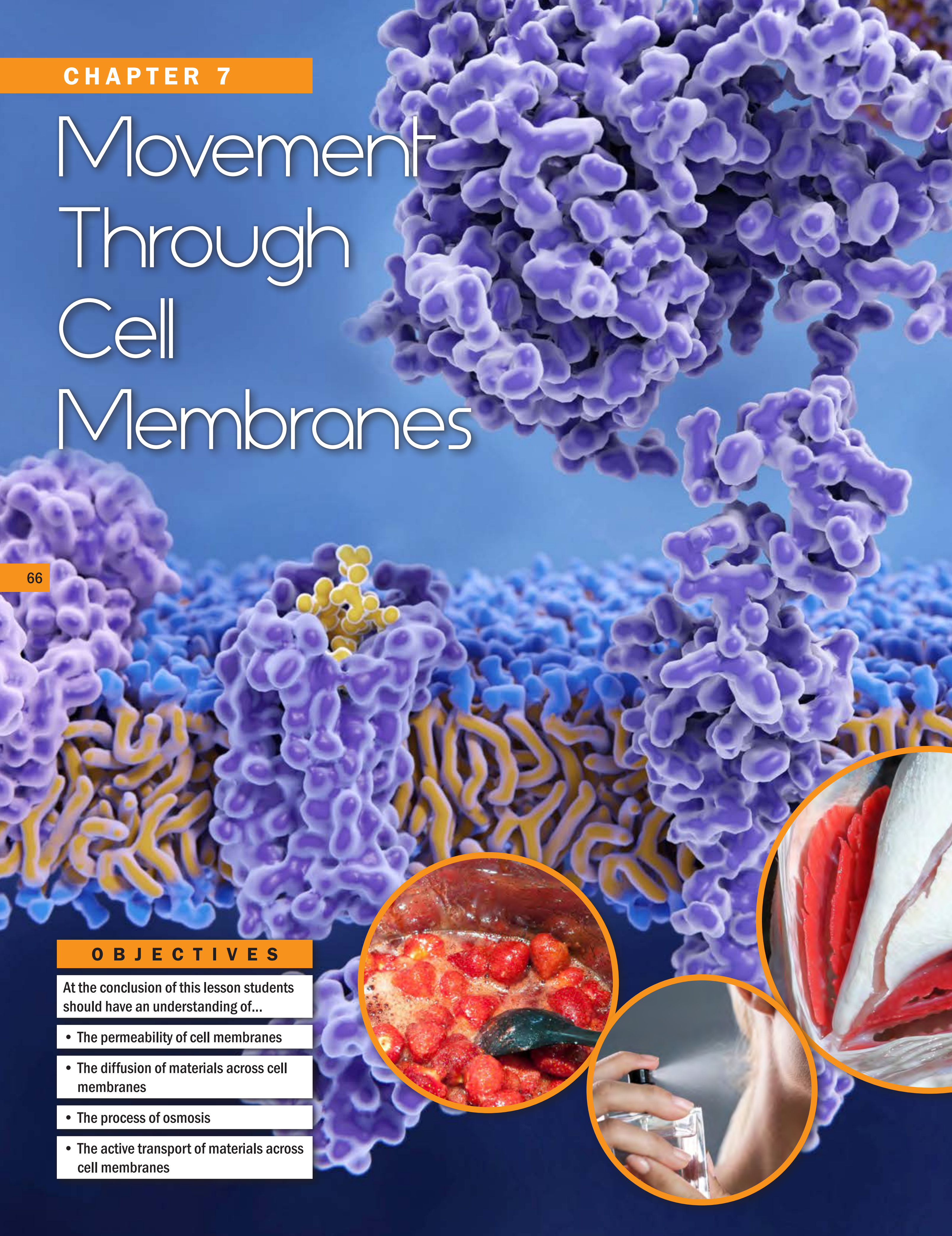


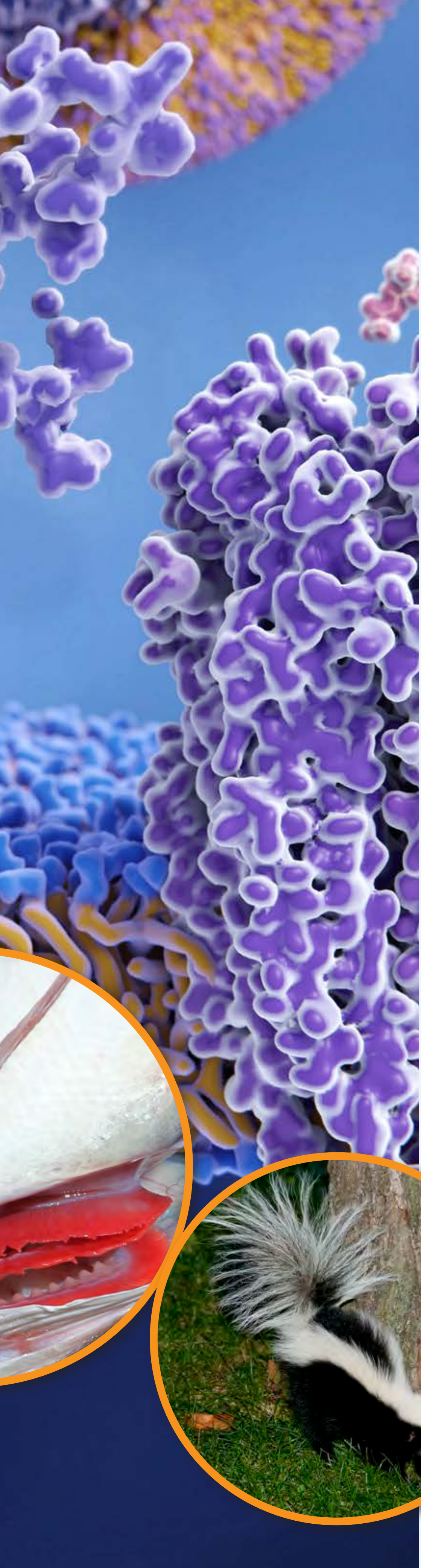
CHAPTER 7

Movement Through Cell Membranes

OBJECTIVES

At the conclusion of this lesson students should have an understanding of...

- The permeability of cell membranes
- The diffusion of materials across cell membranes
- The process of osmosis
- The active transport of materials across cell membranes



CELL MEMBRANES

Cell membranes are selectively **permeable**, meaning that only certain substances are allowed to pass through them, into and out of the cell. It is also sometimes called semipermeable or differentially permeable. The ends of the phospholipids penetrating the middle of cell membranes are non-polar (neutral in charge) so they attract oils and fats and repel water — called hydrophobic. The ends of the phospholipids facing the outer parts of membranes are polar (with negative and positive charged parts) and attract water — called hydrophilic. Molecules can cross cell membranes passively by diffusion or by active transport requiring energy. For some, the movement (kinetic energy) of substances carry them across the membrane and the cell does not have to use energy for the process. This is like when a baseball goes through a window — the energy comes from the baseball and the window just sits there and takes it. For other substances, cells have to use energy to move them.

DIFFUSION THROUGH CELL MEMBRANES

