Module 2C – Membranes and Cell Transport

- All cells are surrounded by a plasma membrane. Eukaryotic cells also contain internal membranes and membrane-bound organelles.
- In this module, we will examine the structure and function of cell membranes. We will also look at how materials move within cells and across cell membranes.

1

Objective # 13

Describe the Fluid Mosaic Model of membrane structure.

2

Objective 13

- In 1972, Singer and Nicolson proposed the Fluid Mosaic Model of membrane structure.
- According to their model, cell membranes are composed of a lipid bilayer with globular proteins embedded in the bilayer.

3

Objective 13

- Further study has shown that cell membranes consist of 4 major components:

1) Lipid bilayer

- mainly 2 layers of phospholipids; the non-polar tails point inward and the polar heads are on the surface
- contains cholesterol in animal cells
- is fluid, allowing proteins to move around within the bilayer

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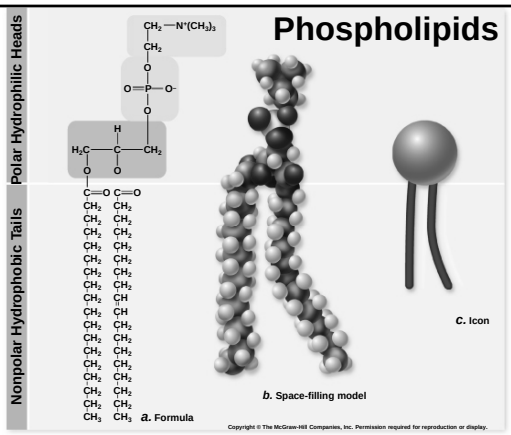

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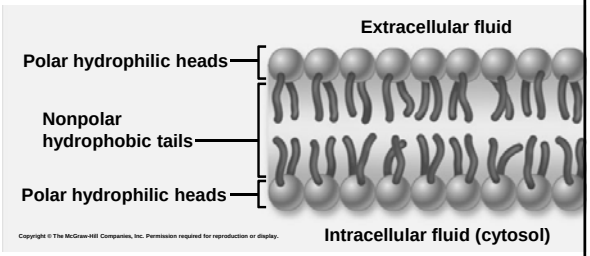
Objective 13

Phospholipid Bilayer



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Objective 13

2) Transmembrane proteins or Integral membrane proteins

- globular proteins that run through both layers of the lipid bilayer
- have hydrophobic regions that anchor them in the hydrophobic interior of the lipid bilayer and hydrophilic regions that protrude from the bilayer
- float freely within the bilayer

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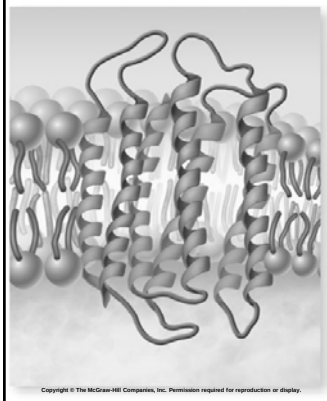

Integral proteins run through both layers of the lipid bilayer. Hydrophobic regions of the protein are shaded in blue and hydrophilic regions in red.

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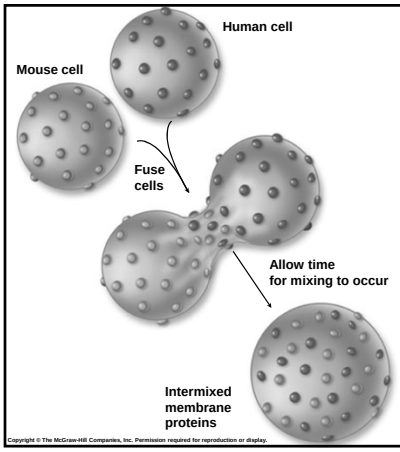

Experiments with cell fusion show that integral proteins can move freely within the fluid lipid bilayer.

