Lecture 3a.

Membranes and Transport

The Cell Membrane

Overview: Membranes

- Structure of cell membranes
- Functions of cell membranes
- How things get in and out of cells

What is a membrane?

- Basically, a covering

Structure of the cell membrane

- Separates intracellular fluids from extracellular fluids
- Contains lipids, proteins and carbohydrates
  - Lipids
    - Phospholipids
    - Cholesterol
  - Proteins
    - Integral
    - Peripheral
  - Carbohydrates
    - Form the glycocalyx

Fluid Mosaic Model

- Double bilayer of lipids with imbedded, dispersed proteins
- Bilayer consists of phospholipids, cholesterol, and glycolipids
  - Glycolipids are lipids with bound carbohydrate
  - Phospholipids have hydrophobic and hydrophilic bipoles

Fluid Mosaic Model

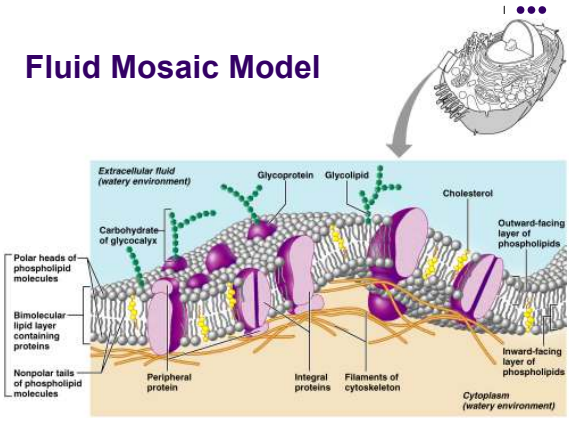


Figure 3.3

Membrane Junctions – link cells together

- **Tight junction** – impermeable junction that encircles the cell
- **Desmosome** – anchoring junction scattered along the sides of cells
- **Gap junction** – a nexus that allows chemical substances to pass between cells

Membrane Junctions: Tight Junction

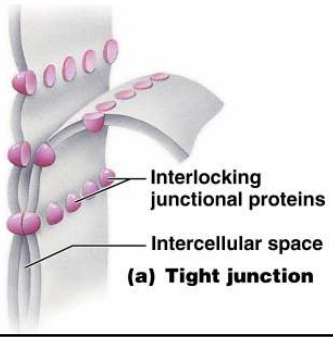


Figure 3.5a

Membrane Junctions: Desmosome

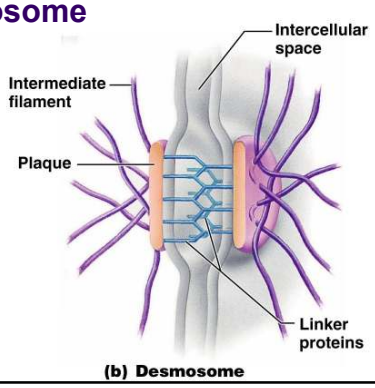


Figure 3.5b

Membrane Junctions: Gap Junction

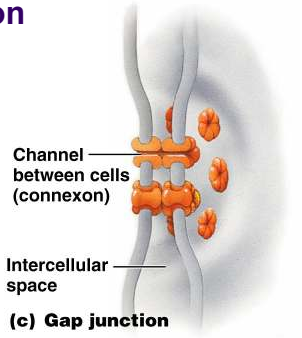
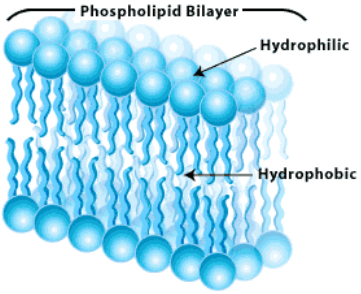


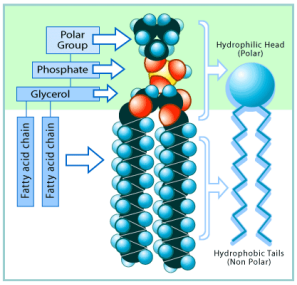
Figure 3.5c

Phopholipid bilayer



Cell Membrane Structure

- **Phospholipids**:
  - Hydrophilic head (likes water)
  - Hydrophobic tails (cannot be in contact with water)

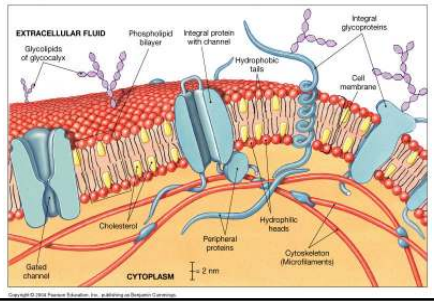


Cell Membrane Structure

- Ions and water soluble compounds **cannot** cross the membrane without help. Why not?
- This separates the extracellular fluid from the cytosol which is important for homeostasis
- Nonpolar molecules, fat soluble organic molecules (e.g. steroids), and water **can** cross

What else is in membranes?

