

Instructor Notes

Semipermeable Membranes and Bioaccumulation

Organisms can be exposed to environmental toxins through a number of biological pathways, including osmosis and diffusion. This exercise examines basic diffusion and osmosis, along with a model organism's response to exposure to two simulated environmental toxins.



The activity is written for workshop participants and may need modification for classroom use.

Suggested Background Readings

- An Introduction to Toxicology
- Principles of Environmental Site Assessment

National Science Education Standards for Grades 5–12

Science as Inquiry

- Abilities Necessary to Do Scientific Inquiry
Conduct scientific investigations. Students place a model organism into different solutions to demonstrate the concepts of osmosis and diffusion across semipermeable membranes.
- Understandings about Scientific Inquiry
Scientific explanations must adhere to specific criteria. After conducting the investigation, students answer questions that require the formation of logically consistent explanations based on the rules of evidence and current scientific knowledge.

Life Science

- The Cell
Cells have particular structures that underlie their functions. Students learn that a cell membrane surrounds a cell, serving to separate internal molecules from their outside environment while allowing some particles to pass into and out of the cell.

Safety

As the instructor, you are expected to provide participants with the necessary safety equipment (including personal protective equipment such as goggles, gloves, aprons, etc.) and appropriate safety instruction to allow them to work safely in the laboratory. Always follow local, state, and school policies. Read and follow all precautions on labels and MSDSs provided by the manufacturer for all chemicals used.

Materials

Per class

- 2 dropper bottles

Per group

- 2, 4½-inch-long pieces of dialysis tubing
- liquid laundry starch
- stirring rod
- string
- scissors
- 2 raw eggs
- vinegar
- Karo® syrup
- 2, 250-mL beakers
- 5 drops of food color (contaminant A)



Do not use blue food coloring, as it may resemble the color of the liquid starch reacting with iodine.



- 20 drops of tincture of iodine (contaminant B)
This solution, available in drugstores, must be the brown type, not the colorless type.

Getting Ready

For Part C, fill a dropper bottle with food color and label the bottle “contaminant A.” Fill another dropper bottle with tincture of iodine and label that bottle “contaminant B.” These bottles can be shared by all groups.

For each group, soak two 4½-inch pieces of dialysis tubing in water overnight to make them pliable. To create two model organisms, fill each piece of tubing with liquid laundry starch and tie off the ends with string. Rinse the model organisms in clean water.

Also for each group, fill each of two 250-mL beakers with 150 mL tap water. Submerge a model organism in each beaker.

Procedure Notes and Outcomes

Participants need to understand the following terms:

- *solute*: a substance dissolved in a solution, usually in the lesser amount (e.g., salt in saltwater)
- *solvent*: a dissolving agent in a solution, usually present in the greater amount (e.g., water in saltwater)
- *diffusion*: spontaneous mixing of particles from a region of higher to lower concentration

- *osmosis*: the movement of water molecules across a semipermeable membrane (Water is the solvent in this case.)
- *dialysis*: the separation of substances in solution by means of their unequal diffusion through semipermeable membranes

Before doing the procedure, be sure the participants understand the basics of bioaccumulation and the different types of particle movement within and through cells.

When a toxic substance enters an organism and cannot be excreted, that substance is said to *bioaccumulate*, or build up, within that organism over time. Consequently, when a larger organism feeds on the organism in question, the larger organism accumulates the toxic “load” of the first organism. After consuming several similarly contaminated smaller organisms, the larger organism will contain and hold all of the inexcretable toxic substances accumulated by the smaller organisms. This is an example of *biomagnification*.

Once inside an organism, toxins can move to various parts of the body, often accumulating in specific organs or locations. The movement and concentration of a toxin is affected by its ability to travel across a *semipermeable membrane* and by other factors that affect its concentration in solution. Animal cells are enclosed by semipermeable membranes that allow the passage of some particles (ions or molecules of solute or solvent) but not others. Particle movement across a membrane helps equalize particle concentration on both sides of the membrane.