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Objective 13

3) Interior protein network

- proteins associated with the surface of the membrane are called peripheral membrane proteins
- the interior surface of the plasma membrane is structurally supported by a network of proteins called spectrins and clathrins

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Objective 13

4) Cell surface markers

- project from the external surface of the membrane
- include glycolipids (lipids with carbohydrate groups attached) and glycoproteins (proteins with carbohydrate groups attached)
- function as cell identity markers

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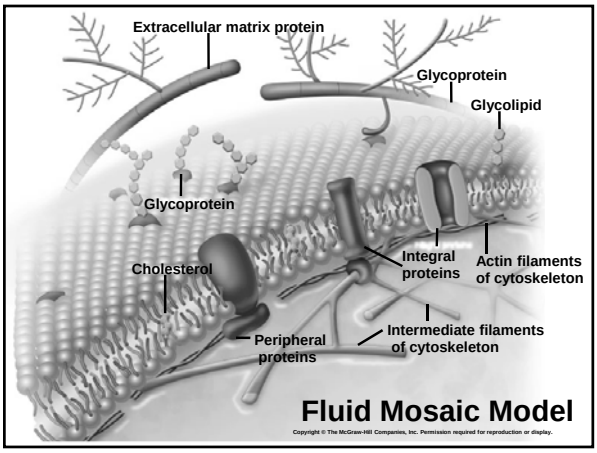

Objective # 14

List and describe the various functions of membrane proteins.

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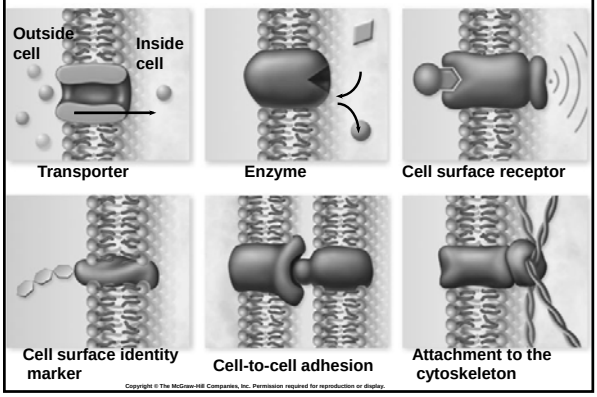
Functions of Plasma Membrane Proteins



Objective # 15

Explain the importance of cell transport.

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Objective 15

- No cell exists as a closed system. In order to survive, materials must enter and leave the cell through the plasma membrane.
- Because different processes take place in different parts of the cell, materials must be transported from one part of the cell to another.

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Objective # 16

Explain what passive transport is, and describe the following methods of passive transport across membranes:

a) Simple diffusion
b) Dialysis
c) Osmosis
d) Facilitated diffusion

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Objective 16

- Passive transport:
  - During passive transport, substances move according to their own natural tendency without an input of energy from the cell. No ATP is required.
  - To understand how passive transport works, we need to examine the kinetic theory of matter.

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Objective 16

- Kinetic theory of matter:
  - All atoms and molecules are in constant random motion. This energy of motion is called kinetic energy.
  - The higher the temperature, the faster the atoms and molecules move.
  - We detect this motion as heat.
  - All motion theoretically stops at absolute zero.

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Objective 16a

- Diffusion:
  - Diffusion is the net movement of a substance from an area where it has a higher concentration to an area where it has a lower concentration i.e. down its concentration gradient.
  - Caused by the constant random motion of all atoms and molecules.

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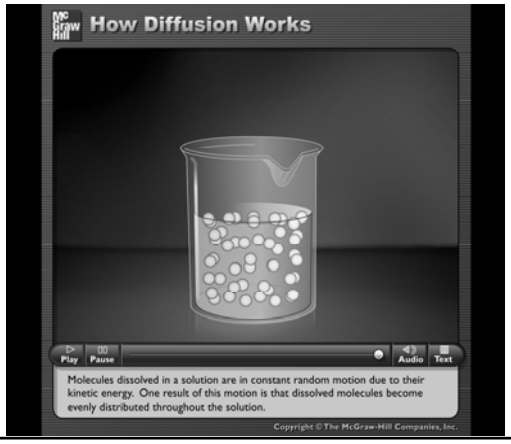

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Objective 16a

- During diffusion, movement of individual atoms and molecules is always random but net movement of each substance is down its own concentration gradient.

