

SNC2D/2P Tissues, Organs, and Systems of Living Things/Tissues, Organs and Systems

Teacher Demo/Student Activity: Limit to Cell Size

Topics	Timing
cell cycle the importance of cell division	preparation: 20 min (1 day before using) demonstration: 15–20 min activity: 30–40 min

Specific Expectations

SNC2D

A1.1 formulate scientific questions about observed relationships, ideas, problems, and/or issues, make predictions, and/or formulate hypotheses to focus inquiries or research

A1.10 draw conclusions based on inquiry results and research findings, and justify their conclusions

B3.1 describe the cell cycle in plants and animals, and explain the importance of mitosis for the growth of cells and repair of tissues

B3.2 explain the importance of cell division and cell specialization in generating new tissues and organs (e.g., the division of stem cells into specialized cells such as muscle cells or nerve cells in humans; the division of meristematic cells to expand and differentiate plant tissue)

SNC2P

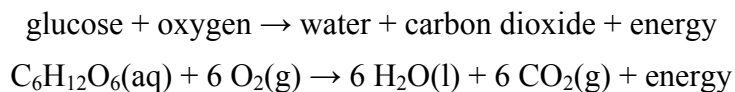
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Introduction

Cells require a constant supply of glucose and oxygen to produce energy. The process of cellular respiration is described in the following equations.



Cellular respiration occurs in the mitochondria of a cell. As a result of this process, large quantities of waste carbon dioxide must be expelled from the cell. All materials involved in this reaction are either imported or exported through the cell membrane by diffusion. Cells come in all sizes ranging from 8 μm in diameter (e.g., red blood cell) to over 1 m long (e.g., nerve cell). Diffusion occurs quickly over short distances. For example, a molecule of oxygen can diffuse from the centre of a small cell to the outside, through the cytoplasm and cell membrane, in less than one second. However, the same molecule would take longer to diffuse from the centre of a

larger cell to outside of the cell. Since the rapid import and export of chemicals is critical to the efficient operation of cells, the mechanism of diffusion effectively places a limit on cell diameter.

In this demonstration, students soak agar “cells” containing phenolphthalein indicator in a solution of sodium hydroxide, NaOH(aq). Students observe the effect of cell volume and surface area on the extent of diffusion of the sodium hydroxide solution through the “cell”.

Safety Considerations

- Provide MSDS sheets for all chemicals used.
- Sodium hydroxide solution is corrosive and will irritate your skin and eyes. Avoid skin or eye contact. Safety goggles, apron/lab coats, and gloves must be worn at all times when handling sodium hydroxide. Wash your hands and flush your eyes immediately if you come into contact with it.
- The phenolphthalein solution is flammable. Keep it away from any heat sources and open flames.

Materials

chemical safety goggles	250 mL beaker
lab coat or apron	stirring rod or spoon
protective gloves	container at least 8 cm deep (e.g., plastic freezer dish)
1 packet of unflavoured gelatin or 7.5 g agar flakes or powder	stirring rod
250 mL water	plastic knife
dropper bottle containing 1% phenolphthalein solution	ruler
350–750 mL 0.1 mol/L sodium hydroxide solution, NaOH(aq)	250 mL beaker
paper towel	plastic spoon
	Petri dish
	stopwatch

Hazardous Materials Identification System Rating

(0-minimal 1-slight 2-moderate 3-serious 4-severe)

1% phenolphthalein 0.1 mol/L sodium
pH indicator solution hydroxide

HMIS (0 to 4)

Health	1
Fire Hazard	3
Reactivity	0

HMIS (0 to 4)

Health	1
Fire Hazard	0
Reactivity	0

Procedure

Ensure that all participants are wearing appropriate PPE: chemical safety goggles, lab coat or apron, and protective gloves.

Prepare the following at least one day before performing the demonstration.

1. Mix 1 packet of unflavoured gelatin with 250 mL of water (a 3% agar solution will also work; 3 g agar/100 mL water), then add 10 drops of 1% phenolphthalein.

2. Pour into the container (e.g., plastic freezer dish). The liquid should be at least 5 cm deep. Refrigerate overnight.

Organize your class into groups of 2-4 students per group. Ensure that all students are wearing appropriate PPE: chemical safety goggles, lab coat or apron, and protective gloves.

