2. DIFFUSION

Background

Consider the simple act of breathing. With each inhalation and exhalation, your body operates under the principles of diffusion. Thanks to this process, oxygen molecules in an area of high concentration (the atmosphere) move to an area of lower concentration—your lungs, and then into the blood flowing through capillaries in the lungs. Oxygen then diffuses from the capillaries into the body's cells. Likewise, waste products from cell activity (CO_2) diffuse out of cells, into capillaries, travel to the lungs and diffuse out to the atmosphere. Both oxygen and carbon dioxide move along a concentration gradient (from high concentration to low concentration). Fortunately for you, this diffusion of gases is efficient and keeps you alive.

Most intercellular traffic occurs via diffusion. Therefore, it is important to understand how this process occurs. It is also important to understand what factors affect diffusion rates, such as the size of the molecule, the "steepness" of the concentration gradient, the distance the molecules must travel, the permeability of the membrane, and the temperature of the environment.

In this activity, you will use dialysis tubing to simulate the cell membrane and apple cider vinegar to represent intracellular fluid, a fluid containing a mixture of substances. With a pH sensor, you can determine the rate of diffusion for one of these intracellular substances: hydrogen ions (H^+).

NOTE: Since hydrogen ions form bonds with water molecules, you are actually determining the rate of diffusion of hydronium ions: $H_3O^+(aq)$.

Driving Question

How quickly do substances diffuse across a membrane?

Materials and Equipment

Use the following materials to complete the initial investigation. For conducting an experiment of your own design, check with your teacher to see what materials and equipment are available.

- Data collection system
- pH sensor
- Graduated cylinder, 25-mL
- Beaker or cup, 250-mL–400-mL
- Dialysis tubing, 1 inch × 28-cm
- Disposable pipet or 10-mL syringe
- Paper clip or binder clip
- Small cup to capture the 25 mL (or less) of fluid from the dialysis bag
- Apple cider vinegar, 25 mL
- Pickle juice, 25 mL
- Magnetic stir bar and plate *(if available)*
- Spring water (or distilled water), 200 mL
- Plastic wash bottle with distilled water

Safety

Follow these important safety precautions in addition to your regular classroom procedures:

- Wear safety goggles at all times.
- Be sure to wear gloves or wash your hands after handling solutions. The solutions can irritate your skin and cause extreme eye irritation if you wipe your eyes with your hands after contact with them.

Initial Investigation

Complete the following investigation before designing and conducting your own experiment. Record all observations, data, explanations, and answers in your lab notebook.

1. Put on your safety goggles.

2. Open the 2 ABI Diffusion lab file. Connect the pH sensor to your device.

   NOTE: If the lab file is not available, create a graph of pH vs. Time. Set the sample rate to 30 seconds.

3. Pour 200 mL of water into a cup or beaker and set the beaker aside.

4. Add 25 mL of apple cider vinegar to a graduated cylinder. Rinse the tip of the pH sensor with water and place the sensor in the vinegar. Begin recording data to measure the pH of the vinegar. After 30 seconds, or when the pH stabilizes, end data collection and remove the sensor from the vinegar.

5. Obtain a piece of dialysis tubing that has soaked in water. Tie a tight knot in one end of the tubing to create a bag. Rub the other end of the tubing between your fingers to open the bag.

6. Use a clean pipet or syringe to add approximately 15–20 mL of vinegar from the graduated cylinder to the dialysis bag. Close the bag by tying a knot or by twisting the tubing and closing it with a binder clip. Rinse the outside of the bag with distilled water.

7. Rinse the pH sensor with water and place it into the beaker of distilled water. If a stir plate is available, add a magnetic stir bar to the beaker and set the stir plate to a medium spin speed. If a stir plate is not used, gently swirl the beaker during data collection.

   NOTE: If using a cup instead of a beaker, be sure the pH sensor does not cause the cup to tip over. You may need to hold the sensor during data collection or use a base and support rod with a clamp to secure the sensor.

8. Start recording data and then slowly add the dialysis bag to the water. If using a clip to close the bag, be sure the clipped end remains above the surface of the liquid when put into the water as shown in Figure 1. Continue recording data for 5 minutes or until the pH value stabilizes. Draw or print a record of the data.

9. At the end of the experiment, empty the contents of the dialysis tubing into a small cup and record the pH of the vinegar. Compare the pH after soaking the dialysis tubing in water to the initial vinegar pH. Explain the results.

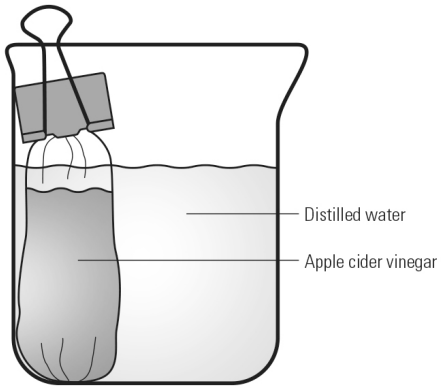


Figure 1: Clip remains above water

10. Is dialysis tubing a *semipermeable* membrane? Support your claim with evidence from the investigation.

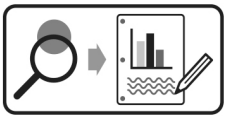
11. If the experiment is repeated with 20 mL of pickle juice in a dialysis bag, how do you expect the results to compare to the first experiment with apple cider vinegar? Explain the basis for your prediction.