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Objective 16

- In addition to simple diffusion, there are 3 special types of diffusion that involve movement of materials across a semipermeable membrane:
  - dialysis
  - osmosis
  - facilitated diffusion

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Objective 16b

- Dialysis refers to the diffusion of solutes across a semipermeable membrane (i.e. a membrane where some substances can pass through while others cannot).
- The ability of solutes to pass through cell membranes depends mainly on size and electrical charge.

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Objective 16c

- Osmosis refers to the diffusion of the solvent across a semipermeable membrane.
- In living systems the solvent is always water, so biologists generally define osmosis as the diffusion of water across a semipermeable membrane:

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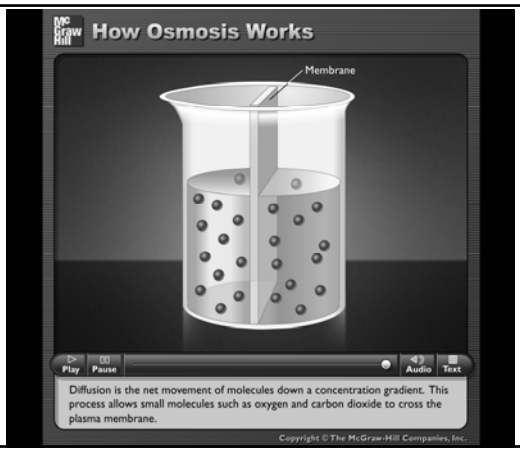

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Objective 16c

- The osmotic pressure of a solution is the pressure needed to keep it in equilibrium with pure H_20.
- The higher the [solutes] in a solution, the higher its osmotic pressure.
- If 2 solutions have the same [solutes], they are called isotonic.

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Objective 16c

- If 2 solutions have different [solutes]:
  - The one with the higher [solutes], and lower [solvent], is hypertonic.
  - The one with the lower [solutes], and higher [solvent], is hypotonic.

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Objective 16c

- What will happen to a cell if it is placed in a hypertonic solution?
- What will happen to a cell if it is placed in a hypotonic solution?

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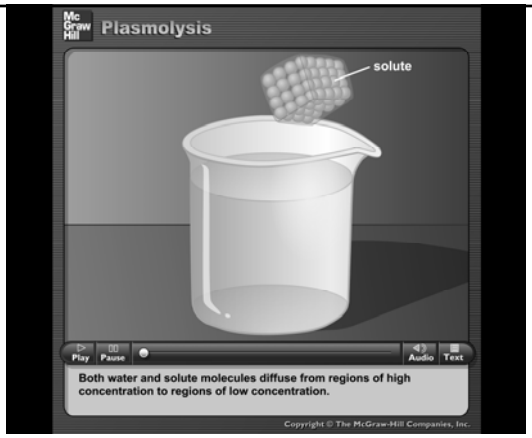

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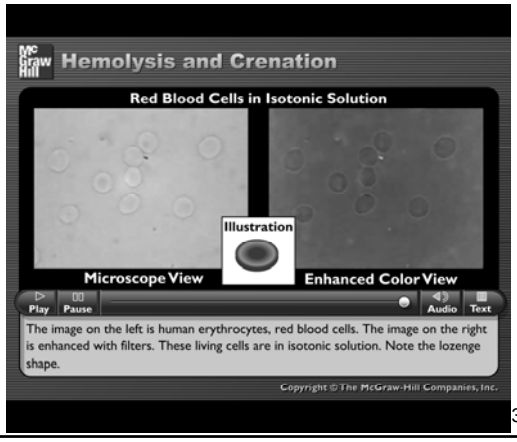

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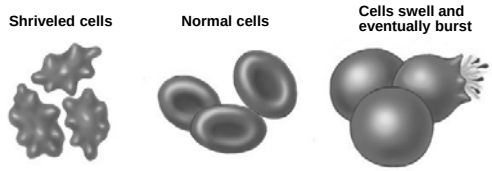
Human Red Blood Cells – which cells are in a hypertonic environment?



