LECTURE PRESENTATIONS
For CAMPBELL BIOLOGY, NINTH EDITION
Jane B. Reece, Lisa A. Urry, Michael L. Cain, Steven A. Wasserman, Peter V. Minorsky, Robert B. Jackson

Chapter 7

Membrane Structure and Function

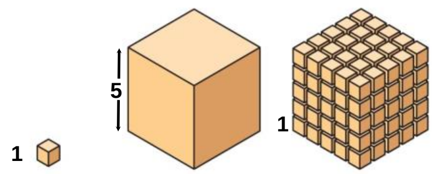
Lectures by
Erin Barley
Kathleen Fitzpatrick

Overview: Life at the Edge

- The plasma membrane is the boundary that separates the living cell from its surroundings
- The plasma membrane exhibits **selective permeability**, allowing some substances to cross it more easily than others

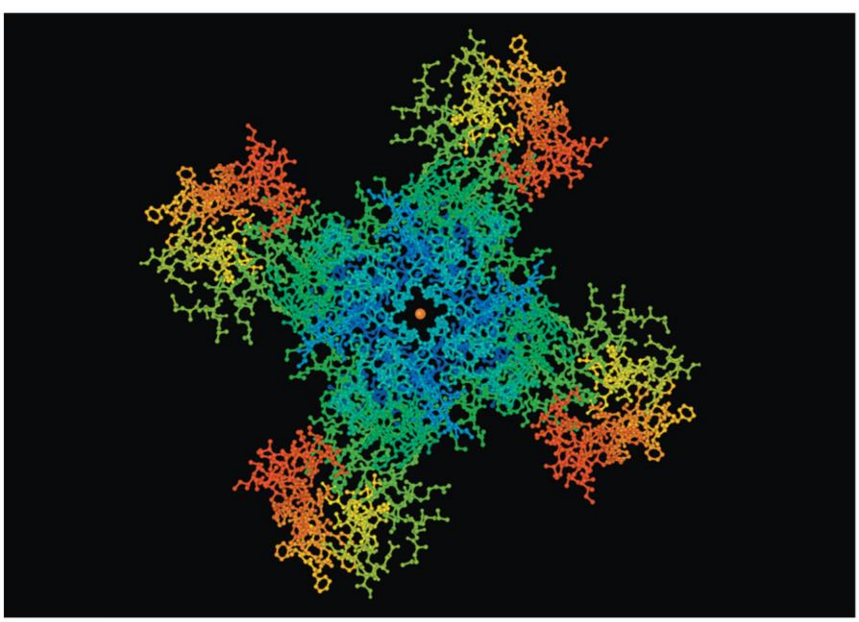
Fig. 6-8

Surface area increases while total volume remains constant



Total surface area [Sum of the surface areas (height × width) of all boxes sides × number of boxes]	6	150	750
Total volume [height × width × length × number of boxes]	1	125	125
Surface-to-volume (S-to-V) ratio [surface area ÷ volume]	6	1.2	6

Figure 7.1



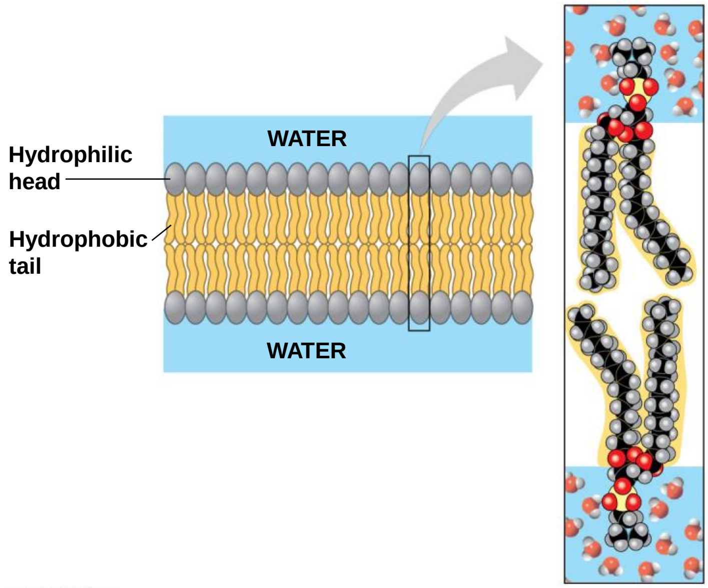
Concept 7.1: Cellular membranes are fluid mosaics of lipids and proteins

- Phospholipids are the most abundant lipid in the plasma membrane
- Phospholipids are **amphipathic molecules**, containing hydrophobic and hydrophilic regions
- The **fluid mosaic model** *states that a membrane is a fluid structure with a "mosaic" of various proteins embedded in it*

Membrane Models: *Scientific Inquiry*

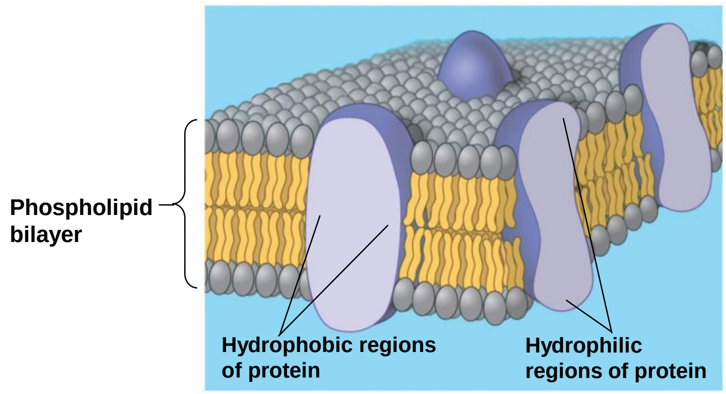
- Membranes have been chemically analyzed and found to be made of proteins and lipids
- Scientists studying the plasma membrane reasoned that it must be a phospholipid bilayer

Figure 7.2



- In 1935, Hugh Davson and James Danielli proposed a **sandwich model** in which the phospholipid bilayer lies between two layers of globular proteins
- Later studies found problems with this model, particularly the placement of membrane proteins, which have hydrophilic and hydrophobic regions
- In 1972, J. **Singer and G. Nicolson** proposed the **fluid mosaic model** which states that the membrane is a *mosaic of proteins dispersed within the bilayer, with only the hydrophilic regions exposed to water*

Figure 7.3



- Freeze-fracture studies of the plasma membrane supported the fluid mosaic model
- Freeze-fracture is a specialized preparation technique that splits a membrane along the middle of the phospholipid bilayer

