Tab 2

Notes

WEEK 7

Cell Membrane and Passive Transport

Diffusion • Osmosis • Facilitated Diffusion • Concentration Gradients • Membrane Permeability

BIG IDEA: The cell membrane helps a cell stay alive by controlling what enters and leaves. Passive transport moves substances down a concentration gradient without requiring cellular energy (ATP).

1. The Cell Membrane: The Cell's Selective Boundary

The cell membrane, also called the plasma membrane, is a thin, flexible boundary surrounding the cell. It separates the cell's internal environment from the external environment while allowing controlled exchange of materials.

Main Functions

- **Protection and separation.** It keeps the cell's contents together and separates them from the surroundings.
- **Selective transport.** It controls which substances enter or leave the cell.
- **Communication.** Membrane proteins receive signals from hormones, neighboring cells, and the environment.
- **Recognition.** Carbohydrate chains on the membrane act like identification tags.
- **Homeostasis.** It helps maintain stable internal conditions such as water balance, ion concentration, pH, and nutrient levels.

The Fluid Mosaic Model

The membrane is described as a fluid mosaic because many different molecules are arranged in a flexible, moving layer. Its main framework is a phospholipid bilayer.

- **Phospholipids.** Each has a hydrophilic (water-attracting) head and hydrophobic (water-repelling) tails. The heads face watery environments; the tails face inward.
- **Membrane proteins.** Some act as channels, carriers, receptors, enzymes, or anchors.
- **Cholesterol.** In animal cells, it helps stabilize the membrane and maintain appropriate fluidity.
- **Carbohydrates.** Attached to proteins or lipids, they help in cell recognition and communication.

SELECTIVELY PERMEABLE: The membrane allows some substances to pass more easily than others. It is not an open door—and it is not a brick wall either.

2. Concentration Gradients and Molecular Motion

Concentration

Concentration refers to the amount of a substance in a given volume. A solution with many dissolved particles has a higher solute concentration than a solution with fewer dissolved particles.

Concentration Gradient

A concentration gradient is a difference in the concentration of a substance between two regions. This difference provides the driving force for passive transport.

- Moving from high concentration to low concentration is moving down the concentration gradient.
- Moving from low concentration to high concentration is moving against the concentration gradient and usually requires energy.

Random Motion and Net Movement

Particles are always moving randomly because they possess kinetic energy. When a gradient exists, particles move in all directions, but the net movement is from the region of higher concentration to the region of lower concentration.

> IMPORTANT: At equilibrium, particles do not stop moving. They continue to cross in both directions at equal rates, so there is no net change. This is called dynamic equilibrium.

3. Passive Transport

Passive transport is the movement of substances across a membrane without the cell directly using ATP. Substances move down their own concentration gradients until equilibrium is approached.

A. Simple Diffusion

Simple diffusion is the direct movement of small molecules from an area of higher concentration to an area of lower concentration. The molecules pass through the phospholipid bilayer without help from a transport protein.

Common examples: oxygen (O_2), carbon dioxide (CO_2), and small lipid-soluble molecules.

- Oxygen diffuses from the lungs into the blood because oxygen concentration is higher in the alveoli than in the deoxygenated blood.
- Carbon dioxide diffuses from body cells into the blood and later from the blood into the lungs.
- Perfume molecules spreading through a room illustrate diffusion, although no cell membrane is involved.

Factors That Affect the Rate of Diffusion

- **Steeper concentration gradient.** A greater difference in concentration generally causes faster net diffusion.
- **Higher temperature.** Particles move faster and collide more often.
- **Larger surface area.** More membrane area allows more particles to cross at the same time.

- **Shorter diffusion distance.** A thinner membrane or shorter path increases the rate.
- **Smaller particle size.** Smaller particles generally move more easily.
- **Greater membrane permeability.** Substances that dissolve in the lipid bilayer cross more readily.

B. Osmosis

Osmosis is the net movement of water across a selectively permeable membrane from a region with higher free-water concentration (lower solute concentration) to a region with lower free-water concentration (higher solute concentration).

MEMORY GUIDE: Water moves toward the side with more nonpenetrating solute—until water balance is reached or another force prevents further movement.

Water may pass slowly through the phospholipid bilayer, but in many cells most water moves through specialized channel proteins called aquaporins. Osmosis is still passive because water moves down its water-concentration gradient and no ATP is directly used.

Tonicity: How a Solution Affects Cell Volume

Tonicity describes how the concentration of nonpenetrating solutes outside a cell affects the cell's water movement and volume. Always compare the surrounding solution with the inside of the cell.

Outside Solution	Relative Solute Concentration	Net Water Movement	Effect on the Cell
Isotonic	Equal to the cell	No net movement	Animal cell stays normal; plant cell is flaccid
Hypotonic	Lower than the cell	Water enters the cell	Animal cell swells and may lyse; plant cell becomes turgid
Hypertonic	Higher than the cell	Water leaves the cell	Animal cell shrivels; plant cell plasmolyzes

Plant-cell advantage: The cell wall resists excessive expansion. A hypotonic environment usually makes a healthy plant cell turgid rather than causing it to burst.