Hypertonic solution | Isotonic solution | Hypotonic solution

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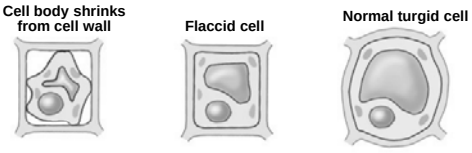
Plant cells – which cell is in a hypotonic environment?



Hypertonic solution | Isotonic solution | Hypotonic solution

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Objective 16c

- Cells have developed several ways to survive in a hypotonic environment:
  - Pump water out using a contractile vacuole.
  - Adjust [solutes] so it is isotonic relative to the environment.
  - Develop a thick cell wall that can withstand high turgor pressure.

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Objective 16c

- Even though water molecules are polar, they can pass through the hydrophobic interior of the lipid bilayer because they are so small. However, the flow is fairly limited.
- Recent studies have shown that movement of water molecules across cell membranes is facilitated by special protein channels called aquaporins.

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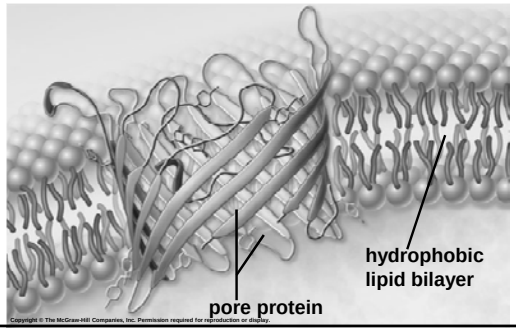
Pore proteins have a hydrophilic interior channel that allows ions and polar molecules, like water, to pass through the membrane



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Objective 16d

- Facilitated diffusion refers to the diffusion of solutes through a semipermeable membrane with the help of special transport proteins.
- Non-polar molecules and small polar molecules can diffuse directly through the lipid bilayer of a membrane.
- Ions and large polar molecules cannot, they need help from transport proteins.

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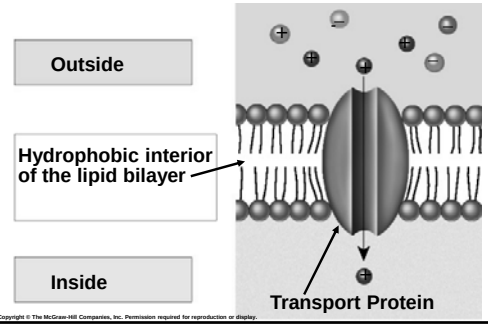
Ions and large polar molecules cannot pass through the hydrophobic interior of the lipid bilayer without the help of transport proteins:



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Objective 16d

- Two types of transport proteins can help ions and large polar molecules diffuse through cell membranes:

1) Channel proteins – have a hydrophilic interior for ions or polar molecules to pass through. Some channel proteins can be opened or closed in response to a stimulus. These are called gated channels.

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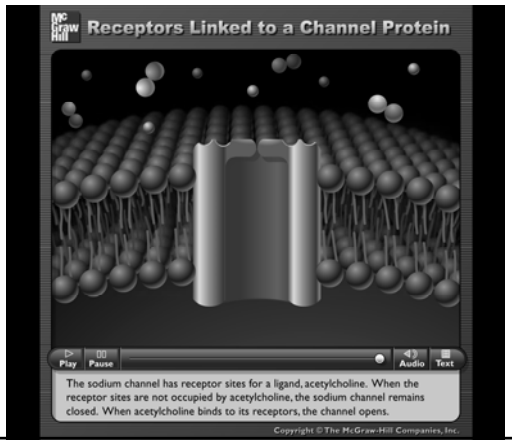

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Objective 16d

2) Carrier proteins – physically bind to the substance being transported on one side of membrane and release it on the other.