Figure 7.4

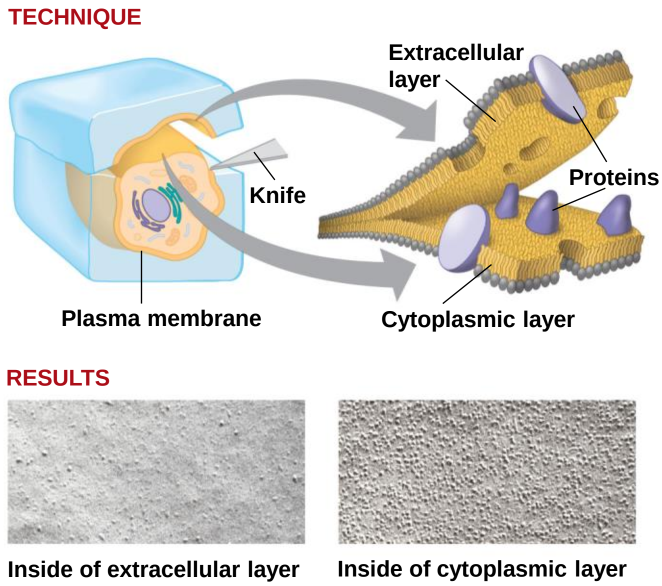


Figure 7.4a

Inside of extracellular layer

Figure 7.4b

Inside of cytoplasmic layer

The Fluidity of Membranes

- *Phospholipids* in the plasma membrane *can move within the bilayer*
- Most of the lipids, and some proteins, drift laterally
- Rarely does a molecule flip-flop transversely across the membrane

Figure 7.5

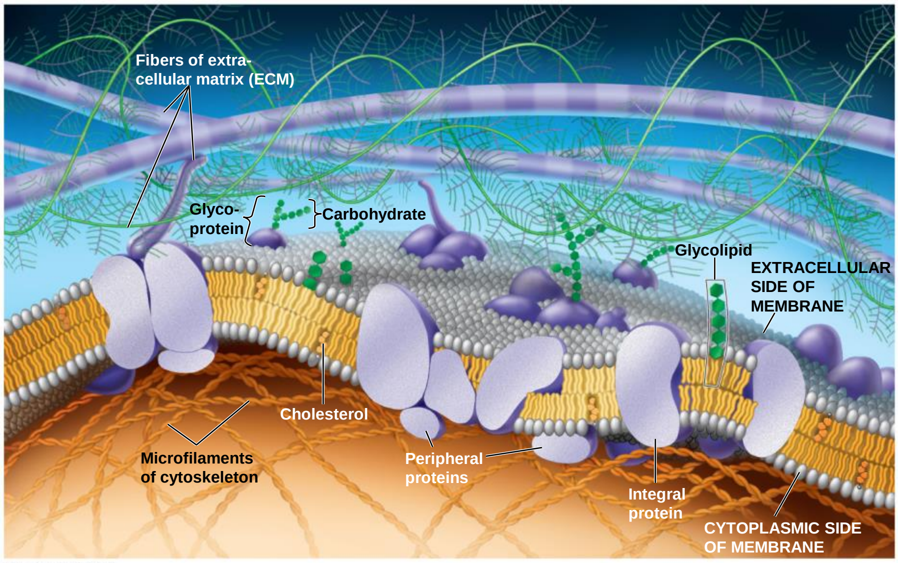


Figure 7.6

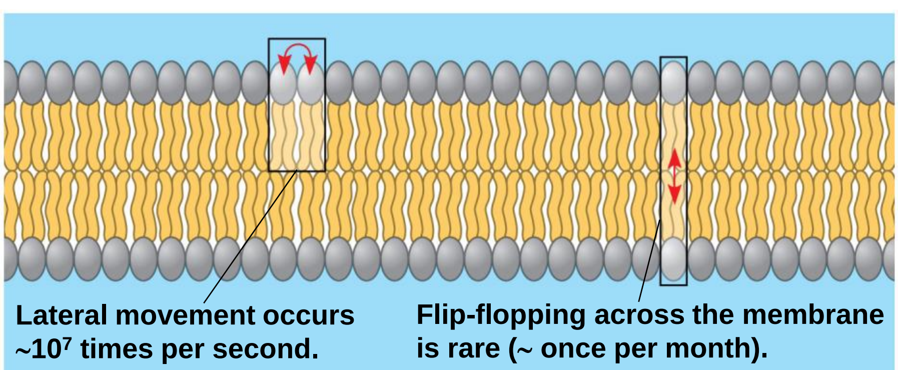
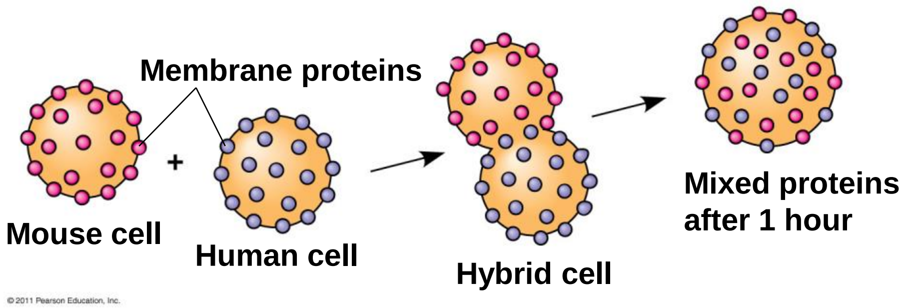


Figure 7.7

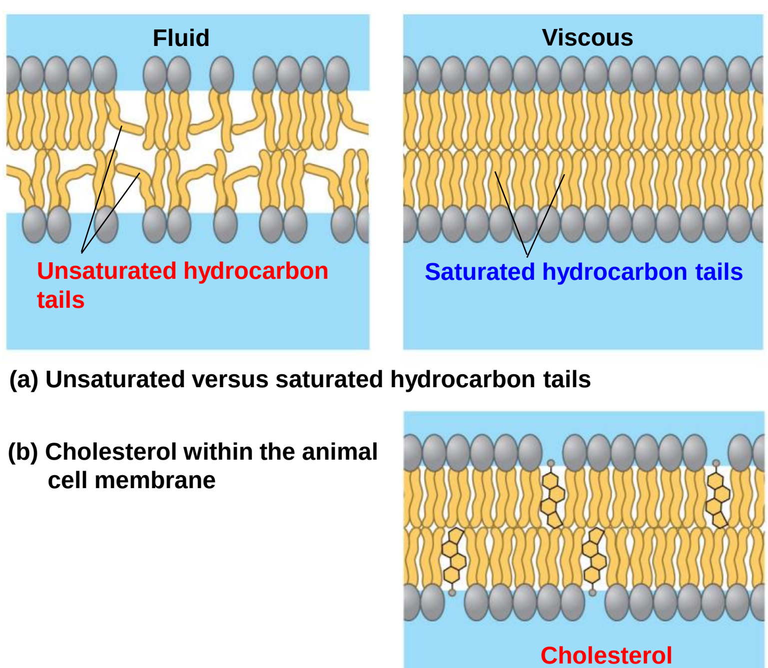
RESULTS



- As temperatures cool, *membranes switch from a fluid state to a solid state*
- The temperature at which a membrane solidifies depends on the types of lipids
- Membranes rich in unsaturated fatty acids are more fluid than those rich in saturated fatty acids
- Membranes must be fluid to work properly; they are usually about as fluid as salad oil