Diffusion is the movement of substances by their kinetic energy, which is the energy of motion. Most molecules are light enough to move about in air. You notice this if a skunk goes by. The scent from the skunk consists of molecules given off by the skunk that move about and find their way to your nose. When the air temperature is higher, the average velocity of the air molecules is faster. The motion of individual molecules is said to be **random**, meaning it is unpredictable. The concept of random depends upon your concept of reality. To some, it means that things just happen and there is no plan or control. To others, that are aware of God's role in the universe, it is under His sovereign control — it is just that we do not know how to predict where any given molecule will be at any given time. But we know that there is control because using the laws that govern the motion of gas molecules, we can predict where most of the molecules will be at any given time. We just

WORDS TO UNDERSTAND

- active transport
- aquapores
- concentration gradient
- crenated
- diffusion
- electrical gradient
- hypertonic (hyperosmotic)
- hypotonic (hyposmotic)
- isotonic (isosmotic)
- membrane pumps
- osmosis
- permeable
- physiological saline
- random
- solute
- turgor pressure

cannot predict where any individual molecule will be. If we can predict where the bulk of the molecules will go, which we can, the individual molecules have to be controlled. Molecules diffuse from where they are more concentrated to where they are less concentrated. This aspect of diffusion is predictable. Perfume will diffuse out of a bottle into a room and not from the room into a bottle.

