Name:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_Date:\_\_\_\_\_\_

**Investigation: Why Are Cells So Small?**

**Intro:**

Most cells are between 2 micrometers and 200 micrometers. Cells constantly exchange ions, gases, nutrients, and wastes with their environment. These exchanges occur across the cell membrane. The movement of these materials occurs mostly by diffusion. The efficiency of diffusion depends on the ratio of surface area to volume. Consequently, cell size is limited by the rate of diffusion. If a cell were 20 cm, it would take days for nutrients to reach the center or for waste to reach the outside. The cell would starve or poison itself in its own waste. A cell must either divide before it gets too big OR have a modified shape that allows for optimal diffusion. Some cells become long and thin, like neurons, some cells develop folds in their membrane like microvilli of the intestines, still others may slow down their metabolism like an unfertilized chicken egg.

**Essential Question: How does the size and shape of a cell influence the speed at which materials can move into and out of the cell?**

**Process**: Create cell models using agar molds to compare rates of diffusion.

**Materials:**

Agar that has been treated with phenolphthalein – a pH indicator that turns pink in the presence of a basic solution, Tweezers, Scalpel (or plastic knife), Ruler, Beaker, Sodium Hydroxide (basic) solution

## **Procedure**

1. Cut three agar cubes with the following approximate dimensions.

1 cm x 1 cm x 1 cm (small)

2 cm x 2 cm x 2 cm (medium)

1 cm x 1 cm x 8 cm (large)

2. Measure your cubes (the actual dimensions may not be perfect, depending on how you cut it) and determine the surface area, the volume, and the SA:V ratio. Record on data table (next page).

3. Drop each block into a beaker or dish containing sodium hydroxide. The agar has been infused with a pH indicator that turns pink in the presence of a base. You will be able to observe this change with your cubes. **Record the time it takes for the block to turn completely pink.**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Actual Dimensions | Surface Area | Volume | SA / V | Time (Pink to reach center) |
| **Small Cube**  (1 cm x 1 cm x 1 cm) |  |  |  |  |  |
| Medium Cube |  |  |  |  |  |
| Large Cube |  |  |  |  |  |

**Part 2: How Does Shape Influence Rates of Diffusion?**

With the remaining agar, **design a cell that maximizes volume and mass, but minimizes diffusion time**. Your "cell" will compete with other cells in the class to see which one has the fastest diffusion time.

**Rules:**

* No donut-like holes through the agar cell - cell membranes cannot sustain this shape
* No poking or agitating the beaker when the cell is submerged
* Instructor determines when 100% diffusion has occurred (or take clear picture for proof)
* Agar cell will be massed at the end of the race and MUST NOT BREAK when handled. If cell breaks upon massing, then your cell will be disqualified.
* Winner = highest ratio of mass divided by time

|  |
| --- |
| Sketch your design below. Label dimensions. |

Complete the chart when race is done:

|  |  |  |
| --- | --- | --- |
|  | Mass (g) | Diffusion Time |
| Your Cell |  |  |
| Winner |  |  |

## **Analysis**

1. Complete the chart below:

|  |  |  |  |
| --- | --- | --- | --- |
| Cube (cm x cm) | Surface Area | Volume | SA : V ratio |
| 1 x 1 x 1 |  |  |  |
| 2 x 2 x 2 |  |  |  |
| 3 x 3 x3 |  |  |  |

1. As the cubes in the chart above increase in size, what happens to the surface area to volume ratio?
2. Which “cell” in Part 1 had the fastest diffusion time? Explain why.
3. The 2x2x2 cell and the 1 x 1x 8 cell in Part 1 had the SAME VOLUME. Were their diffusion times the same? Explain why or why not?
4. If the blocks were actual cells, which would be the most efficient in terms of permitting materials to enter and leave the cell?
5. **How does the agar cube model the cell and the cell membrane?**
6. What designs (Part 2) seemed to have the fastest diffusion rate?
7. **Give an example of a type of cell in a living organism (animal or plant) that is shaped very differently than the classical round or boxy shape. Explain how that unique shape is tied to the function those cells perform.**
8. Describe different ways that cell shape can be modified so that diffusion rate will be decreased to support life processes.
9. In general, what is the relationship between the SA:V ratio and diffusion time?

OR: As introductory use questions from Lab Manual.

Based on this investigation,, what one factor may limiet the growth of a cell…

Propose a hypothesis that explains why the growth of a cell decreases as its size increases.

Going further: calculate the surface-area-to-volume ratios for cells that are 0.1 cm and 0.01 cm on a side. Which ahs the great surface area in proportion to its volume?

**Agar Recipe:**

15 g of agar in 1 liter water (or follow directions on packaging). You do want the agar to be thick so that it can be handled, so reduce water amounts. Agar is boiled in DI water and then allowed to cool. Knox gelatin can also be subsituted, but you may need to play around with the measurements.

While it is cooling, add .1 g of bromothymol blue (or about 10 ml aqueous solution, you just need to ensure that the agar turns a dark blue.) If the mixture is green/yellow, then add NaOH until it turns blue.

Pour agar into trays for students. You can be creative with the trays (ziploc tupperware containers should work, or even metal dissecting trays.) The molds must be at least 2 cm deep. Molds can be covered and refrigerated.

These are the molds I created using specimen containers and the lids from a box of micropipettes. You can be creative!

Alternatively, you can add phenolphthalein to the agar and then submerge cubes in sodium hydroxide. <-- this tends to be more expensive than white vinegar, and NaOH is dangerous to handle.

Image below shows saturation of agar by vinegar. The yellow area started as blue. A ruler placed under the flask can be used as another way to measure the rate of diffusion.