- The steroid cholesterol has different effects on membrane fluidity at different temperatures
- At warm temperatures (such as 37° C), cholesterol restrains movement of phospholipids
- At cool temperatures, it maintains fluidity by preventing tight packing

Figure 7.8

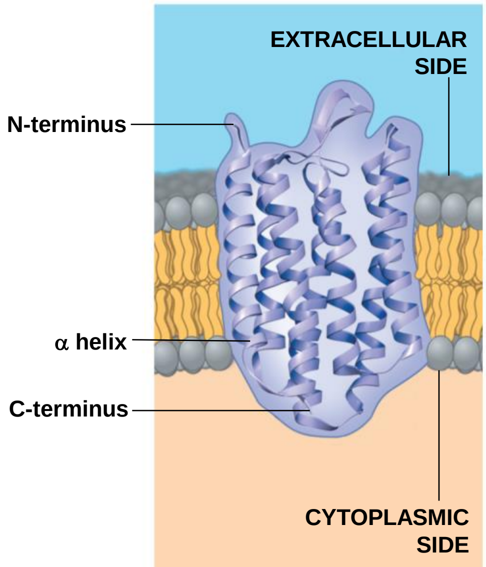


Membrane Proteins and Their Functions

- A membrane is a collage of different proteins embedded in the fluid matrix of the lipid bilayer
- Proteins determine most of the membrane's specific functions

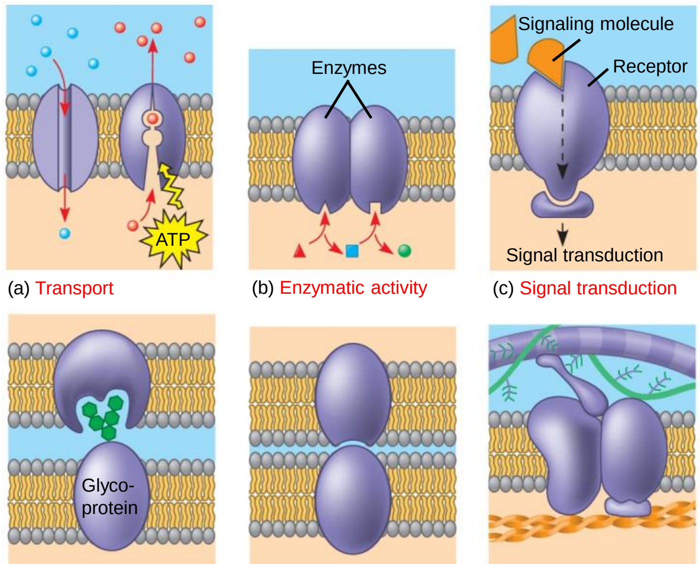
- **Peripheral proteins** are bound to the surface of the membrane
- **Integral proteins** penetrate the hydrophobic core
- Integral proteins that span the membrane are called transmembrane proteins
- The hydrophobic regions of an integral protein consist of one or more stretches of nonpolar amino acids, *often coiled into alpha helices*

Figure 7.9



- **Six major functions** of membrane proteins:
  - **Transport**
  - **Enzymatic activity**
  - **Signal transduction**
  - **Cell-cell recognition**
  - **Intercellular joining**
  - **Attachment to the cytoskeleton and extracellular matrix (ECM)**

Fig. 7-9



(a) Transport (b) Enzymatic activity (c) Signal transduction
(d) Cell-cell recognition (e) Intercellular joining (f) Attachment to the cytoskeleton and extracellular matrix (ECM)

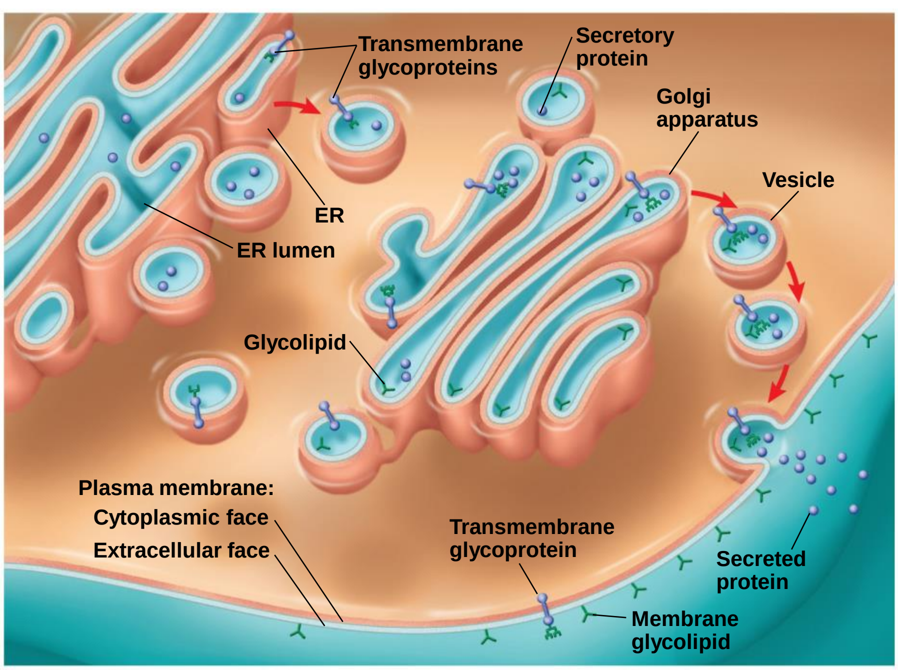
The Role of Membrane Carbohydrates in Cell-Cell Recognition

- Cells recognize each other by binding to surface molecules, often carbohydrates, on the plasma membrane
- Membrane carbohydrates may be covalently bonded to lipids (forming **glycolipids**) or more commonly to proteins (forming **glycoproteins**)

Synthesis and Sidedness of Membranes

- Membranes have distinct inside and outside faces
- The asymmetrical distribution of proteins, lipids, and associated carbohydrates in the plasma membrane is determined when the membrane is built by the ER and Golgi apparatus

Figure 7.12



Concept 7.2: Membrane structure results in selective permeability

- A cell must exchange materials with its surroundings, a process controlled by the plasma membrane
- Plasma membranes are selectively permeable, regulating the cell's molecular traffic