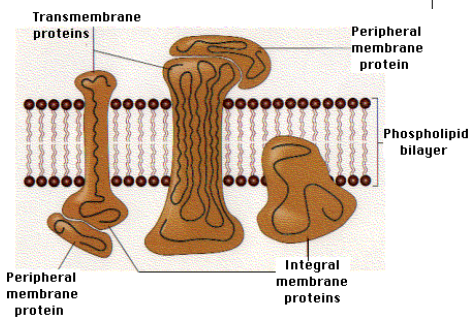
1. Cholesterol

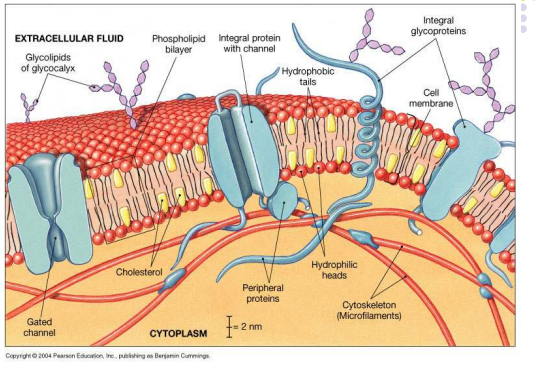


What else is in membranes?

2. Proteins
   - Integral proteins (many are transmembrane)
   - Peripheral proteins

Membrane Proteins





Membrane protein functions

1. Anchoring - attach to cytoskeleton
2. Enzymes - catalyze reactions
3. Recognition (identifiers) usu. glycoproteins (e.g. MHC, ABO)
4. Receptors - signaling (ligand)
5. Transport
   Carriers - transport things in/out
   Channels – pore allowing ions in/out

What else is in membranes?

3. Membrane carbohydrates

Glycocalyx:

- Glycoproteins
- Glycolipids

- Used for cell-cell recognition
- Often, doctors can tell if certain cells are normal or abnormal by their glycoproteins and glycolipids

Why have a cell membrane anyway?

Cell Membrane AKA "plasma membrane"

- General functions
  1. Physical isolation
     - Important to maintain a different environment **inside** the cell relative to **outside**. --May not sound that interesting, but this is key to life: need to separate ion concentrations to create potential energy, preserve homeostasis. Note: this is also important for internal organelles (e.g lysosome, mitochondrion). **Cf. bacteri**
  2. Regulation of exchange in the environment
     - Controlling this exchange is critical
  3. Sensitivity
  4. Structural support

Overcoming the Cell Barrier

- The cell membrane is a barrier, but:
- Things must get in and out (like what?)
  - Nutrients, oxygen must get in
  - products and wastes must get out

Cell membranes are selectively permeable.

- What does this mean?

→ Only certain things can cross

- How are compounds transported across the cell membrane?
  - Passive transport (no ATP needed)
  - Active transport (ATP required)

Types of Transport

- Diffusion (passive)
- Carrier-mediated transport (passive or active)
- Vesicular transport (active)

Terms

- Before we get into detail about the types of transport, we need to discuss some key terms…
  - Solutions
    - Molecules (solutes) dissolved in a liquid (solvent)
    - All molecules are constantly in random motion, which causes mixing
  - Brownian motion
    - Random tendency of ALL molecules to move due to their inherent *kinetic energy*: energy of motion
  - Concentration
    - The amount of solute in a solvent

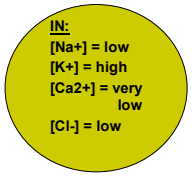
Concentration Gradient

- More solute in one region of a solvent than in another

  Examples?

