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Investigative Lab 6

Design a Cell

Comparing the Effects of Cell Shape on Diffusion Rate

Question What cell shapes are the most efficient at bringing in substances by diffusion?

Lab Overview In this investigation you will design your own cell shapes, carve model cells from gel cubes, and test how rapidly a substance can diffuse throughout each model cell. Your team will then design and make a model cell for a class "diffusion race," in which the cell with the largest ratio of mass to diffusion time wins.

Introduction You will use what you have learned about cell shapes and diffusion to design a cell best suited for rapid diffusion. You will carve your design from a blue agar cube. The agar cube is blue because it contains the pH indicator bromothymol blue. When you place your model cell into vinegar solution (a weak acid), acid will slowly diffuse into the agar and change its color from blue to yellow. You will observe the color change and record how long it takes the acid to reach the middle of your cell model—when your model turns yellow all the way through. This change will tell you how long it would take for nutrients to travel all the way through your "cell" by diffusion.

After designing and testing your first model cell, you will revise your design and make a second model cell for the class "diffusion race." Your goal is to give your model cell a shape that will allow it to change color quickly, while still having significant mass. The models that change color fastest are those that have the largest surface area/volume ratio. To win, your cell design must be the one that has the greatest mass and changes color the fastest, measured as the greatest value for mass per unit time (g/min). The winning cell also must be in one piece and cannot have any holes that reach from one side to the other.

Prelab Activity To prepare to design your own cell, first you will calculate surface area and volume for three different-sized agar cubes. Record your calculations in Data Table 1 on the next page. Then you will observe which cube changes color the fastest when placed in vinegar.

1. Which cube changed color the fastest? The slowest?

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Data Table 1

Length of Cube Side	Surface Area*	Volume**	Surface Area to Volume Ratio***
Cube 1: 0.5 cm			
Cube 2: 1.0 cm			
Cube 3: 2.0 cm			

*Surface area = length of a side × width of a side × number of sides
**Volume = length × width × height
***Surface area to volume ratio = surface area ÷ volume

2. From the results of the Prelab Activity, what characteristic of cell shape do you think is most important in enabling cells to obtain nutrients and eliminate wastes efficiently?

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3. From this activity, what factor(s) do you think might limit cell size?

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4. What happens to the surface area/volume ratio if you increase the volume of a cell? If you decrease the cell surface area? Would either of these approaches increase the rate of diffusion? Explain.

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5. Consider other shapes for a cell besides a cube. What cell shape might increase the surface area and decrease the volume? Explain.

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Materials

- agar cubes containing bromothymol blue (about 2 cm on each side)
- plastic knife
- paper or plastic plate
- plastic cup or beaker
- vinegar solution
- stopwatch or clock with second hand
- laboratory balance

Procedure

Part A: Making and Testing a Model Cell

1. Work with your team to plan and sketch your cell design. Explain why you designed it as you did. Give the design a name so you can identify it in the data table.

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2. Obtain a blue agar cube from your teacher. **CAUTION:** *Wear safety goggles, plastic gloves, and lab aprons while working with the agar cubes*.
3. Using the plastic knife, carefully carve the agar cube into the shape you have decided on for your model cell. **CAUTION:** *Handle all sharp and/or pointed instruments carefully*.
4. Using a laboratory balance, determine the mass of your model cell. Record the mass in Data Table 2 on the next page.
5. Place your model cell into an empty cup or beaker.
6. Cover your model cell completely with the vinegar solution and start the stopwatch. Or, if you are using a clock with a second hand, record the start time in Data Table 2.
7. Watch your model cell closely. When it has turned completely yellow, record the time in Data Table 2. Enter the elapsed time in the data table.
8. Calculate the mass/time ratio (g/min) by dividing the mass of your model cell by the time it took to turn completely yellow. Compare this value with those of other groups in your class.

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Data Table 2

Model Cell Design Name	Mass (g)	Start Time (If Using a Clock)	End Time (If Using a Clock)	Elapsed Time (min)	Mass/Time (g/min)

Part B: Making Redesigned Model Cells for the "Diffusion Race"

While your model cell is changing color, part of the team can work on one or more revised cell designs that you think could have faster diffusion times. Repeat steps 1–8 of Part A to experiment with different shapes until you find a design that will give you the greatest value for mass/time.

When all the teams have tested their redesigned model cells, compare mass/time data to find the winner of the class diffusion race.

Analysis and Conclusions

1. How did your team's best model-cell design differ from others you designed?

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2. What were the characteristics of the model cell with the highest mass/time ratio in the class?

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3. Why do you think most cells are microscopic? What do you think limits cell size?

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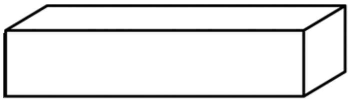
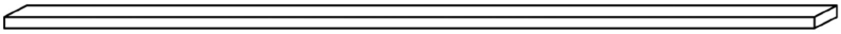
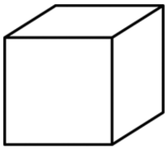
4. All of the cells shown below have approximately the same volume. Circle the letter of the one with the largest surface area.

a. 

b. 

c. 

5. Which one of the cells shown in Question 4 would change color most quickly in the experiment you just performed? Explain.

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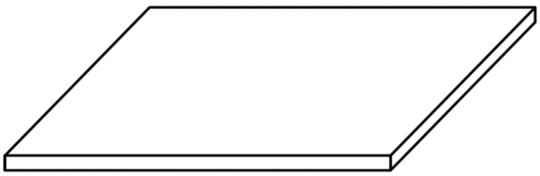
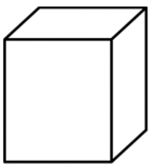
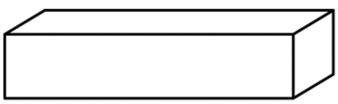
6. Some of the cells in your body (such as the walls of small blood vessels and the linings of air sacs in your lungs) are designed to allow the quick passage of nutrients and gases. Which of the following shapes would you expect those cells to be? Explain.

a. 

b. 

c. 

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7. When a cell is very thin, flat, or narrow, it can obtain nutrients more quickly. What possible disadvantages might there be to such a cell shape? (*Hint:* Think about how you handled the cells you designed.)

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Extension

An organism's surface area to volume ratio also affects its ability to retain heat. To determine how, design a simple experiment with the following materials: three thermometers, a watch or clock, hot tap water (about 50°C), and three square or rectangular plastic food-storage containers with covers. The containers represent organisms with different surface area-to-volume ratios. The containers should be of different sizes, but made of similar materials. Discuss your hypothesis and experiment design with your teacher before carrying out any investigations. Write a report to explain your conclusions.