The Permeability of the Lipid Bilayer

- Hydrophobic (nonpolar) molecules, such as hydrocarbons, can dissolve in the lipid bilayer and pass through the membrane rapidly
- Polar molecules, such as sugars, do not cross the membrane easily

Transport Proteins

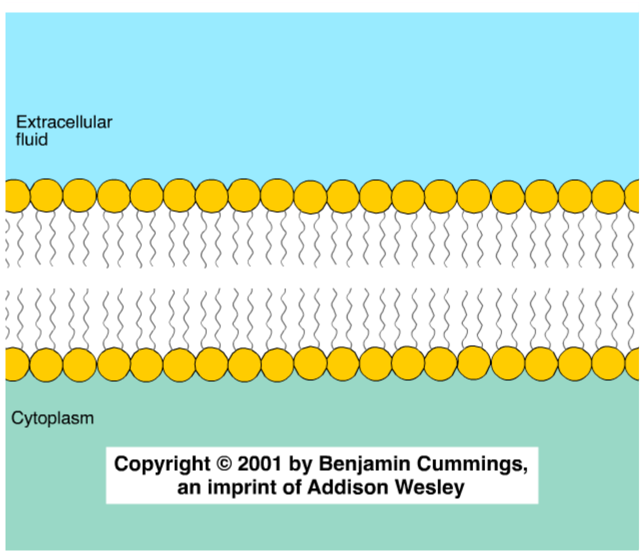
- **Transport proteins** allow passage of hydrophilic substances across the membrane
- Some transport proteins, called 1) **channel proteins**, have a hydrophilic channel that certain molecules or ions can use as a tunnel
- Channel proteins called **aquaporins** facilitate the passage of water

- Other transport proteins, called **2) carrier proteins**, *bind to molecules and change shape to shuttle them across the membrane*
- A transport protein is **specific** for the substance it moves

Copyright © 2008 Pearson Education, Inc., publishing as Pearson Benjamin Cummings

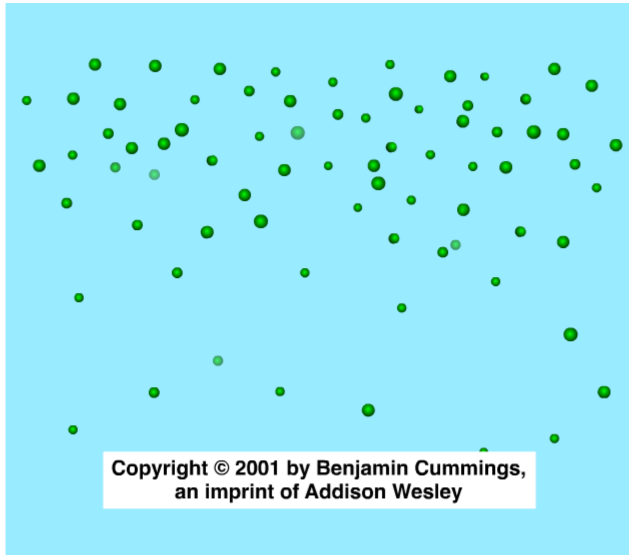
Concept 7.3: Passive transport is diffusion of a substance across a membrane with no energy investment

- **Diffusion** is the tendency for molecules to spread out evenly into the available space
- Although each molecule moves randomly, diffusion of a population of molecules may exhibit a net movement in one direction
- At dynamic equilibrium, as many molecules cross one way as cross in the other direction



Animation: Membrane Selectivity

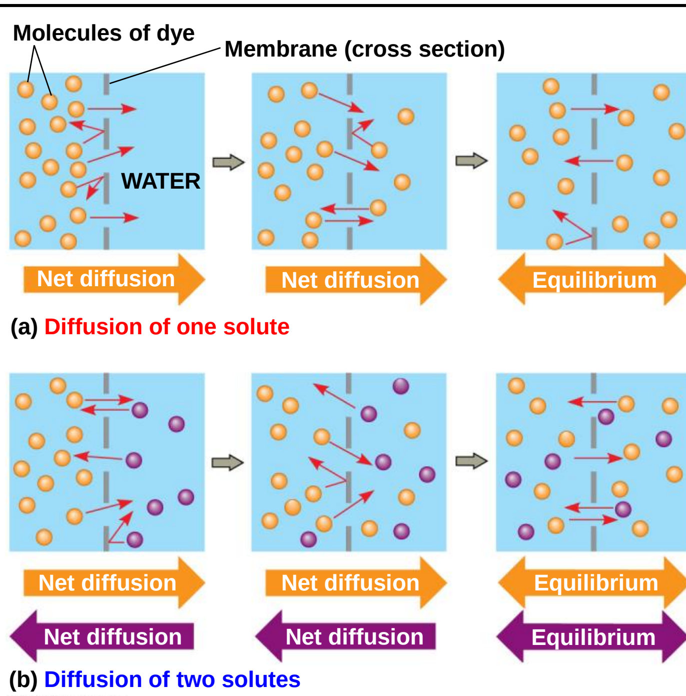
Right-click slide / select "Play"



Animation: Diffusion

Right-click slide / select "Play"

Figure 7.13

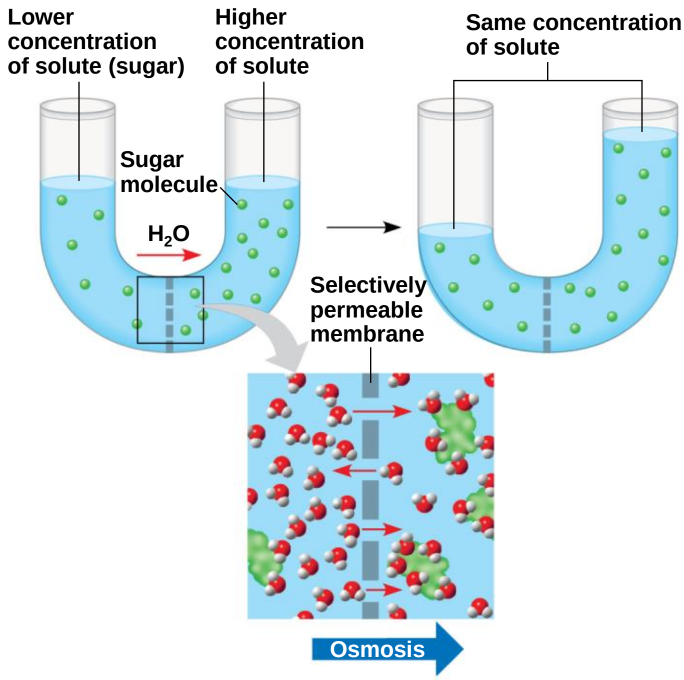


- Substances diffuse **down their concentration gradient**, the difference in concentration of a substance from one area to another
- No work must be done to move substances down the concentration gradient
- The diffusion of a substance across a biological membrane is **passive transport** because it requires no energy from the cell to make it happen