C. Facilitated Diffusion

Facilitated diffusion is the passive movement of substances down their concentration gradients through specific membrane proteins. It is needed when a substance cannot easily pass through the hydrophobic interior of the phospholipid bilayer.

Types of Transport Proteins

- **Channel proteins.** Form hydrophilic passageways through the membrane. Some channels are always open, while gated channels open or close in response to signals.
- **Carrier proteins.** Bind a specific substance, change shape, and release it on the other side of the membrane.
- **Aquaporins.** Water-channel proteins that greatly increase the rate of osmosis.

Examples: glucose enters many cells through glucose carrier proteins; ions such as Na^+, K^+, Cl^-, and Ca^{2+} pass through specific ion channels.

DO NOT CONFUSE: Facilitated diffusion uses proteins but not ATP. The word "facilitated" means helped—not energized.

4. Comparing Passive Transport Mechanisms

Mechanism	What Moves?	Direction	Transport Protein?	ATP Required?	Example
Simple diffusion	Small nonpolar molecules	High → low concentration	No	No	O_2 and CO_2
Osmosis	Water	Higher free water → lower free water	Often aquaporins	No	Water entering root cells
Facilitated diffusion	Ions and larger/polar molecules	High → low concentration	Yes: channel or carrier	No	Glucose entering a cell

5. Membrane Permeability

Membrane permeability is the ability of a substance to cross a membrane. Whether a substance passes easily depends on its size, charge, polarity, lipid solubility, and the presence of suitable transport proteins.

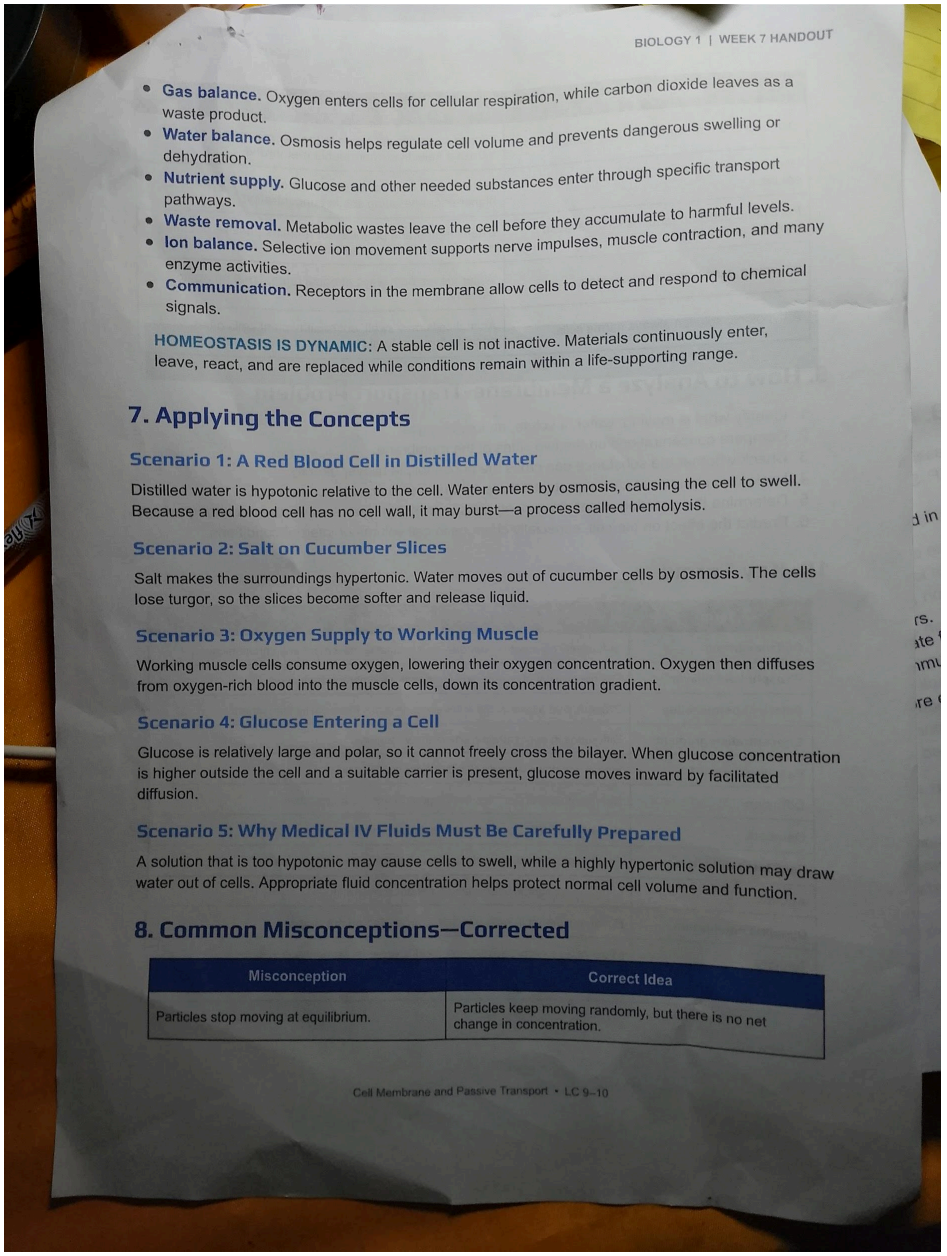
- **Cross easily.** Small nonpolar molecules such as O_2 and CO_2 dissolve in the lipid bilayer.
- **Cross slowly or in limited amounts.** Small uncharged polar molecules, including water, may cross, but water movement is much faster through aquaporins.
- **Need transport proteins.** Ions and many large or polar molecules cannot cross the hydrophobic core unaided.
- **May not cross at all.** A substance may remain blocked if the membrane has no suitable channel or carrier.