Concentration gradients

- Concentrations of some key ions are very different on the inside versus the outside of cells creating a gradient



OUT:
[Na+] = high
[K+] = low
[Ca2+] = low
[Cl-] = high

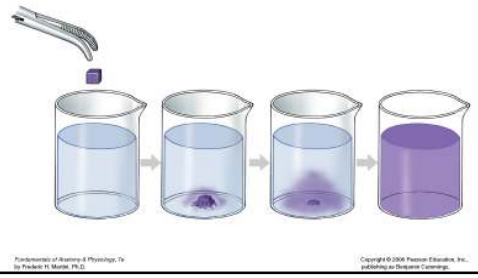
(blood, interstitial fluid)

Types of Transport

Passive transport: Diffusion

- Due to: random motion and collision of molecules (NOT a pulling or pushing force)
- Movement "down" a concentration gradient (from area of high concentration to area of low concentration)
- **Simple diffusion** – nonpolar and lipid-soluble substances
  - Diffuse directly through the lipid bilayer
- **Facilitated diffusion** – larger, polar molecules
  - Transported substances bind carrier proteins or pass through protein channels (e.g. glucose, amino acids, and ions)

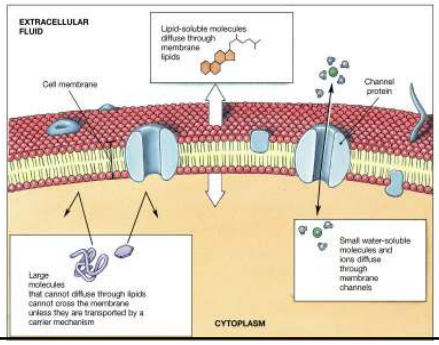
Diffusion – solid in water



What factors Affect Diffusion Rates?

- Distance
- Molecule size
- Temperature
- Gradient
- Electrical force

What can/can't diffuse through the cell membrane?



Simple Diffusion

- Materials which diffuse **directly** through cell membrane:
  - lipid-soluble compounds (alcohols, fatty acids, and steroids)
  - dissolved gases (oxygen and carbon dioxide)

Channel-Mediated Facilitated Diffusion

- Materials which pass through transmembrane proteins (channels):
  - water soluble compounds
  - ions

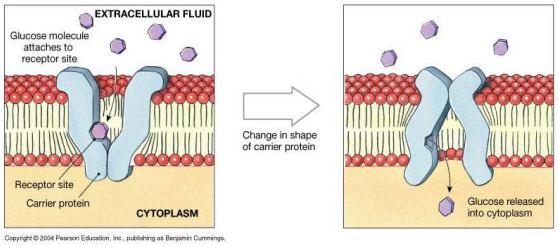
Note: even though a channel is required, this is still a passive process. Diffusion, by definition, is **always** passive.

Carrier-Mediated Facilitated Diffusion

- Carrier-mediated transport of ions and organic substrates into or out of the cell down their concentration gradient. Still passive
- Can also be called *passive carrier-mediated* transport

Note: if energy is required to move something in or out of the cell using a carrier protein, it is called **active transport** (ATP required)

Facilitated Diffusion is passive transport with a carrier



Animation

How Facilitated Diffusion Works

- **Carrier proteins** transport molecules too large to fit through channel proteins (glucose, amino acids):
  - molecule binds to **receptor site** on carrier protein
  - protein changes shape, molecules pass through
  - receptor site is specific to certain molecules

Diffusion Through the Plasma Membrane

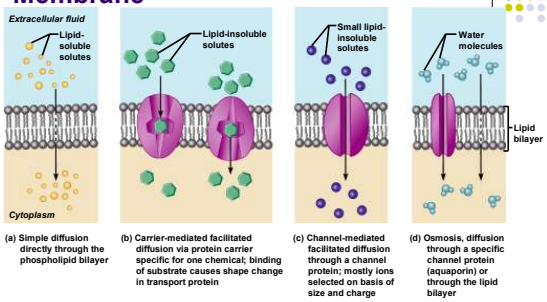


Figure 3.7

Osmosis is the net diffusion of water across a membrane.

- How can water move across a cell membrane?
  - aquaporins
  - directly?

