot of the time versus OD (optical density) reading** within your spreadsheet.~~
- [x] ~~**Compute a log base 2 ($\log_2$) transformation of the OD readings** by inserting a column to the right of your average columns for each of your assigned bacteria/temperatures. The spreadsheet command for this is =LOG(cell reference,2).~~

- [x] ~~**Create a second scatterplot of time vs. $\log_2$(OD) for each assigned bacteria type and temperature** within your spreadsheet, below the first.~~

2. Your scatterplots can now help you identify the **exponential growth phase**. A quantity *Q* that is growing exponentially over time will:

    - Have a graph of *t* vs. *Q* that looks exponential, meaning it is increasing at an increasing rate.

    - Have a graph of *t* vs. $\log_2(Q)$ that looks like a line.

   Also remember that the exponential growth phase is temporary, so <u>you only need to find two early points on each graph that meet this criteria</u>.

   - [x] ~~By remembering the above facts about the graphs, choose **two** points that are in the exponential growth phase for each temperature and bacteria and report them as ordered pairs (*t*, *log2(OD)*) in this table:~~

Bacteria: E.Coli		
Temperature:	**Point 1 (*t*, $\log_2(OD)$)**	**Point 2 (*t*, $\log_2(OD)$)**
32 C	(0, 1.81)	(.3, 2.13)
Bacteria: A. Tumefaciens		
Temperature:	**Point 1 (*t*, $\log_2(OD)$)**	**Point 2 (*t*, $\log_2(OD)$)**
32 C	(0, .998)	(.3, .963)
Bacteria: V. Natriegens		
Temperature:	**Point 1 (*t*, $\log_2(OD)$)**	**Point 2 (*t*, $\log_2(OD)$)**
32 C	(0, 2.73)	(.3, 2.90)

3. Use the points you found in #2 and a formula for the slope of a secant line between two points to find the **average rate of change in bacteria** (AKA, the bacterial growth rate R)

for each of your assigned bacteria/temperatures. See page 1 of this document for a reminder of the units.

- [x] ~~Report **all three** growth rates in the table:~~

Temperature: 32 C	**Bacterial growth rate** R (generations per hour)
Bacteria: E.Coli	1.066667 gen/hr
Bacteria: A. Tumefaciens	-0.11667 gen/hr
Bacteria: V. Natriegens	.566 gen/hr

4. Calculate the doubling time (generation time) in the growth phase of this bacteria.

- [x] ~~Include units~~

Temperature: 32	**Doubling time**
Bacteria: E.Coli	.937499 hr/gen
Bacteria: A. Tumefaciens	-8.5712 hr/gen
Bacteria: V. Natrigens	1.766 hr/gen

5. Update your documentation:

- [x] ~~Make sure all of your graphs in the spreadsheet are titled, and have labeled axes.~~

6. **To turn in:**

- [x] ~~Enter your results for Bacterial growth rate and Doubling time into the MASTER tab of the shared spreadsheet (link on page 2)~~
- [ ] Save this document to a .doc or .pdf file with YOUR LAST NAMES_LAB 1 in the title and upload to the Box folder “F23 MATH 211 Student Work”
- [x] ~~Give your spreadsheet the same name and also upload it to the same folder.~~