Not all semipermeable membranes permit general movement of solute particles. Some membranes allow only the passage of the solvent. These membranes are said to be *differentially permeable membranes*. Osmotic membranes, for example, only allow water molecules to cross them. (The movement of water across a semipermeable membrane is called *osmosis*.) When osmosis occurs, water molecules move across the membrane to dilute the solution on the more concentrated side, which also increases the volume of solution on that side. As the water moves away from the side of the membrane that was originally more dilute, its volume is lessened and its concentration increased. If the process is allowed to continue, the concentration on both sides becomes equal. The expanding and contracting of red blood cells in solutions of different concentrations results from the osmotic membrane that surrounds the cells.

Diffusion—the spontaneous mixing of particles from an area of high concentration to an area of low concentration—is another important process. For example, if you squeeze a drop of food color into a cup of water, the food color spontaneously begins to mix with the water. Diffusion does not require the movement across a membrane.

Plausible Answers to Questions

1. Which contaminant caused the model organism to change color? By what process did the contaminant penetrate the membrane in Part B?

Contaminant A produced no noticeable color change because the food color did not penetrate the membrane. Contaminant B caused a color change to dark blue. The contaminant (the triiodide ion, I_3^-) moved by dialysis through the membrane of the tubing and reacted with the liquid starch to form the dark blue color.

2. What happened to the model organism that changed color when you removed it from the contaminated water and placed it into clean water? Did the color of the contaminant stay with the organism? If not, was all of the "toxin" removed?

When the organism was removed from the contaminant B environment and placed in a clean water environment, the color inside the organism lessened and eventually went away completely because the contaminant moved from an area of high concentration to an area of low concentration.

3. What potential problems might an actual organism experience if a toxin cannot be eliminated?

Toxins that cannot be eliminated from an actual organism can cause health problems and bioaccumulate over time. Larger organisms may feed on organisms that have bioaccumulated toxins, resulting in biomagnification.

Activity Instructions

Semipermeable Membranes and Bioaccumulation

This activity demonstrates the concepts of diffusion and osmosis, along with a model organism's response to exposure to two simulated environmental toxins.

Safety

In a laboratory setting, you are ultimately responsible for your own safety and for the safety of those around you. It is your responsibility to specifically follow the standard operating procedures (SOPs) that apply to you, including all local, state, and national guidelines on safe handling, storage, and disposal of all chemicals and equipment you may use in the labs. This includes determining and using the appropriate personal protective equipment (e.g., goggles, gloves, apron). If you are at any time unsure about an SOP or other regulation, check with the course instructor.

Procedure

Part A: Diffusion

1. Place a drop of food color into room-temperature water. Do not stir. Observe the diffusion.
2. Predict how the rate of diffusion is affected by the temperature of the water. Then try step 1 with ice-cold water and hot water.

Part B: Osmosis

1. Remove the shell from the two raw eggs by soaking the eggs in vinegar overnight, rinsing them under running water, then soaking them in fresh vinegar. Repeat this procedure for several days or until the shell has decomposed and the egg membrane is revealed.
2. Weigh and record the mass of the two raw eggs with their shells removed.
3. Place one egg in tap water and the other in Karo syrup.
4. Record the mass, volume, and appearance of the eggs every day for about a week. To do this, you will need to cautiously dry the wet egg by patting it with paper towels. For the Karo-soaked egg, rinse briefly with water, pat dry, and weigh. Return the eggs to the appropriate liquids.
5. Compare the mass, volume, and appearance changes that you observed in the two eggs.

Part C: Dialysis Membranes and the Movement of Toxins

1. Simulate the input of a toxin by contaminating two different 150-mL water samples in the following manner. Add 5 drops of food color (contaminant A) to one of the 250-mL beakers of tap water containing a model organism. Add 20 drops of tincture of iodine (contaminant B) to the second 250-mL beaker containing the other model organism.
2. After 10 minutes, remove the model organisms from each contaminated beaker and blot them dry. Record your observations.
3. Place the model organisms into beakers of fresh water with no added contaminant. Record your observations to determine if elimination of the toxins by the organisms occurs.

Questions

1. Which contaminant caused the model organism to change color? By what process did the contaminant penetrate the membrane in Part B?
2. What happened to the model organism that changed color when you removed it from the contaminated water and placed it into clean water? Did the color of the contaminant stay with the organism? If not, was all of the "toxin" removed?
3. What potential problems might there be for an actual organism if a toxin cannot be eliminated?