# A Study of the Relationship between Diffusion and Cell Size

## Equipment Needs:

Agar-agar – non-nutritive

Magnetic stirrer/hot plate or microwave oven

Phenolphthalein can be purchased in solution (1% in 95% ethanol) or in powder form to dissolve in alcohol to the same concentration. (Note: Phenolphthalein is a pH indicator and turns bright pink in the presence of a base of pH 10.0 – 13.0)

0.1 M NaOH can be purchased in solution or can be made by dissolving 4.0 grams of reagent NaOH pellets in 1 liter of distilled water to make a 0.1 M solution. Label a plastic bottle as 0.1 M NaOH and store the solution at room temperature. This solution can last for several years.

Square or rectangular glass or plastic pans, at least 3 cm deep

Refrigerator

plastic millimeter rulers

250 ml beakers

plastic spoons

plastic knives or dull scalpels to cut agar

paper towels

pink/purple colored pencils for drawing the results.

**Day before the lab preparation:**

To make the agar blocks, boil 23 grams of Agar-agar (Hint: Use non-nutritive agar since you don't want bacteria or fungi to grow.) in 1000 ml of distilled water. Stir the mixture continuously to keep the agar from sticking to the bottom of the beaker as it heats - a magnetic stirrer/hot plate is recommended for this method. An even easier way to prepare the agar solution is by using a Microwave. Less stirring is required but you do have to be careful not to let it come to a full boil which will boil over. (Hint: The solution is ready when the solution turns from cloudy brown to clear brown.)

After the agar solution cools a bit but is still liquid, add several drops of phenolphthalein to the agar solution. Test a few drops of agar/phenolphthalein solution with a few drops of NaOH solution to make sure the combination turns pinkish-purple. (Hint: Phenolphthalein is an indicator of a base and turns pinkish-purple in the presence of a base.)

Pour the agar/phenolphthalein solution into a glass Pyrex- or plastic Tupperware-type rectangular or square pan making sure the depth of the solution is at least 3 cm to ensure the largest cube can be made. (Hint: Thrift stores are good sources of inexpensive pans for this lab. Do not use metal pans.) Place the pans in the refrigerator overnight to solidify. Solid agar for this lab can remain in the refrigerator for up to a week. After a week, the agar begins to dehydrate and shrink.

Equipment needed **per pair of students** is a plastic millimeter ruler, a 250 ml beaker, a plastic spoon, a plastic knife or dull scalpel, paper towels, and pink/purple colored pencils for drawing the results.

Students love playing with the agar while cutting the cubes and carving up the remainder agar. Make sure student wash their hands after cutting the cubes since phenolphthalein is a component of many laxatives. And the students should be careful when handling the agar cubes that have been soaked in NaOH and wash their hands after touching anything containing the NaOH solution.

## Answers to the questions:

**Table**

| Cube Dimension (cm/side) | Surface Area ($cm^2$) | Volume ($cm^3$) | Simplest Ratio |
|---|---|---|---|
| 3 | 54 | 27 | 54/27 = 2/1 cm |
| 2 | 24 | 8 | 24/ 8 = 3/1 cm |
| 1 | 6 | 1 | 6 / 1 = 6/1 cm |
| 0.1 | 0.06 | 0.001 | 0.06/0.001 = 60/1 cm |
| 0.01 | 0 .0006 | 0.000001 | 0.0006/0.000001 = 600/1 cm |

**Cut each cube in half and record your observations by drawing each cube. Measure the depth of diffusion in each cube of the NaOH in cm. What is the rate of diffusion?**

There should be 3 drawings which are accurately measured, drawn, and colored. The 1 cm on edge cube would all be purple since the depth of diffusion was 0.5 cm on all sides. The 2 cm on edge cube would have a purple border of 0.5 cm diffusion depth on all sides leaving a 1 cm on edge clear space inside. The 3 cm on edge cube would have a purple border of 0.5 cm diffusion depth on all sides leaving a 2 cm on edge clear space inside.

The depth of diffusion for all 3 cubes is 0.5 cm.

The rate of diffusion is 0.5 cm/10 minutes = 0.05 cm/ minute.

**1a) List the agar cubes in order of size, from largest to smallest.**

3 cm, 2 cm, 1 cm, 0.1 cm, 0.01 cm

**1b) List the agar cubes in order of surface to volume ratio, from largest to smallest and compare the two lists.**

0.01 cm, 0.1 cm, 1 cm, 2 cm, 3 cm The two lists are in the opposite order.

**2a) Why did we include the 0.1 and 0.01 cubes in the table?**

These sizes approach the size of a real cell but are too small to handle in this experiment.

**2b) When comparing a cube 3 cm/side and a cell the size of an onion cell, which has the greatest surface area?**

The cube 3 cm/side has the greatest surface area – 54 $cm^2$ compared to 0.0006 $cm^2$, assuming the onion cell is 0.01 cm on edge.

2**c) Which of the two cells in part b has the greatest surface area in proportion to its volume?**

The onion cell has the greatest surface area in proportion to its volume – 600/1 cm compared to 2/1 cm.

**3a) What evidence is there that the sodium hydroxide diffuses into the agar?**

We know the sodium hydroxide diffuses into the agar cube because the cube turned purple as it entered the cube containing the phenolphthalein, an indicator of base.

**3b) Is there any evidence that something was diffused out of the agar? Explain.**

There is evidence that something diffused out of the agar since the clear sodium hydroxide solution into which the agar cubes were placed turned purple from the phenolphthalein diffusing out of the agar cube.

**4. If the agar cubes were living cells and the sodium hydroxide was a vital nutrient, which block would**

**have the most efficient ratio of surface area to volume? Explain why.**

The smallest agar cube (1 cm tested) or (0.01 cm untested) had the most efficient surface area to volume ratio. From the table, the 1 cm cube had a ratio of (6/1) or (600/1) compared to a ratio of 2/1 for the 3 cm cube or 3/1 for the 2 cm cube, which is a much larger number. This shows that more vital nutrient will diffuse into the center of the smallest cube in the same amount of time, thus nourishing the cell.

**5. What happens to the surface area to volume ratio of a cell as a cell grows?**

As the cell grows from 1 cm to 2 cm, the surface area to volume ratio decreases from 6/1 to 3/1.

**6a) Why does the growth rate of a cell slow down as it gets larger?**

The growth rate of a cell slows down as it gets larger because it is less efficient at getting vital nutrients to the center of the cell.

**6b) How does cell division affect the cell's ability to absorb material for growth?**

When the cell divides, it forms two smaller cells which each have a larger surface to volume ratio. Given a set rate of diffusion, the center of the new smaller cells will be able to have vital nutrients reach the center of the cell.