Bigger Isn't Necessarily Better

There is a reason cells are small! There seems to be a limit to the size they can grow. Consider your little toe: it is made of about 2-3 billion cells! A newly-made cell will grow, but once it reaches a certain size it will divide to form two new cells rather than growing bigger. Why is this? Why aren't you made of a few dozen, or a few hundred cells, instead of trillions? Why don't single-celled organisms like amoebas and paramecia grow as big as a human? In this lab, we will investigate this question using model cells.

This activity will enable you to explore the relationship between the surface area, volume and rate of diffusion by experimenting with model "cells." In this investigation, cells will be represented by cubes of potato in which the rate of diffusion will be measured. The cubes will be put into a solution of iodine. The iodine will gradually diffuse into the potatoes from the sides. When the iodine comes in contact with the starch in the potato, it will turn black, making it easier to track the diffusion of the iodine.

Problem Questions:

1. How does the size of the cell affect the <u>surface area to volume ratio</u>?
2. How does the size of the cell affect the <u>rate</u> of diffusion of nutrients into the cell?
3. How does the size of the cell affect the <u>efficiency of diffusion</u> of nutrients into the cell?

Manipulated Variable:

The manipulated variable is the size of the "cell," as measured by the length of one side of the potato cube. There are four levels of the manipulated variable (one level is each size of cube; since there are four sizes of cubes, there are four "levels"). Individual groups will collect data for 1 trial at each level of the manipulated variable. Then, class data will be compiled for a total of 8 trials at each level of the manipulated variable.

Responding Variables:

1. Surface area to volume ratio (cm^{-1}).
2. Rate of diffusion (mm/min).
3. Efficiency of diffusion (percent of the cell volume into which diffusion occurred).

Materials (for each lab station)

Potato cubes
Iodine solution **please read hazardous materials information regarding this chemical**
Metric ruler
Beakers
Scalpel
Spoon
Water
Stop watch

IODINE

Potential Acute Health Effects:
Very hazardous in case of skin contact (irritant), of eye contact (irritant), of ingestion, of inhalation. Hazardous in case of skin contact (corrosive), of eye contact (corrosive). Slightly hazardous in case of skin contact (permeator). The amount of tissue damage depends on length of contact. Eye contact can result in corneal damage or blindness. Skin contact can produce inflammation and blistering. Inhalation of dust will produce irritation to gastro-intestinal or respiratory tract, characterized by burning, sneezing and coughing. Severe over-exposure can produce lung damage, choking, unconsciousness or death. Inflammation of the eye is characterized by redness, watering, and itching. Skin inflammation is characterized by itching, scaling, reddening, or, occasionally, blistering.

Potential Chronic Health Effects:
Hazardous in case of skin contact (irritant), of eye contact (irritant), of ingestion, of inhalation. CARCINOGENIC EFFECTS: Not available. MUTAGENIC EFFECTS: Not available. TERATOGENIC EFFECTS: Not available. DEVELOPMENTAL TOXICITY: Not available. The substance is toxic to thyroid. The substance may be toxic to blood, kidneys, liver, skin, eyes. Repeated or prolonged exposure to the substance can produce target organs damage. Repeated exposure of the eyes to a low level of dust can produce eye irritation. Repeated skin exposure can produce local skin destruction, or dermatitis. Repeated inhalation of dust can produce varying degree of respiratory irritation or lung damage.

PART 1: RAW DATA COLLECTION PROCEDURE

Please note: you must wear goggles while working at the lab stations.

1. Each group will be given four potato cubes with side lengths of 0.5 cm, 1.0 cm, 2.0 cm, and 3.0 cm (+/-0.5cm).

2. Using a spoon, place each cube into the beaker filled with an iodine solution. Each potato cube should be completely submerged in the solution. Begin the timer.

3. Let the potato cubes soak for until there are about 15 minutes remaining in the period. Periodically, *gently* stir and turn the cubes (about once every 3-4 minutes).

4. While waiting, complete the following in your lab book:

- Write the problem questions, manipulated variable and responding variables for this lab.
- Write a hypothesis for each problem question. What do you expect to see happen and why?
- Copy this data table into your lab book. Be sure to add a specific title.

Cube Side Length (cm, +/- 0.5 cm)	Cube Surface Area (cm^2)	Cube Volume (cm^3)	Cube SA:V ratio (cm^{-1})	Time for Diffusion (min, +/-0.5)	Diffusion Distance (mm, +/- 0.5)	Diffusion rate (mm/min)
0.5						
1.0						
2.0						
3.0						

measurement	calculation	calculation	calculation	measurement	measurement	calculation

- Calculate and record the potato cube surface area, the potato cube volume and the potato cube SA:V ratio. Be sure to use a consistent, correct number of digits. *Remember, in a calculation you can round to one decimal place beyond the original measurement precision.*

5. With about 15 minutes left in the class period, use the spoon to remove the potato cubes from the iodine solution and blot them dry with a paper towel. **DO NOT DISPOSE OF THE IODINE SOLUTION.** It can be reused throughout the day. Note the elapsed time of diffusion in your data table. Be sure your precision matches the uncertainty provided. Reporting times as a decimal place can be tricky! For example, a common mistake is for people to write 1 minute 30 seconds as 1.3 minutes, which is WRONG! The correct way to write 1 minute 30 seconds is 1.5 minutes.