12. Repeat the procedures, replacing apple cider vinegar with pickle juice in the dialysis bag. Draw or print a record of the data.

13. Explain any similarities or differences in the results for the two solutions. Consider general trends in the data as well as the relative rates of diffusion.

Design and Conduct an Experiment

The dialysis tubing and the cup with distilled water were used to simulate intracellular and extracellular environments. The apple cider vinegar represents a solution containing some of the same materials as cytoplasm and interstitial fluid, such as hydrogen and sodium ions. How can you change a component of this model system, or change the environmental conditions, to test factors that affect diffusion?



Design and carry out your experiment using either the Design and Conduct an Experiment Worksheet or the Experiment Design Plan. Then complete the Data Analysis and Synthesis Questions.

Design and Conduct an Experiment: Data Analysis

1. From your observations and your data:

    a. Describe how the independent variable you manipulated affected the rate of diffusion out of the dialysis bag and into the beaker. Does the data support your hypothesis? Justify your claim with evidence from your experiment.

    b. Based on the evidence you collected, explain why the results occurred.

2. Is there any evidence in your data or from your observations that experimental error or other uncontrolled variables affected your results? If yes, is the data reliable enough to determine if your hypothesis was supported?

3. Identify any new questions that have arisen as a result of your research.

Synthesis Questions

1. The structure and properties of a biological membrane allows the membrane to carry out important functions for cells.

    a. What does it mean to say that the plasma membrane is semipermeable? Describe the structure of the plasma membrane and explain how it provides a selective barrier for cells.

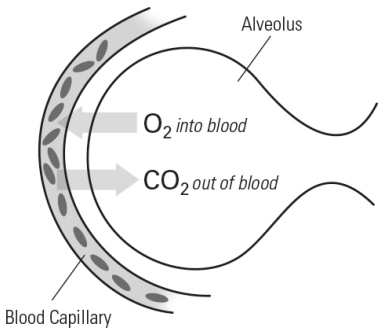
    b. Provide specific examples of molecules or other particles that enter or exit cells and for each example describe the mechanism of transportation.

    c. Eukaryotic cells have a number of membrane-bound organelles. Explain the function of these membranes within cells and describe the structures and functions of two organelles that consist of one or more membranes.

2. There are many examples of diffusion in living things. One example is the gas exchange that occurs in the alveoli of the lungs.

    a. Describe the concentration gradients that exist between the alveoli and the blood within capillaries surrounding the alveoli and explain how these gradients facilitate gas exchange. Use evidence to support your explanation.

    b. Identify and describe two additional examples of diffusion in living things.



3. Use the data presented in the table below to predict how altitude would affect a runner's ability to complete a five-kilometer (5k) race in each of the given cities. Explain your predictions.

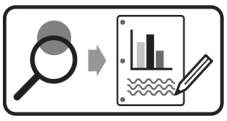
Table 1: Atmospheric oxygen concentration at various elevations

City	Elevation above Sea Level (feet)	Atmospheric O_2 Concentration (%)
Birmingham, AL	600	21
Boulder, CO	5,430	17.8
Nederland, CO	8,230	15.9
Breckenridge, CO	9,300	15.1

NAME PERIOD DATE

Design and Conduct an Experiment Worksheet

The dialysis tubing fluid and the cup with distilled water were used to simulate intracellular and extracellular environments, respectively. The apple cider vinegar represents a solution containing some of the same materials as cytoplasm and interstitial fluid, such as hydrogen and sodium ions. How can you change a component of this model system, or change the environmental conditions, to test factors that affect diffusion?



Develop and conduct your experiment using the following guide.

1. Based on your knowledge of membranes and diffusion, what factors could affect the rate of diffusion?

2. Create a driving question: choose one of the factors you've identified that can be controlled in the lab and develop a testable question for your experiment.

3. What is the justification for your question? That is, why is it biologically significant, relevant, or interesting?

4. What will be the independent variable of the experiment? Describe how this variable will be manipulated in your experiment.

5. What is the dependent variable of the experiment? Describe how the data will be collected and processed in the experiment.

6. Write a testable hypothesis (If…then…).

7. What conditions will need to be held constant in the experiment? Quantify these values where possible.

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8. How many trials will be run for each experimental group? Justify your choice.

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9. What will you compare or calculate? What analysis will you perform to evaluate your results and hypothesis?

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10. Describe at least 3 potential sources of error that could affect the accuracy or reliability of data.

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11. Use the space below to create an outline of the experiment. In your lab notebook, write the steps for the procedure of the lab. (Another student or group should be able to repeat the procedure and obtain similar results.)

12. Have your teacher approve your answers to these questions and your plan before beginning the experiment.