Specificity and Saturation

- Specificity: A transport protein usually recognizes only one substance or a small group of related substances.
- Saturation: Carrier-mediated transport has a maximum rate. When all carriers are occupied, adding more solute does not proportionally increase transport.

6. Cell Membranes and Homeostasis

Homeostasis is the maintenance of relatively stable internal conditions despite changes in the external environment. The membrane supports homeostasis by regulating material exchange and responding to cellular needs.



- **Gas balance.** Oxygen enters cells for cellular respiration, while carbon dioxide leaves as a waste product.
- **Water balance.** Osmosis helps regulate cell volume and prevents dangerous swelling or dehydration.
- **Nutrient supply.** Glucose and other needed substances enter through specific transport pathways.
- **Waste removal.** Metabolic wastes leave the cell before they accumulate to harmful levels.
- **Ion balance.** Selective ion movement supports nerve impulses, muscle contraction, and many enzyme activities.
- **Communication.** Receptors in the membrane allow cells to detect and respond to chemical signals.

HOMEOSTASIS IS DYNAMIC: A stable cell is not inactive. Materials continuously enter, leave, react, and are replaced while conditions remain within a life-supporting range.

7. Applying the Concepts

Scenario 1: A Red Blood Cell in Distilled Water

Distilled water is hypotonic relative to the cell. Water enters by osmosis, causing the cell to swell. Because a red blood cell has no cell wall, it may burst—a process called hemolysis.

Scenario 2: Salt on Cucumber Slices

Salt makes the surroundings hypertonic. Water moves out of cucumber cells by osmosis. The cells lose turgor, so the slices become softer and release liquid.

Scenario 3: Oxygen Supply to Working Muscle

Working muscle cells consume oxygen, lowering their oxygen concentration. Oxygen then diffuses from oxygen-rich blood into the muscle cells, down its concentration gradient.

Scenario 4: Glucose Entering a Cell

Glucose is relatively large and polar, so it cannot freely cross the bilayer. When glucose concentration is higher outside the cell and a suitable carrier is present, glucose moves inward by facilitated diffusion.

Scenario 5: Why Medical IV Fluids Must Be Carefully Prepared

A solution that is too hypotonic may cause cells to swell, while a highly hypertonic solution may draw water out of cells. Appropriate fluid concentration helps protect normal cell volume and function.

8. Common Misconceptions—Corrected

Misconception	Correct Idea
Particles stop moving at equilibrium.	Particles keep moving randomly, but there is no net change in concentration.

Misconception	Correct Idea
Osmosis is the movement of any solute.	Osmosis specifically refers to the net movement of water across a selectively permeable membrane.
Water always moves to the side with less solute.	Water moves from lower solute concentration toward higher nonpenetrating solute concentration.
Facilitated diffusion requires ATP because proteins are involved.	It uses membrane proteins but remains passive because movement is down a gradient.
Isotonic means water does not move.	Water moves both ways at equal rates, creating no net movement.
A hypotonic solution always harms cells.	Animal cells may swell, but healthy plant cells often become firm and turgid because of the cell wall.

9. How to Analyze a Membrane-Transport Problem

1. Identify what is moving: water, a solute, an ion, or a gas.
2. Compare concentrations on the two sides of the membrane.
3. Check whether the substance can cross the phospholipid bilayer directly.
4. Look for a channel or carrier protein if the substance is polar, charged, or large.
5. Determine the direction of net movement: passive transport moves down the relevant gradient.
6. Predict the effect on the cell, especially changes in cell volume or internal conditions.

10. Key Terms

Term	Meaning
Cell membrane	Selectively permeable boundary that regulates movement and communication.
Phospholipid bilayer	Double layer of phospholipids forming the membrane framework.
Selective permeability	Property that allows some substances to cross more easily than others.
Concentration gradient	Difference in concentration between two regions.
Passive transport	Movement down a gradient without direct ATP use.
Diffusion	Net movement of particles from higher to lower concentration.
Osmosis	Net movement of water across a selectively permeable membrane.
Facilitated diffusion	Passive movement through specific channel or carrier proteins.
Aquaporin	Membrane channel specialized for water movement.
Dynamic equilibrium	Equal movement in both directions, producing no net change.
Tonicity	Effect of an external solution on a cell's water movement and volume.
Homeostasis	Maintenance of relatively stable internal conditions.