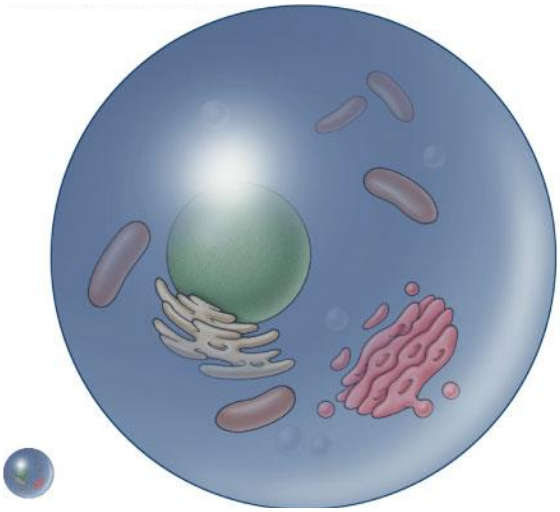
AP Biology

Limits to Cell Size Lab



Most cells are between 2 micrometers and 200 micrometers—too small to be seen with naked eye. Remember, a micrometer is 1 millionth of a meter! Why can't cells ever become larger than that? Why don't we regularly find one-celled organisms the size of small multicellular animals, like frogs or even flies? In other words, why can't there ever be an organism which is visible to the naked eye and that is one giant cell?

In order for cells to survive, they must constantly exchange ions, gases, nutrients, and wastes with their environment. These exchanges take place at the cell's surface—across the cell membrane. The movement of these materials is accomplished mostly by diffusion (flow of solutes down a concentration gradient) across the cell membrane. Consequently, factors that affect diffusion can affect the survival of a cell.

One of the core principles that govern the efficiency of diffusion is the ratio of surface area to volume. Surface area is the amount of cell membrane available for diffusion. So for a cell, surface area actually represents how much diffusion that can happen at one time. Whereas volume is the amount of cytoplasm contained within the cell membrane. So for a cell, volume is how long It takes to get from the membrane to the center of the cell by diffusion. Therefore, to perform diffusion efficiently, there must be an adequate ratio between the cell's surface area and its volume. But as a sphere (the simplest model of cell shape) gets larger, its volume increases at a different rate than its surface area. In this lab, we will investigate this relationship and how it affects diffusion time. The prime limitation to cell size is the limitation imposed by diffusion. Diffusion is a very slow process. If a cell were 20 cm (~8 inches), it would take days for nutrients to reach its center or for wastes to reach the cell membrane. The cell would quickly starve to death or poison itself with its own wastes. So what's the solution, if a cell approaches its maximum size? It's time to divide! If cells receive the proper signals, they will divide by mitosis before they become too big.

PART 1

In this lab activity, you will use agar cubes as cell models. You will investigate how increasing a cell's size affects the time for diffusion to move material across the cell. The agar for the cubes has been dyed with bromothymol blue—a pH indicator. When the agar cubes are placed in vinegar, they will begin to change color as the vinegar diffuses into the agar. You will time this diffusion process for 3 different sized cells and compare them. Diffusion will be considered complete when the blue color completely disappears from the center of the cell.

Pre-Lab Questions:

1. Bromothymol Blue is a pH indictor that changes blue in the presence of weak bases and yellow in the presence of weak acids. If the agar is already a blue (potentially blue-green), then, other than the indicator, what was also added to the agar?

2. You will be placing your cubes in vinegar. What color should you expect them to change? Why?

3. Based on your knowledge of surface area to volume ratios, develop a hypothesis for which cube size will diffuse the fastest.

Procedure:

1. Obtain two small plastic cups. With a permanent marker, label one 1x1x1 and the other 2x2x2.
2. Bring your cups to the materials table and CAREFULLY obtain these cubes. Hint: slide them off the table & into each cup.
3. Make sure you have 2 timers prepared to start. You may use personal technology.
4. Obtain and pour 20 ml of vinegar into the cup labeled 1x1x1 and start the first timer.
5. Obtain and pour 40 ml of vinegar into the cup labeled 2x2x2 and start the second timer.