→Osmosis occurs when solutes cannot cross the membrane (no diffusion) so the solvent, water, crosses instead

Osmosis = Water Movement

- Water molecules diffuse across membrane toward solution with more solutes
- Volume increases on the side with more solutes

Effect of Membrane Permeability on Diffusion and Osmosis

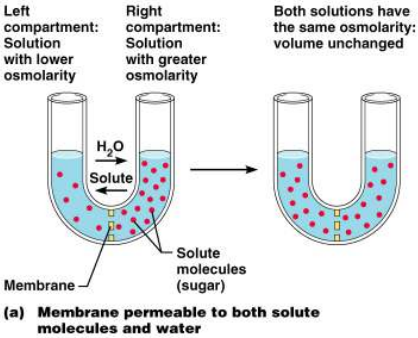
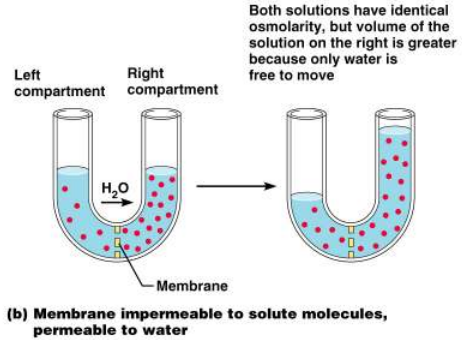


Figure 3.8a

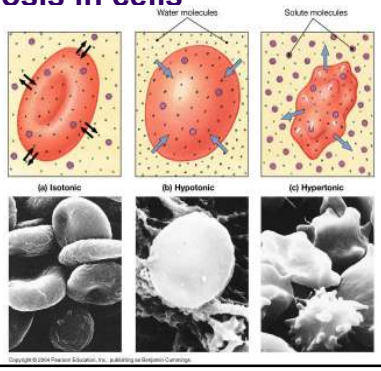
Effect of Membrane Permeability on Diffusion and Osmosis



(b) Membrane impermeable to solute molecules, permeable to water

Figure 3.8b

Osmosis in cells



Osmosis

- Isotonic → cell ok
- Hypotonic → Swelling or **hemolysis** (burst). Like in the bathtub
- Hypertonic → **crenation** (shrinkage)

How Osmosis Works

- More solute molecules, lower concentration of water molecules
- Key to osmosis: membrane must be **freely permeable** to water, **selectively permeable** to solutes.

  (i.e. some solutes must be impermeable. Otherwise, diffusion would occur)

KEY CONCEPT

- Concentration gradients tend to even out due to random motion of particles
- In the absence of a membrane, diffusion eliminates concentration gradients
- When different solute concentrations exist on either side of a selectively permeable membrane, either:

1. diffusion of permeable molecules equalizes concentrations OR
2. osmosis moves water through the membrane to equalize the concentration gradients

Active Transport

- Active transport proteins:
  - move substrates *against* concentration gradient
  - Uses carrier proteins (just like carrier-mediated facilitated diffusion)
  - requires energy, such as ATP
  - Examples
    - ion pumps move ions (Na^+, K^+, Ca^+, Mg^{2+})
    - exchange pump countertransports 2 ions at the same time

Active Transport

- **Primary** active transport requires ATP at the same time that substrate is moved
- **Secondary** active transport requires energy later
  - use of an exchange pump (such as the Na^+-K^+ pump) indirectly to drive the transport of other solutes

Primary Active Transport: Sodium-Potassium Exchange Pump

- Primary Active transport (carrier mediated):
  - sodium ions (Na+) out, potassium ions (K+) in
  - 1 ATP moves 3 Na+ out, 2 potassium ions (K+) in
- Maintains concentrations of Na+ and K+
- Also an example of countertransport

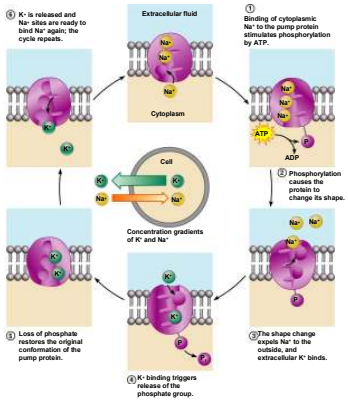


Figure 3.10

Secondary Active Transport Example: Na+/glucose symporter

- Na^+ concentration gradient drives glucose transport
- ATP energy pumps Na^+ back out