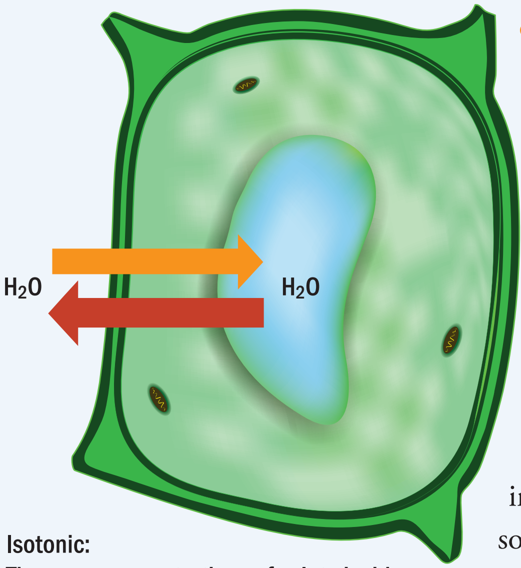
Some molecules diffuse in and out of cells because they are small enough to go through pores if they collide with the opening at the right angle and velocity. Water molecules diffuse through **aquapores**, which are protein-lined channels through cell membranes. Otherwise, water molecules would be repelled by the hydrophobic phospholipids in the middle of the membranes.

When a substance is at the same concentration on both sides of a membrane, it will diffuse in and out of the cell at the same rate. They are at equilibrium.

Because diffusion is caused by the movement of the molecules themselves, there is no cost to the cell. Even though there is no net change in the concentrations of the substance at equilibrium, the individual molecules are still moving just as much as before. When the concentration of the substances is not the same on both sides of the membrane, a **concentration gradient** exists. This is where molecules of the same kind are more concentrated on one side of a membrane than the other.

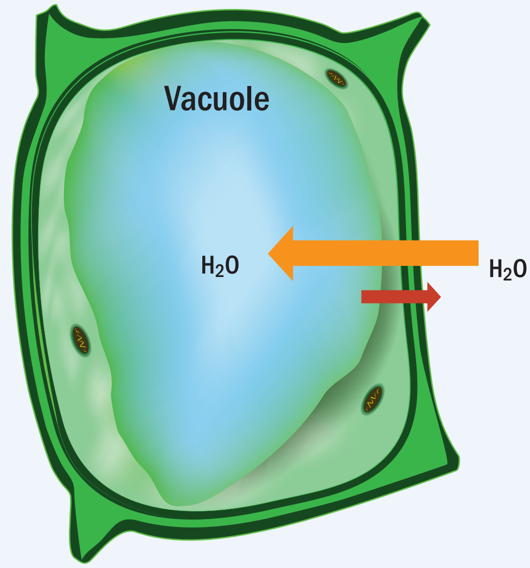
PROCESS OF OSMOSIS

The most abundant molecule that diffuses across a cell membrane is water. The diffusion of water across a cell membrane is called **osmosis**. Water is a solvent (other molecules will dissolve into it) and what dissolves into it is called the **solute**. When salt (sodium chloride, NaCl) is added to water, the Na^+ ions and the Cl^- ions separate and become dispersed between the water molecules. The term ion refers to an atom or molecule that is + or – charged. Positive-charged Na^+ (sodium) ions are attracted to the negative-charged side of water molecules and the negative-charged Cl^- (chloride) ions are attracted to the positive-charged side of water molecules. When the NaCl solutions are the same concentrations on both sides of the cell membrane, they are called **isotonic** or **isosmotic**. The prefix iso- means same. The NaCl concentration inside of a living cell is 0.9%. When a cell is placed in a 0.9% NaCl solution, it will not absorb too much water or lose too much water. This is called **physiological saline**.