Effects of Osmosis on Water Balance

- **Osmosis** is the diffusion of water across a selectively permeable membrane
- Water diffuses across a membrane from the region of lower solute concentration to the region of higher solute concentration

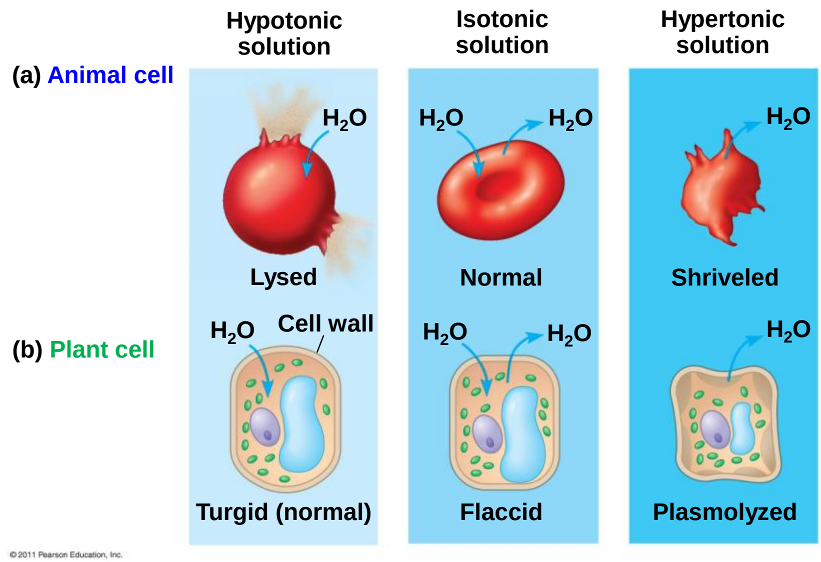
Figure 7.14



Water Balance of Cells Without Walls

- **Tonicity** *is the ability of a solution to cause a cell to gain or lose water*
- **Isotonic** solution: Solute concentration is the same as that inside the cell; no net water movement across the plasma membrane
- **Hypertonic** solution: Solute concentration is greater than that inside the cell; cell loses water
- **Hypotonic** solution: Solute concentration is less than that inside the cell; cell gains water

Figure 7.15

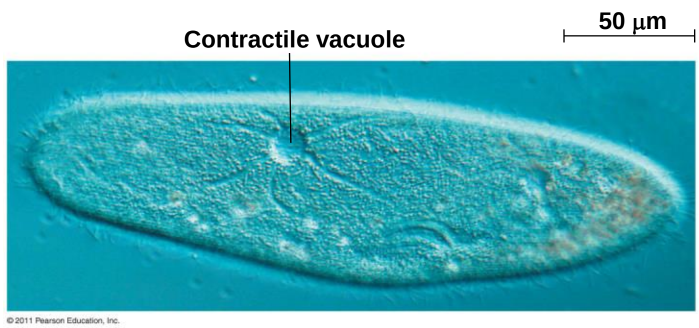


- **Hypertonic** or **hypotonic** environments create osmotic problems for organisms
- **Osmoregulation**, the control of water balance, is a necessary adaptation for life in such environments
- The protist *Paramecium,* which is hypertonic to its pond water environment, has a contractile vacuole that acts as a pump

PLAY Video: *Chlamydomonas*

PLAY Video: *Paramecium* Vacuole

Figure 7.16



Water Balance of Cells with Walls

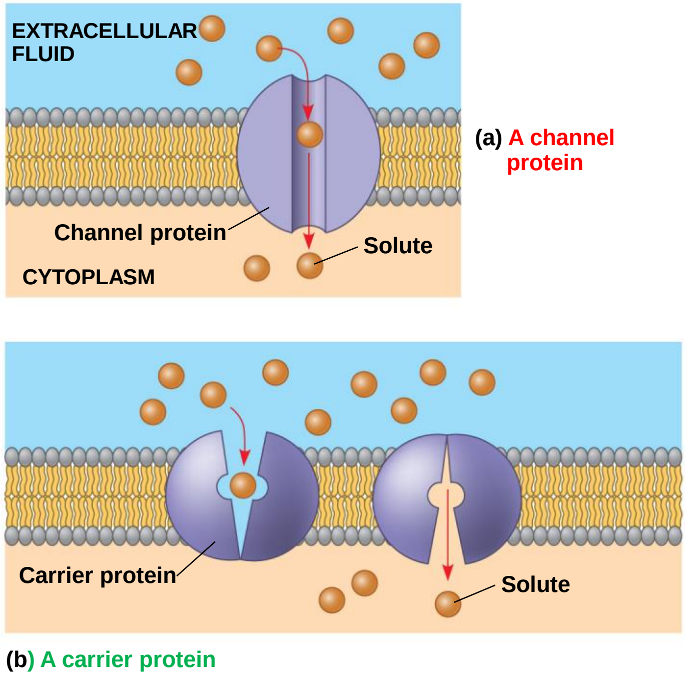
- Cell walls help maintain water balance
- A plant cell in a hypotonic solution swells until the wall opposes uptake; the cell is now **turgid** (firm)
- If a plant cell and its surroundings are isotonic, there is no net movement of water into the cell; the cell becomes **flaccid** (limp), and the plant may wilt

- In a hypertonic environment, plant cells lose water; eventually, the membrane pulls away from the wall, a usually lethal effect called **plasmolysis**

Facilitated Diffusion: Passive Transport Aided by Proteins

- In **facilitated diffusion**, transport proteins speed the passive movement of molecules across the plasma membrane
- Channel proteins provide corridors that allow a specific molecule or ion to cross the membrane
- Channel proteins include
  - **Aquaporins**, for facilitated diffusion of water
  - **Ion channels** that open or close in response to a stimulus (**gated channels**)

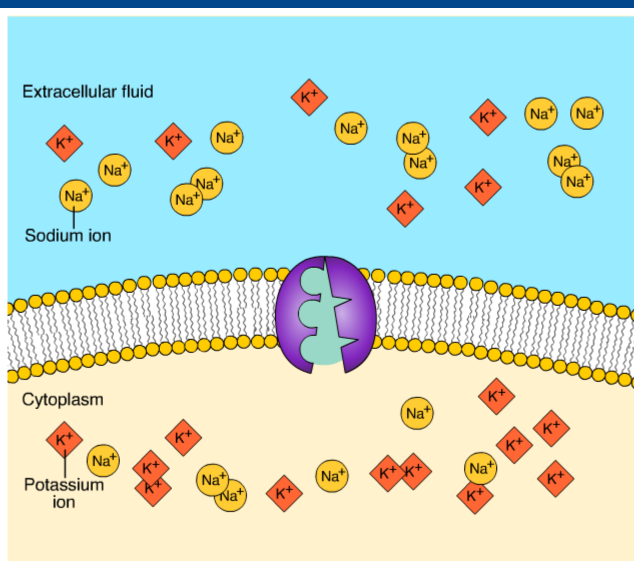
Figure 7.17



- **Carrier proteins** undergo a subtle change in shape that translocates the solute-binding site across the membrane