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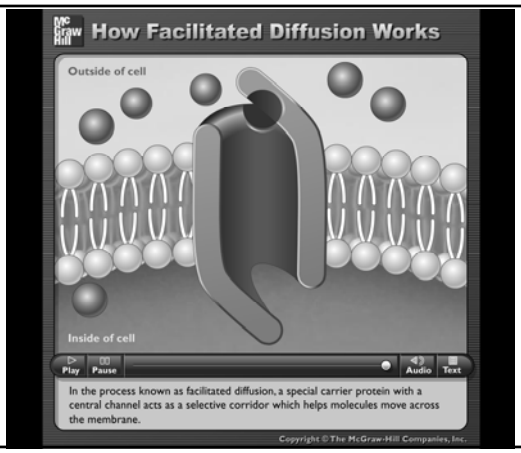

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Objective 16d

- Facilitated diffusion:
  - is specific – each channel or carrier transports certain ions or molecules only
  - is passive – direction of net movement is always down the concentration gradient
  - saturates – once all transport proteins are in use, rate of diffusion cannot be increased further

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Objective # 17

Explain what active transport is, and describe the following methods of active transport across membranes:

a) membrane pumps
b) coupled transport

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Objective 17

- Active transport:
  - a cell expends some of its own energy (from ATP) to move a substance against its natural tendency e.g. up a concentration gradient.
  - Requires the use of carrier proteins (transport proteins that physically bind to the substance being transported).

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Objective 17a

- We will examine 2 types of active transport: membrane pumps (protein-mediated active transport) and coupled transport (cotransport).
- With membrane pumps, a carrier protein uses energy from ATP to move a substance across a membrane, up its concentration gradient:

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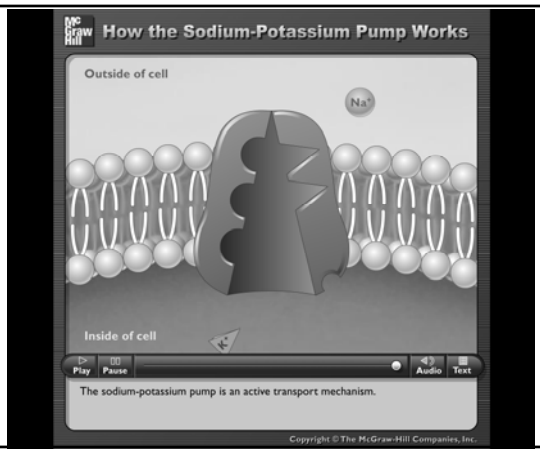

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Objective 17b

- Coupled transport occurs in 2 stages:
  - First, a carrier protein uses energy from ATP to move a substance across the membrane, up its concentration gradient. This gradient stores energy.

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Objective 17b

- Second, a coupled transport protein allows the substance to move back down its concentration gradient. As this happens, the stored energy is released and used to move a second substance up its concentration gradient:

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Objective # 18

Explain what bulk transport is, and describe the following methods of bulk transport:

a) Endocytosis including phagocytosis, pinocytosis, and receptor-mediated endocytosis
b) exocytosis

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Objective 18

- Bulk transport allows small particles, or groups of molecules to enter or leave a cell without actually passing through the membrane.
- We will examine 2 types of bulk transport: endocytosis and exocytosis.

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Objective 18a

- In endocytosis, part of the plasma membrane envelops small particles or fluid, then seals on itself to form a vesicle or vacuole which enters the cell:
  - Phagocytosis – the substance engulfed is a solid particle
  - Pinocytosis - the substance engulfed is a liquid

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Objective 18a

- A third type of endocytosis is called receptor-mediated endocytosis.
- In this process, the molecules to be transported join to specific receptors on the membrane. This causes the membrane to indent , and the molecules are engulfed in a coated vesicle which enters the cell.