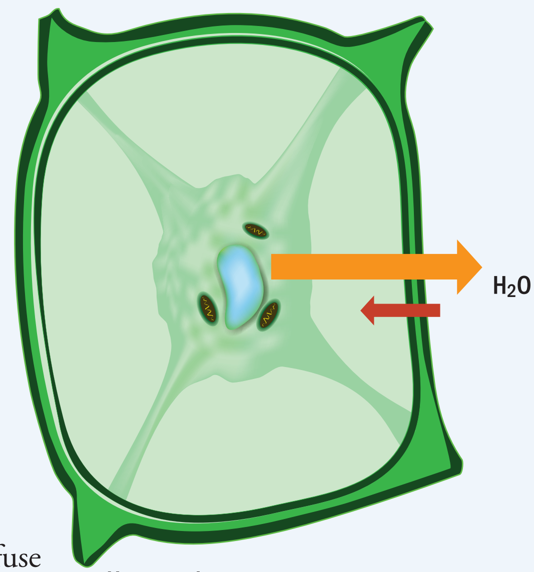
Isotonic:
The same concentrations of solute inside and outside the cell

In distilled water, the NaCl concentration is 0% and the water concentration is 100%. When cells are placed in distilled water, water will diffuse from a region of greater concentration to a region of lesser concentration; so more water will diffuse from outside of the cell to the inside of the cell. Inside the cell, the NaCl is 0.9% and the water concentration is 99.1%. So the water diffuses down the concentration gradient from 100% to 99.1%. This may not seem like a big difference but in this case it is. The cell will swell up and burst, or if it is a plant cell it will swell and push out on the outer cell wall. The 0% NaCl concentration outside the cell is called **hypotonic** or **hyposmotic** to the solution in the cell. The prefix hypo- means under or less, so it refers to a solution with a lower solute concentration.



Hypotonic:
Greater concentrations of solute inside the cell than outside the cell

When water enters a cell by osmosis, the additional water molecules in the confined space of a cell produce pressure against the inside walls of the cell called **turgor pressure**. It can burst animal cells and stiffen plant tissues because the cell membranes of plant cells push out against their outer cell walls. This is why well-watered plants do not wilt.



Hypertonic:
Greater concentrations of solute outside the cell than inside the cell

If a cell is placed in a solution of 10% NaCl (90% water), water will diffuse out of the cell faster than it will diffuse into the cell. This is from 99.1% water in the cell to 90% water outside of the cell. The cell will lose water and shrivel up. The cell is said to become **crenated**. The 10% NaCl is called **hypertonic** or **hyperosmotic** when contrasted to the solution inside the cell.

Sugar acts as a preservative in jelly. As a solute, sugar in jelly is hypertonic to bacteria and mold (fungus) cells. Water molecules diffuse at a greater rate from bacteria and mold cells into the jelly, causing the bacteria and mold cells to shrivel up and die.

The predictability of the process of osmosis is another example of the overall predictability of the movement of molecules that are said to move randomly. This is a great demonstration that even the physical processes that govern living organisms appear to be part of an intelligent design. It is a form of worship to recognize and give God the credit for what He has so wonderfully provided by His grace. As a result of osmosis, water moves from soil into root cells supplying water to thirsty plants. As well, osmosis transports water from one cell to another within animal tissues and from plant cells within leaves to neighboring cells.

ACTIVE TRANSPORT ACROSS CELL MEMBRANES

In many situations, molecules are moved against a concentration gradient at the expense of cellular energy. This is **active transport** because the cell is active in moving molecules from where they are less concentrated to where they are more concentrated. This would be like catching perfume molecules in the room and stuffing them back into a bottle. Well, maybe not quite as difficult, but that is the idea. This process involves specialized proteins in the cell membrane that can physically catch molecules on one side of a membrane and deposit them on the other side where they are more concentrated. Active transport can be detected by adding poison to cells blocking the transport proteins by cutting off their energy supply. If the process is stopped by the poison, it is active transport and not diffusion.