6. Promptly cut each block in half using a scalpel. Measure and record the distance of diffusion of iodine into the potatoes in mm. Measure the distance from the outside edge of the potato towards the center of the cube. Be sure your precision matches the uncertainty provided. You will notice the iodine might diffuse differently on different sides. If this is the case, measure the side with the most amount of diffusion. If the iodine has diffused all the way to the center of the potato, record the distance from the edge of the potato cube to the center of the cube.

7. Carefully dispose of the potato pieces and used paper towels in the trash. Return the goggles to the sanitizing cabinet for cleaning before the next class period. Please leave your station as clean as you originally found it.

PART 2: GROUP DATA ANALYSIS

Rate of Diffusion

1. Calculate the diffusion rate (mm/min) for each potato cube. *Remember, in a calculation you can round to one decimal place beyond the original measurement precision.* Results should be presented in the table created in part 1.

Efficiency of Diffusion

2. Copy this second data table into your lab book. Be sure to add a specific title. This table will be used to determine the "efficiency" of diffusion into the cells of different sizes. Sample data is provided. See if you can use this sample data to determine how each value was determined. Then, complete the table for <u>your</u> data. Show your working for one example of each calculation (you should have a calculation for each column labeled with an *).

Cube Side Length (cm, +/- 0.5 cm)	Cube Side Length (converted to mm)*	Volume of Cube (mm^3)*	Diffusion distance into cube (mm, +/- 0.5)	Length of cell in which NO diffusion occurred (mm)*	Volume of cell in which NO diffusion occurred (mm^3)*	Volume of cell in which diffusion occurred (mm^3)*	% of volume that had diffusion ("efficiency")*
0.5	5	125.0	1.0	3.0	27.0	98.0	78.4
1.0							
2.0							
3.0							

From previous table

From previous table

PART 3: CLASS DATA COLLECTION AND ANALYSIS

Rate of Diffusion

1. Create a third data table in which you will record the class data for diffusion rate (mm/min) for each of the four levels of the manipulated variable. Be sure to add a specific title, units and column headings. Each group completed one "trial" of data collection. Since we had eight groups, we had eight trials.

2. Find the average diffusion rate (mm/min) for each level of the manipulated variable (meaning, for each cube size). Show your working for one example calculation. Include the results in your third data table.

3. Find the standard deviation for the mean diffusion rate (mm/min) for each of the four cube sizes. Show your working for one example calculation. Include the results in your third data table.

Efficiency of Diffusion

1. Create a fourth data table in which you will record the class data for "efficiency" for each of the four levels of the manipulated variable. Be sure to add a specific title, units and column headings. Each group completed one "trial" of data collection. Since we had eight groups, we had eight trials.

2. Find the average "efficiency" for each level of the manipulated variable (meaning, for each cube size). Show your working for one example calculation. Include the results in your fourth data table.

3. Find the standard deviation for the mean "efficiency" percent for each of the four cube sizes. Show your working for one example calculation. Include the results in your fourth data table.

PART 4: GRAPHING

If you recall, there were three problem questions in this lab:

1. How does the size of the cell affect the <u>surface area to volume ratio</u>?
2. How does the size of the cell affect the <u>rate</u> of diffusion of nutrients into the cell?
3. How does the size of the cell affect the <u>efficiency of diffusion</u> of nutrients into the cell?

You are going to create a graph related to each problem question. Since there are three problem questions, you'll be making three graphs.

Surface Area to Volume Ratio

Create a graph to depict the relationship between cube side length and the surface area to volume ratio of the cube. Be sure to:

- Select the correct type of graph for the data (pie, bar, histogram, line, or scatter)
- Fully title and label your graph
- Place the MV on the X axis and the RV on the Y axis

Rate of Diffusion

Create a graph to depict the relationship between cube side length and the <u>mean</u> rate of diffusion into the cube. Be sure to:

- Select the correct type of graph for the data (pie, bar, histogram, line, or scatter)
- Fully title and label your graph
- Place the MV on the X axis and the RV on the Y axis
- Add standard deviation bars to each point on the graph

Efficiency of Diffusion

Create a graph to depict the relationship between cube side length and the <u>mean</u> diffusion efficiency into the cube. Be sure to:

- Select the correct type of graph for the data (pie, bar, histogram, line, or scatter)
- Fully title and label your graph
- Place the MV on the X axis and the RV on the Y axis
- Add standard deviation bars to each point on the graph

PART 5: STATISTICAL ANALYSIS

Rate of Diffusion

The rate of diffusion graph from Part 4 has overlapping standard deviation bars for each point on the graph. We would conclude that there is "probably" not a significant difference in the rate of diffusion into the potato cubes of different sizes. The next step is to determine if the "probably" conclusion we made based on the data in the graph is valid by performing T-tests.

Perform T-tests comparing the rate of diffusion of each cube to each other cube. That's 6 T-tests in all. In your lab book, show your working for one example calculation and use a tool like an online calculator for the rest.