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Objective 18b

- The reverse of endocytosis is called exocytosis.
- During this process, the membrane of a vesicle fuses with the plasma membrane and its contents are released outside the cell:

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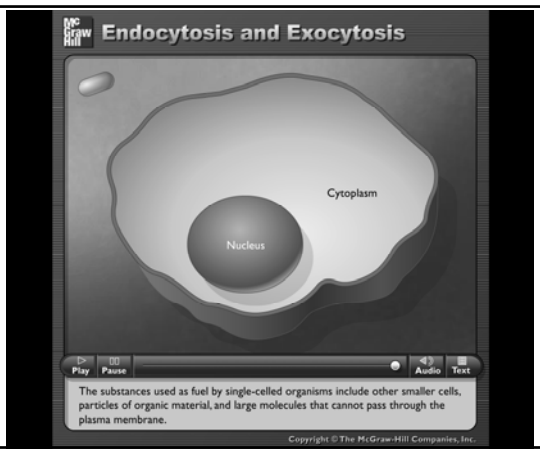

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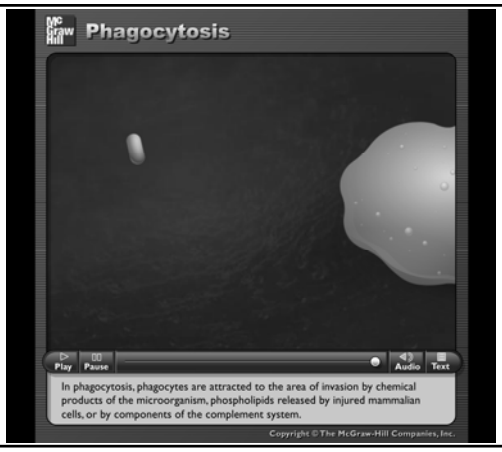

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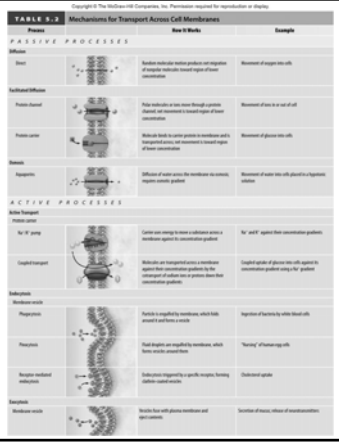

TABLE 9.2 Mechanisms for Transport Across Cell Membranes

Process	How It Works	Example
PASSIVE PROCESSES		
Diffusion		
Direct	Random molecular motion produces net migration of nonpolar molecules toward region of lower concentration	Movement of oxygen into cells
Facilitated Diffusion		
Protein channel	Polar molecules or ions move through a protein channel; net movement is toward region of lower concentration	Movement of ions in or out of cell
Protein carrier	Molecule binds to carrier protein in membrane and is transported across; net movement is toward region of lower concentration	Movement of glucose into cells
Osmosis		
Aquaporins	Diffusion of water across the membrane via osmosis; requires osmotic gradient	Movement of water into cells placed in a hypotonic solution
ACTIVE PROCESSES		
Active Transport		
Protein carrier		
Na^+/K^+ pump	Carrier uses energy to move a substance across a membrane against its concentration gradient	Na^+ and K^+ against their concentration gradients
Coupled transport	Molecules are transported across a membrane against their concentration gradients by the cotransport of sodium ions or protons down their concentration gradients	Coupled uptake of glucose into cells against its concentration gradient using a Na^+ gradient
Endocytosis		
Membrane vesicle		
Phagocytosis	Particle is engulfed by membrane, which folds around it and forms a vesicle	Ingestion of bacteria by white blood cells
Pinocytosis	Fluid droplets are engulfed by membrane, which forms vesicles around them	"Tearing" of human egg cells
Receptor-mediated endocytosis	Endocytosis triggered by a specific receptor, forming clathrin-coated vesicles	Cholesterol uptake
Exocytosis		
Membrane vesicle	Vesicles fuse with plasma membrane and eject contents	Secretion of mucus; release of neurotransmitters

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