Some of the proteins imbedded in the two phospholipid layers of the cell membrane are called **membrane pumps**. The most extensive studied system of membrane pumps is the sodium–potassium exchange pumps in neurons (nerve cells). Sodium (Na^+) ions are pumped out of the cell faster than they can diffuse back in. This results in the Na^+ ions being more than 10 x more concentrated outside of the membrane than in the cytoplasm. The protein pumps are highly selective as to what they move across the membrane. At the same time, potassium (K^+) ions are pumped into the cytoplasm from outside of the cell, with 3 Na^+ ions pumped out for every 2 K^+ ions pumped in. This results in more positive charges being outside of the membrane than in the cytoplasm. This is a concentration gradient and an **electrical gradient** (more positive charge on the outer part of the cell membrane than inside the cell). This prepares the membrane of the neuron for a nerve impulse. When the pump ceases and the Na^+ gates (also formed by proteins in the membrane) open, Na^+ ions rush into the cytoplasm. This is called a nerve impulse, which is going on in your brain right now.

Energy from the energy storage molecules adenosine triphosphate (ATP) is required for the membrane pumps. When energy is released from ATP molecules they lose their third phosphate ion, becoming adenosine diphosphate, phosphate, and energy.

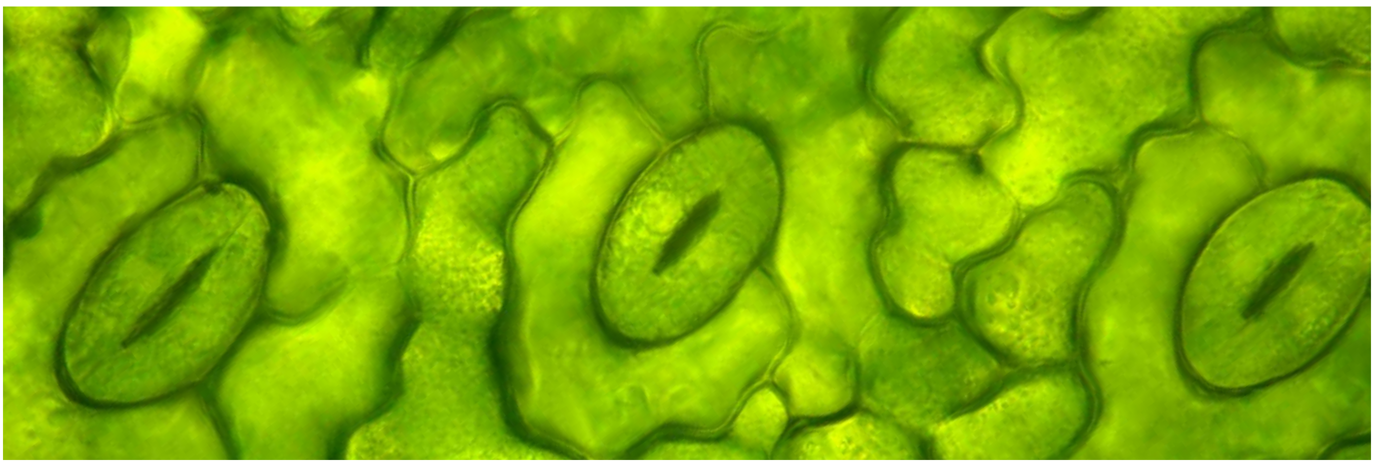
$$\text{ATP} \rightarrow \text{ADP} + \text{Phosphate} + \text{Energy}$$

This energy-releasing process is universal among living organisms. This happens in most cases where a cell uses energy. This consistent pattern would not be expected from constantly changing evolutionary processes, but would be expected with the same Designer creating all life forms.

Other examples of membrane pumps include the movement of Ca^{++} (calcium) ions across cell membranes within cells involved in muscle contraction, the filtration processes in the kidneys, uptake of salts by the gills of freshwater fish, and the transport of salts out of the gills of salt water fish.

Life processes of cells involve moving materials in and out of cells through their outer membranes. The dominant role of the cell membranes is to control the movement of water in and out of cells. This is mainly carried out by the diffusion of water molecules from regions of greater water concentration to regions of lower concentration which is osmosis. This is a huge example of God's grace because it does not cost the cell any energy – it is driven by the energy of motion of the water molecules. It is like opening the door on a windy day and using the energy of the air molecules to move it into a room. All you have to do is open the door. You do not have to push the air into the room. It is like saying that most of the necessary things in life are free. For the health of our cells, it is huge to keep the water balance. I trust that you can see God's design and grace throughout this study which should encourage and strengthen your faith. Life does not depend on us – God has already abundantly provided.