Concept 7.4: Active transport uses energy to move solutes against their gradients

- Facilitated diffusion is still passive because the solute moves down its concentration gradient
- Some transport proteins, however, can move solutes against their concentration gradients
- Active transport requires energy, usually in the form of ATP
- Active transport is performed by **specific proteins** embedded **in the membranes**



Animation: Active Transport

Right-click slide / select "Play"

- Active transport allows cells to maintain concentration gradients that differ from their surroundings
- The **sodium-potassium pump** is one type of active transport system

Figure 7.18-1

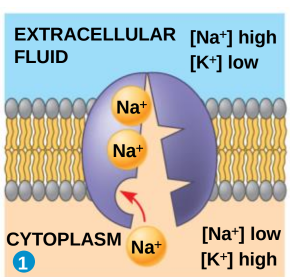


Figure 7.18-2

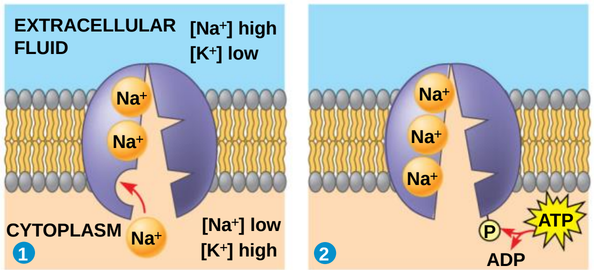


Figure 7.18-3

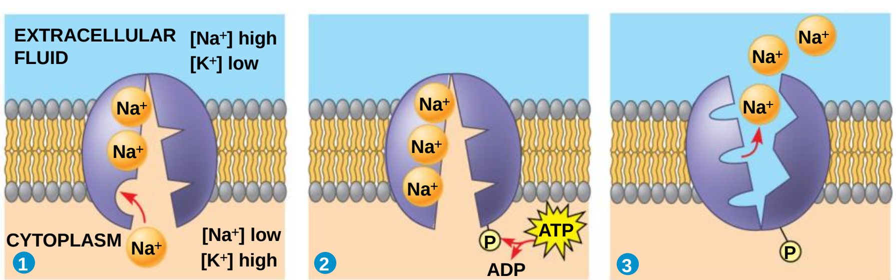


Figure 7.18-4

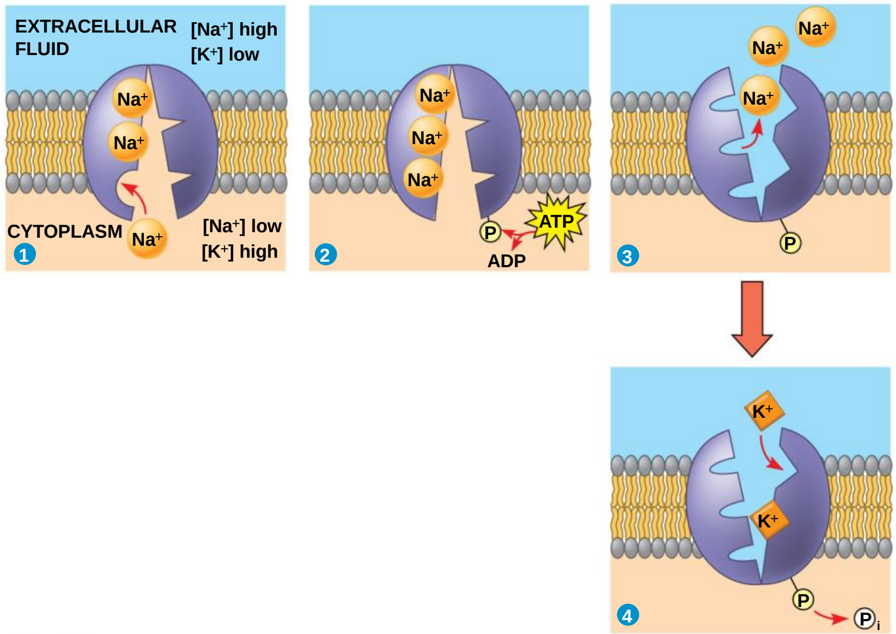


Figure 7.18-5

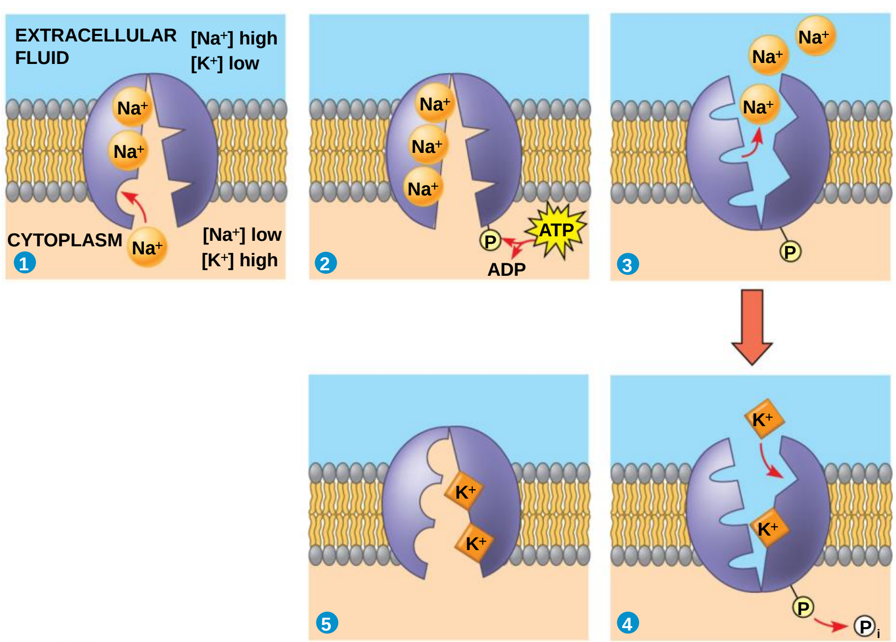


Figure 7.18-6

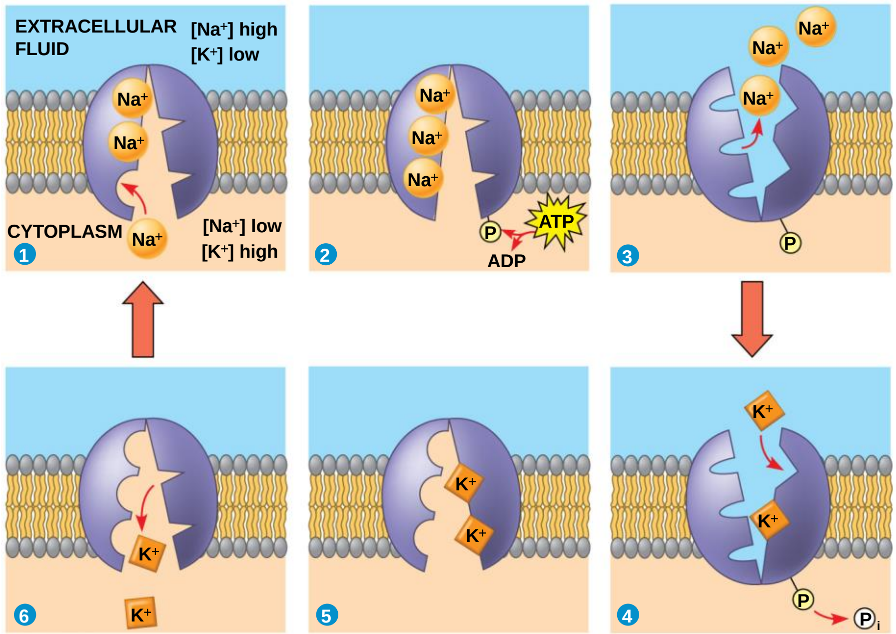
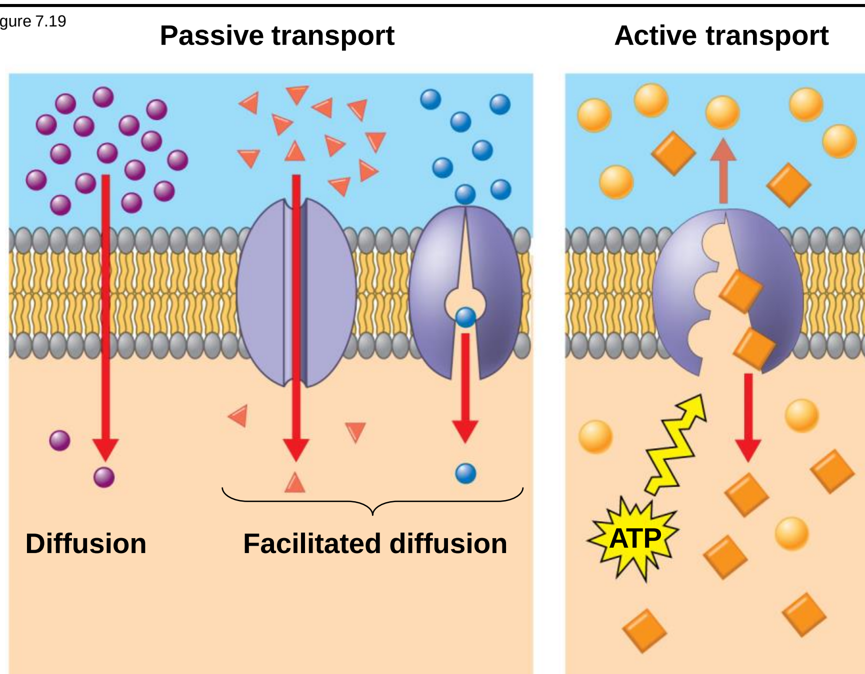


Figure 7.19



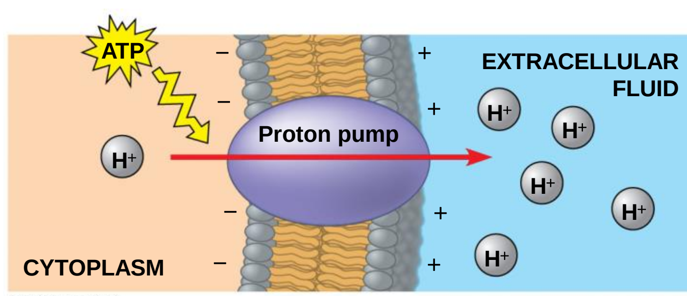
How Ion Pumps Maintain Membrane Potential

- **Membrane potential** is the voltage difference across a membrane