6. Obtain a clear plastic tray. DO NOT WRITE ON THIS TRAY. CAREFULLY obtain a 1x1x8 cube and slide it into your tray.
7. Prepare a third timer. Then pour 200ml of vinegar into the tray and start the third timer.
8. Copy and complete the data table and answer the Analysis Questions below while you wait for the diffusion.

Cell Size (cm)	**Surface Area a^2x6**	**Volume lxwxh**	**SA:V ratio**	**Time for Complete Diffusion**
.5x.5x.5				----------
1x1x1				
2x2x2				
1x1x8*				
4x4x4				----------

* SA= 2lh +2lw +2wh

Analysis Questions (Answer in complete sentences)

1. As the cube increases in size, what happens to the surface **area** to volume ratio? Explain.

2. Which cell in PART 1 had the fastest diffusion time? Did this support or reject your hypothesis.

   Explain why or why not.

3. The 2x2x2 cell and the 1x1x8 cell have the same volume. Were their diffusion times the same?

   Explain why or why not.

4. In general, what is the relationship between the SA:V ratio and diffusion time?

5. Explain why cells can't get very, very big.

Clean Up:

- Dump vinegar down the sink, and trash cups and yellow cubes.
- Clean out plastic tray and graduated cylinder with soap and water. Fully dry and return to middle lab station.

PART 2 (completed by each lab group/ 2 people)

Now that you have been able to explore the relationship between cell dimensions and diffusion time, let's see if you can put your new-found understanding to good use. Cells do come in many shapes and sizes in organisms. Natural selection has crafted them to do their jobs better with their unique form. You will find that the relationship between structure and function is a recurrent theme throughout biology. Let's give you the anointed role of "Intelligent Designer" for a competitive Cell Diffusion Race. Each student will get an equal size blob of bromothymol blue agar and will have the opportunity to design a cell to **maximize mass** but **minimize diffusion time**. **The cell with the greatest mass *and* the shortest diffusion time will be judged the winner.**

THE CELL DIFFUSION RACE RULES:

1. No donut-like holes through the agar cell—this is biologically impossible.
2. Once agar cell is in beaker of vinegar, no poking, prodding, touching beaker.
3. Teacher determines when 100% diffusion takes place. Diffusion will be considered complete when the blue color completely disappears from the center of the cell.
4. Students mass agar at end of race and cell must not break when handled! If cell breaks upon massing, then entry is disqualified.
5. **WINNER** = **highest ratio** of **mass divided by time**.

Procedure:

1. Starting from a cube-like structure, design a "cell" that has the greatest mass possible but could provide the shortest diffusion time.
2. Draw your final design on your lab paper.

Contest Day Procedures

1. Obtain the following from the materials table (for a group of 2)
    - an agar cube
    - petri dish (bottom or lid)
    - small plastic ruler
    - plastic knife
    - plastic cup

2. Label your cup with your lab member names.
3. Ready a timer and obtain 50 ml of vinegar.
4. Using a plastic knife, cut your design into the agar.
5. Invert the petri dish over the cup until it falls into the cup.
6. **STOP HERE UNTIL THE TEACHER STARTS THE RACE.**

7. When the teacher gives the "go-ahead" pour the 50ml of vinegar into the cup and start the timer.
8. As you wait ~~to win~~ for the contest to be over, copy the following table onto your lab paper and answer the summary questions below.

Table 2. Cell Mass and Time for Diffusion (Part 2)

	Cell Mass (gm)	Time for Complete Diffusion (minutes)	Mass (g) / Time (min)
Your Custom Cell			

Summary Questions (Answer in complete sentences):

1. Describe your cell design. What principles/ideas were you basing your design on to decrease diffusion time?
2. Describe different ways that cell shape can be modified so that diffusion rate will be decreased to support life processes.
3. Give an example of a type of cell in a living organism (animal or plant) that is shaped different than the classical round or boxy shape that you see drawn in introductory chapters on cells. Explain how that unique shape is tied to the function that those cells perform.
4. Once the race is over, describe which design won the race. Offer an educated guess as to why.

Clean Up:

- Dump vinegar down the sink, and trash cup and agar cell design
- Trash the plastic knife.
- Clean out graduated cylinder and petri dish with soap and water.
- Fully dry and return to cylinder, ruler, and petri dish middle lab station.