Osmosis



REQUIRED MATERIALS

- Fresh apple
- Fresh potato
- Distilled water (available from grocery store)
- NaCl (salt from grocery store)
- Knife to cut the potato and apple
- Teaspoon
- 100 ml beakers (3) (from the supply kit)
- Metric ruler (from the supply kit)
- 50 ml graduated cylinder (from the supply kit)
- Wax pencil (from the supply kit) or a non-permanent marker

INTRODUCTION

Water diffuses into and out of cells through pores (called aquapores) in cell membranes. Diffusion occurs from a region where molecules are more concentrated to where they are less concentrated. The concentration of water in distilled water is 100% because there is nothing besides water. A 10% NaCl (salt) solution has a water concentration of 90%. The fluid inside of cells is 99.1% water, so if a cell is placed in a 10% NaCl solution, water will diffuse out of the cell more than will diffuse into the cell (from 99.1% to 90%) and the cell will shrivel up.

If cells are placed in distilled water (100% water), it will diffuse more into the cell with (99.1% water) than out of the cell and the cell will swell and perhaps burst.

PURPOSE

To observe a practical example of osmosis.

PROCEDURE

1. Label a beaker as distilled water, another beaker as 1.0% NaCl, and a third beaker as 10.0% NaCl.
2. Measure out a 50 ml (milliliter) portion of distilled water with a graduated cylinder and pour it into each of the three beakers.
3. Add 0.5 gram of NaCl to the 50 ml of distilled water in the second beaker — 0.5 gram is the amount on the tip of a table knife. This is accurate enough for this procedure. This beaker should be labeled as 1.0% NaCl.
4. Add 5 grams of NaCl to the water in the third beaker. One teaspoon of NaCl is 5 grams. This beaker should be labeled as 10.0% NaCl.
5. Cut 3 rectangles of potato and 3 rectangles of apple about 2 cm (centimeters) long, 1 cm tall, and 1 cm wide. Use the metric ruler from your supply kit.
6. Dry each of the potato and apple rectangles by blotting them with a paper towel.
7. Place a potato and apple rectangle in each of the 3 beakers.
8. After 30 minutes, remove the rectangles and place them on a paper towel. Blot each one with paper towel. Keep track of which pieces came from which beaker. Describe the appearance of each rectangle. Are they swollen, shriveled, or the same as before?
9. Write a complete sentence describing how the potato and apple pieces compare to their appearance before they were placed in the beakers.
10. **Osmosis** is the diffusion (movement) of water across a cell membrane from the side of the membrane where it is more concentrated to the other side of the membrane where it is less concentrated. Distilled water is 100% water. The beaker with 0.5 grams of NaCl in 50 ml of water is 1.0% NaCl and 99% water (100 – 1 = 99). The beaker with 5 grams of NaCl in 50 ml of water is 10% NaCl and 90% water (100 – 10 = 90).

    A. For the first beaker, the potato and apple pieces with 99% water are place in distilled water (100%). Would you expect the water to move more into or more out of the potato and apple cells? From your observations what do you think happened? If more water moved into the potato and apple cells, they would swell up. If more water moved out of the potato and apple cells, they would shrink. If the same amount of water entered the cells as came out of them, they would stay pretty much the same. Did it happen the way you thought it would?

    B. For the second beaker, the potato and apple pieces with 99% water are placed in 1% NaCl (99% water). The fluid within the cells is 99.1% water to begin with. Would you expect the water to move more into or out of the potato and apple cells? From your observations, what do you think happened? Did it happen the way you thought it would?

    C. For the third beaker, the potato and apple pieces with 99% water are placed in 10% NaCl (90% water). Would you expect the water to move more into or more out of the potato and apple cells? From your observations what do you think happened? Did it happen the way you thought it would?

11. Answer the questions in this lab in your lab report with complete sentences.

Osmosis is a simple concept (that many make confusing), which is very predictable when the basics are understood. Hopefully, this lab helps you to visualize its effects and understand it much better.