- Voltage is created by differences in the distribution of **positive and negative ions** across a membrane.

- Two combined forces, collectively called the **electrochemical gradient**, drive the diffusion of ions across a membrane:
  - A chemical force (the ion's concentration gradient)
  - An electrical force (the effect of the membrane potential on the ion's movement)

- An **electrogenic pump** is a transport protein that generates voltage across a membrane
- The **sodium-potassium pump** is the major electrogenic pump of animal cells
- The main electrogenic pump of plants, fungi, and bacteria is a **proton pump**

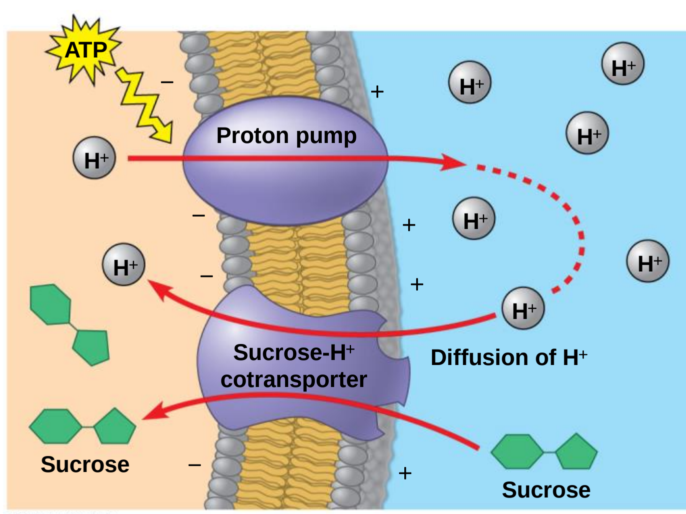
Figure 7.20



Cotransport: Coupled Transport by a Membrane Protein

- **Cotransport** *occurs when active transport of a solute indirectly drives transport of another solute*
- Plants commonly use the gradient of hydrogen ions generated by proton pumps to drive active transport of nutrients into the cell

Figure 7.21



Concept 7.5: Bulk transport across the plasma membrane occurs by exocytosis and endocytosis

- Small molecules and water enter or leave the cell through the lipid bilayer or by transport proteins
- Large molecules, such as polysaccharides and proteins, cross the membrane in bulk via vesicles
- Bulk transport requires energy