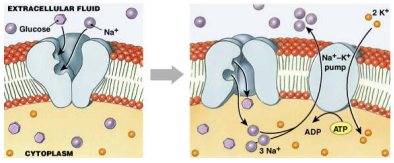


Figure 3-20

Types of Active Transport

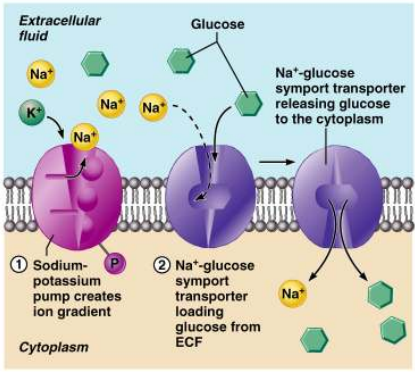


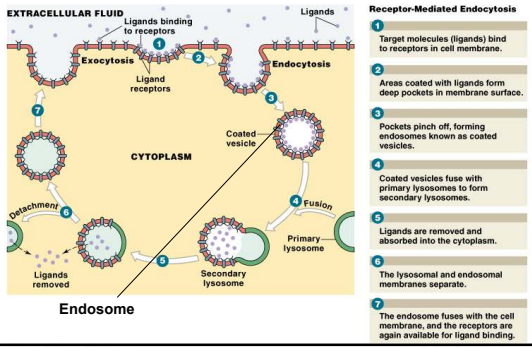
Figure 3.11

Vesicular Transport

- Materials move into or out of the cell by means of vesicles, also called **bulk transport**
  - Endocytosis (Clathrin-mediated)
    - Receptor mediated endocytosis
    - Pinocytosis
    - Phagocytosis
  - Exocytosis

  ALL are active processes (require ATP) though they are not usually referred to as “active transport”

Receptor-Mediated Endocytosis



Pinocytosis

- Pinocytosis (*cell drinking*)
- Endosomes "drink" extracellular fluid

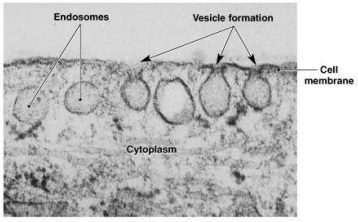
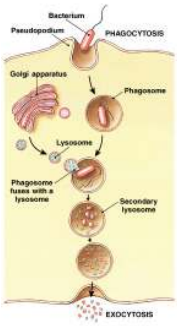


Figure 3-22a

Phagocytosis

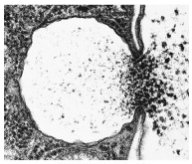


- Phagocytosis (*cell eating*)
  - pseudopodia (*psuedo* = false, *podia* = feet)
  - engulf large objects in phagosomes

Figure 3-22b

Exocytosis

- Is the reverse of endocytosis



(b) Exocytosis

Figure 3-7b

Summary

- The 7 methods of transport

SUMMARY TABLE 3-1 | MECHANISMS INVOLVED IN MOVEMENT ACROSS CELL MEMBRANES

Mechanism	Process	Factors Affecting Rate	Substances Involved (Sites)
Diffusion (includes simple diffusion and channel-mediated diffusion)	Molecular movement of solutes, direction determined by relative concentrations	Size of gradient; size of molecules; charge; lipid solubility; temperature; additional factors apply to channel-mediated diffusion	Small inorganic ions; lipid-soluble materials (all cells)
Osmosis	Movement of water molecules toward solution containing relatively higher solute concentration; requires selectively permeable membrane	Concentration gradient; opposing osmotic or hydrostatic pressure; number of aquaporins (water channels)	Water only (all cells)
Carrier-Mediated transport			
Facilitated diffusion	Carrier proteins passively transport solutes across a membrane down a concentration gradient	Size of gradient; temperature; and availability of carrier protein	Glucose and amino acids (all cells, but several different regulatory mechanisms exist)
Active transport	Carrier proteins actively transport solutes across a membrane, often against a concentration gradient	Availability of carrier, substrates, and ATP	Na^+, K^+, Ca^{2+}, Mg^{2+} (all cells); other solutes by specialized cells
Secondary active transport	Carrier proteins passively transport two solutes, with one (normally Na^+) moving down its concentration gradient; the cell must later expend ATP to eject the Na^+	Availability of carrier, substrates, and ATP	Glucose and amino acids (specialized cells)
Vesicular Transport			
Endocytosis	Creation of membranous vesicles containing fluid or solid material	Stimulus and mechanics incompletely understood; requires ATP	Fluids, nutrients (all cells); debris, pathogens (specialized cells)
Exocytosis	Fusion of vesicles containing fluids or solids (or both) with the cell membrane	Stimulus and mechanics incompletely understood; requires ATP	Fluids, debris (all cells)

Table 3-3

Summary

- Structure of cell membranes
  - Phospholipid bilayer, proteins, carbohydrates, cholesterol
- Functions of the cell membrane
- Transport Mechanisms of the cell membrane:
  - diffusion and osmosis
  - active transport proteins
  - vesicles in endocytosis and exocytosis