3. **Predict/Explain**

Ask each group to predict what will happen when different-sized blocks of agar/gelatin are placed in the sodium hydroxide solution. If necessary, review the colour change of phenolphthalein when it is added to a basic solution. Each group should also attempt to come up with a rationale for their prediction and explain any differences in predictions between blocks of different sizes.

4. Give each group a piece of agar, Petri dish, ruler, stirring rod and plastic knife. Have them use the plastic knife to cut a cube that is one of the following sizes, ensuring that there is a variety of sizes throughout the class. (Alternatively, the teacher could pre-cut the cubes and distribute them to save time.)

$$0.5 \text{ cm} \times 0.5 \text{ cm} \times 0.5 \text{ cm}$$

$$1 \text{ cm} \times 1 \text{ cm} \times 1 \text{ cm}$$

$$2 \text{ cm} \times 2 \text{ cm} \times 2 \text{ cm}$$

$$3 \text{ cm} \times 3 \text{ cm} \times 3 \text{ cm}$$

5. Have students place their agar cube into a 250 mL beaker and pour in the NaOH solution until the cube is submerged. Start timing using the stopwatch.
6. Students should gently turn the cube, without scratching it, using a stirring rod every few minutes for the next 10 min, ensuring that all sides come into contact with the solution.
7. While waiting, students should calculate and record the following pieces of information:
 - a. surface area (SA) of cube in cm^2
 - b. volume (V) of cube in cm^3
 - c. surface area to volume ratio (SA/V)
8. After 10 min, students should remove the cube using a plastic spoon, and use a paper towel to blot it dry. Place it on a Petri dish.
9. Using the plastic knife, students should cut each block in half.
10. **Observe**
Students should measure and record the depth of the coloured area.
11. Students should then measure (to the nearest mm) the distance across the uncoloured area and determine the volume of the uncoloured part of the block in cm^3 . They can then calculate the percentage of the volume of the cube affected by the colour or percent diffusion of the colour using the formula
$$\frac{((\text{Initial volume} - \text{Final volume uncoloured})/\text{Initial volume}) \times 100\%}{}$$
12. One member from each group can put their data into a class observation table on the front board and each group could then observe any trends in the data.
13. **Explain**
Ask the groups to revise their explanations, if necessary.

Disposal

The agar/gelatin can be disposed of as solid waste in the garbage. Add vinegar to neutralize the sodium hydroxide prior to disposal. Follow disposal procedures that are consistent with school board protocol and appropriate for your municipality.

What happens?

As each cube comes into contact with the sodium hydroxide solution, NaOH (aq), it will turn pink. The pink colour will first appear on the surface of the cube, and then will gradually diffuse in toward the centre of each cube. The percent diffusion of the colour will be inversely proportional to the size of the cube (i.e., the smallest cube will have the highest percent diffusion of the colour).

How does it work?

As the volume of the cubes increase, the surface area to volume ratio also increases. As long as the cubes are exposed to the same concentration of sodium hydroxide for the same amount of time, the percent diffusion of the colour decreases as the size of the cell increases. This model demonstrates that when cells grow larger, it takes more time for required substances to diffuse into the cell and for waste materials to exit out of the cells. As a result, they become less efficient and ultimately cannot sustain life beyond a certain size, hence the necessity to undergo cell division and thus reduce the distance of the centre of the cell from the fluid surrounding the cell.

Teaching Suggestions/Hints

Possible probing questions to ask students:

- a. How does the surface area to volume ratio affect the percent diffusion of the colour?
- b. Why does a cell's growth rate slow down as it gets larger?
- c. How does cell division affect the cell's ability to absorb materials needed for growth and repair?
- d. What are some errors in the design of this demonstration?
- e. What could you investigate to explore cell diffusion further?

Next Steps

This demonstration could be used to introduce an inquiry in which students investigate a factor that could affect the rate of diffusion into a cell.

Additional Resources

1. Information about phenolphthalein pH indicator solution:
<http://www.chemguide.co.uk/physical/acidbaseeqia/indicators.html>
2. Extension Investigation: comparing the size of molecules with their diffusion rates into a cell: <http://www.umassk12.net/nano/materials/web2012/jen/gel.html>
3. Alternative Investigation: using cardboard models instead of agar to investigate the relationship between surface area and volume of a cell:
http://www.biologyjunction.com/cell_size.htm