Exocytosis

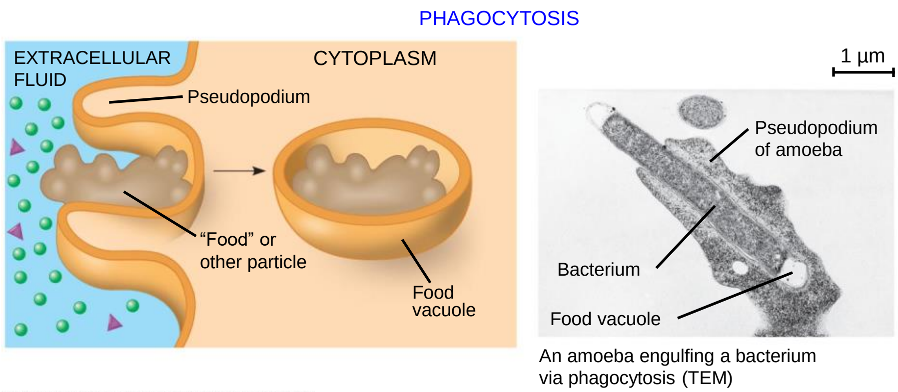
- In **exocytosis**, transport vesicles migrate to the membrane, fuse with it, and release their contents
- Many secretory cells use exocytosis to export their products

Endocytosis

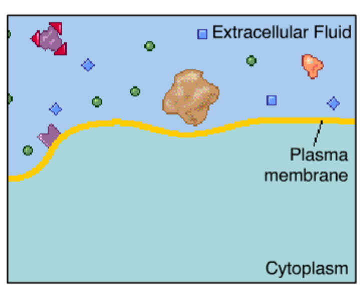
- In **endocytosis**, the cell takes in macromolecules by forming vesicles from the plasma membrane
- Endocytosis is a reversal of exocytosis, involving different proteins
- There are **three types of endocytosis**:
  - Phagocytosis ("cellular eating")
  - Pinocytosis ("cellular drinking")
  - Receptor-mediated endocytosis

- In **phagocytosis** a cell engulfs a particle in a vacuole
- The vacuole fuses with a lysosome to digest the particle

Fig. 7-20a



An amoeba engulfing a bacterium via phagocytosis (TEM)



Animation: Phagocytosis

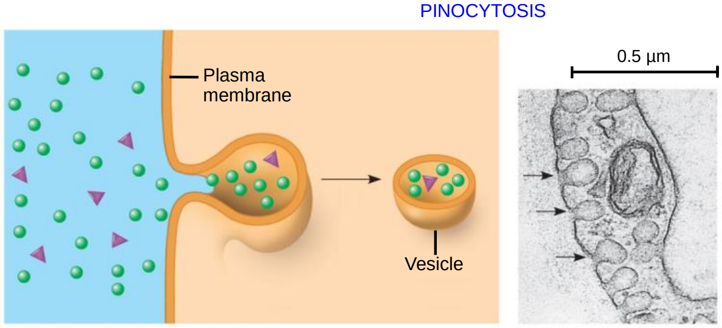
Right-click slide / select "Play"

- In **pinocytosis**, molecules are taken up when extracellular fluid is “gulped” into tiny vesicles

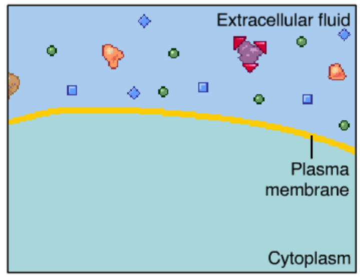
PLAY Animation: Pinocytosis

Fig. 7-20b

PINOCYTOSIS



Pinocytosis vesicles forming (arrows) in a cell lining a small blood vessel (TEM)

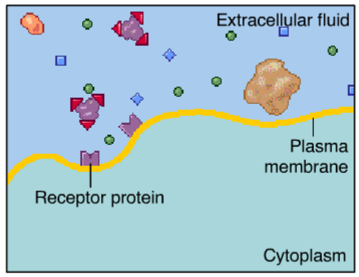


Animation: Pinocytosis

Right-click slide / select "Play"

- In **receptor-mediated endocytosis**, binding of ligands to receptors triggers vesicle formation
- A **ligand** is any molecule that binds specifically to a receptor site of another molecule

PLAY Animation: Receptor-Mediated Endocytosis

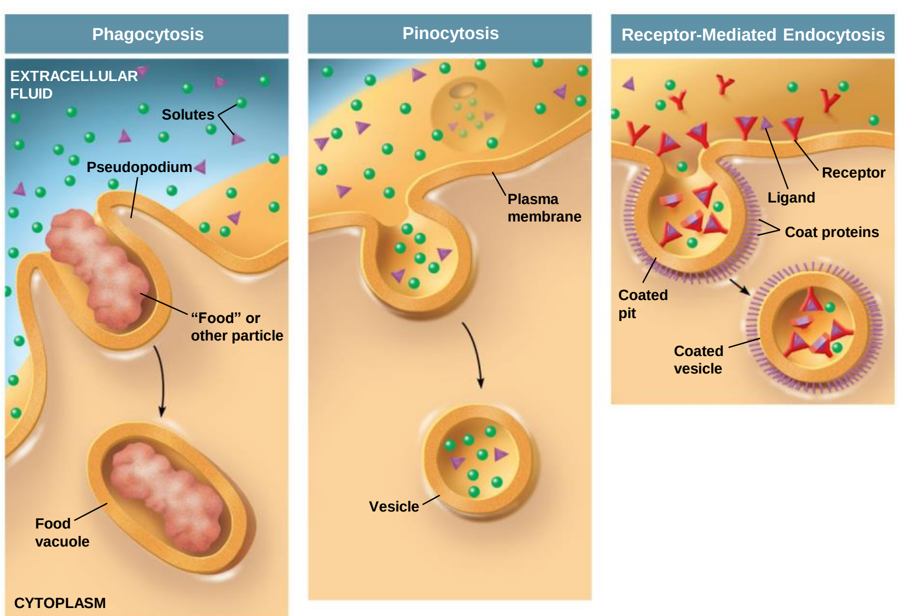


Copyright © 2001 by Benjamin Cummings, an imprint of Addison Wesley

Animation: Receptor-Mediated Endocytosis

Right-click slide / select "Play"

Figure 7.22



Familial hypercholersterolemia (FH)

- Cholesterol is transported in blood in particles called LDL
- LDL binds to receptors on plasma membranes & enter cells by receptor-mediated endocytosis
- In FH, LDL receptors are defective or missing >> cholesterol accumulates in blood vessels and lead to athersclerosis