- 0.5 cm vs. 1.0 cm
- 0.5 cm vs. 2.0 cm
- 0.5 cm vs. 3.0 cm
- 1.0 cm vs. 2.0 cm
- 1.0 cm vs. 3.0 cm
- 2.0 cm vs. 3.0 cm

Summarize your results in a table like this (be sure to add a specific title, units and column headings):

	MV level 2			
MV level 1	**0.5 cm**	**1.0 cm**	**2.0 cm**	**3.0 cm**
0.5 cm	**NA**	T_{calc}= T_{crit}= $\alpha = 0.05$ Significant= Y or N	T_{calc}= T_{crit}= $\alpha = 0.05$ Significant= Y or N	T_{calc}= T_{crit}= $\alpha = 0.05$ Significant= Y or N
1.0 cm	**NA**	**NA**	T_{calc}= T_{crit}= $\alpha = 0.05$ Significant= Y or N	T_{calc}= T_{crit}= $\alpha = 0.05$ Significant= Y or N
2.0 cm	**NA**	**NA**	**NA**	T_{calc}= T_{crit}= $\alpha = 0.05$ Significant= Y or N

Efficiency of Diffusion

The efficiency of diffusion graph from Part 4 has some overlapping standard deviation bars and some bars that do not overlap. We would conclude that there is “probably” not a significant difference in the efficiency of diffusion into some the potato cubes of different sizes and that there “probably” is a significant difference in the efficiency of diffusion into some the potato cubes of different sizes. The next step is to determine if the “probably” conclusion we made based on the data in the graph is valid by performing T-tests.

Perform T-tests comparing the efficiency of diffusion of each cube to each other cube. That’s 6 T-tests in all. In your lab book, show your working for one example calculation and use a tool like an online calculator for the rest.

- 0.5 cm vs. 1.0 cm
- 0.5 cm vs. 2.0 cm
- 0.5 cm vs. 3.0 cm
- 1.0 cm vs. 2.0 cm
- 1.0 cm vs. 3.0 cm
- 2.0 cm vs. 3.0 cm

Summarize your results in a table like this (be sure to add a specific title, units and column headings):

	MV level 2			
MV level 1	**0.5 cm**	**1.0 cm**	**2.0 cm**	**3.0 cm**
0.5 cm	NA	T_{calc}= T_{crit}= α = 0.05 Significant= Y or N	T_{calc}= T_{crit}= α = 0.05 Significant= Y or N	T_{calc}= T_{crit}= α = 0.05 Significant= Y or N
1.0 cm	NA	NA	T_{calc}= T_{crit}= α = 0.05 Significant= Y or N	T_{calc}= T_{crit}= α = 0.05 Significant= Y or N
2.0 cm	NA	NA	NA	T_{calc}= T_{crit}= α = 0.05 Significant= Y or N

SCROLL DOWN FOR PART 6 …

PART 6: CONCLUSION and FINAL DRAFT QUALITY

Here's what should be in your lab book:

- ☐ Three problem questions
- ☐ List of variables (manipulate and responding)
- ☐ Hypothesis and explanation for each problem question
- ☐ Raw data table (from part 1)
- ☐ Calculated data table (from part 2)
- ☐ Example calculations (there are 6, from part 2)
- ☐ Diffusion rate class data table (from part 3)
- ☐ Efficiency class data table (from part 3)
- ☐ Example calculation of mean (diffusion or efficiency, from part 3)
- ☐ Example calculation of standard deviation (diffusion or efficiency, from part 3)
- ☐ Mean and standard deviation of rate of diffusion summarized in a table (from part 3, can be same table as class data)
- ☐ Mean and standard deviation of efficiency of diffusion summarized in a table (from part 3, can be same table as class data)
- ☐ Example calculation of T-test (rate or diffusion or efficiency, from part 5)
- ☐ Rate of diffusion T-test results table (from part 5)
- ☐ Efficiency of diffusion T-test results table (from part 5)

The lab book work will be scored for completion, out of 15 points.

Now, make a final draft quality (typed and pretty) version of your work. Include the following:

- ☐ Three problem questions
- ☐ List of variables (manipulate and responding)
- ☐ Hypothesis and explanation for each problem question
- ☐ Raw data table (from part 1)
- ☐ Calculated data table (from part 2)
- ☐ Diffusion rate class data table (from part 3)
- ☐ Efficiency class data table (from part 3)
- ☐ Mean and standard deviation of rate of diffusion summarized in a table (from part 3, can be same table as class data)
- ☐ Mean and standard deviation of efficiency of diffusion summarized in a table (from part 3, can be same table as class data)
- ☐ Surface area to volume graph (from part 4)
- ☐ Rate of diffusion graph (from part 4)
- ☐ Efficiency of diffusion graph (from part 4)
- ☐ Rate of diffusion T-test results table (from part 5)
- ☐ Efficiency of diffusion T-test results table (from part 5)
- ☐ Conclusion statements for each problem question
    - Answer the problem question
    - Cite data and calculated numbers to support your conclusion
    - Indicate whether your hypothesis was supported or refuted

The final draft quality version of this lab is due Wednesday, 7 November 2012.