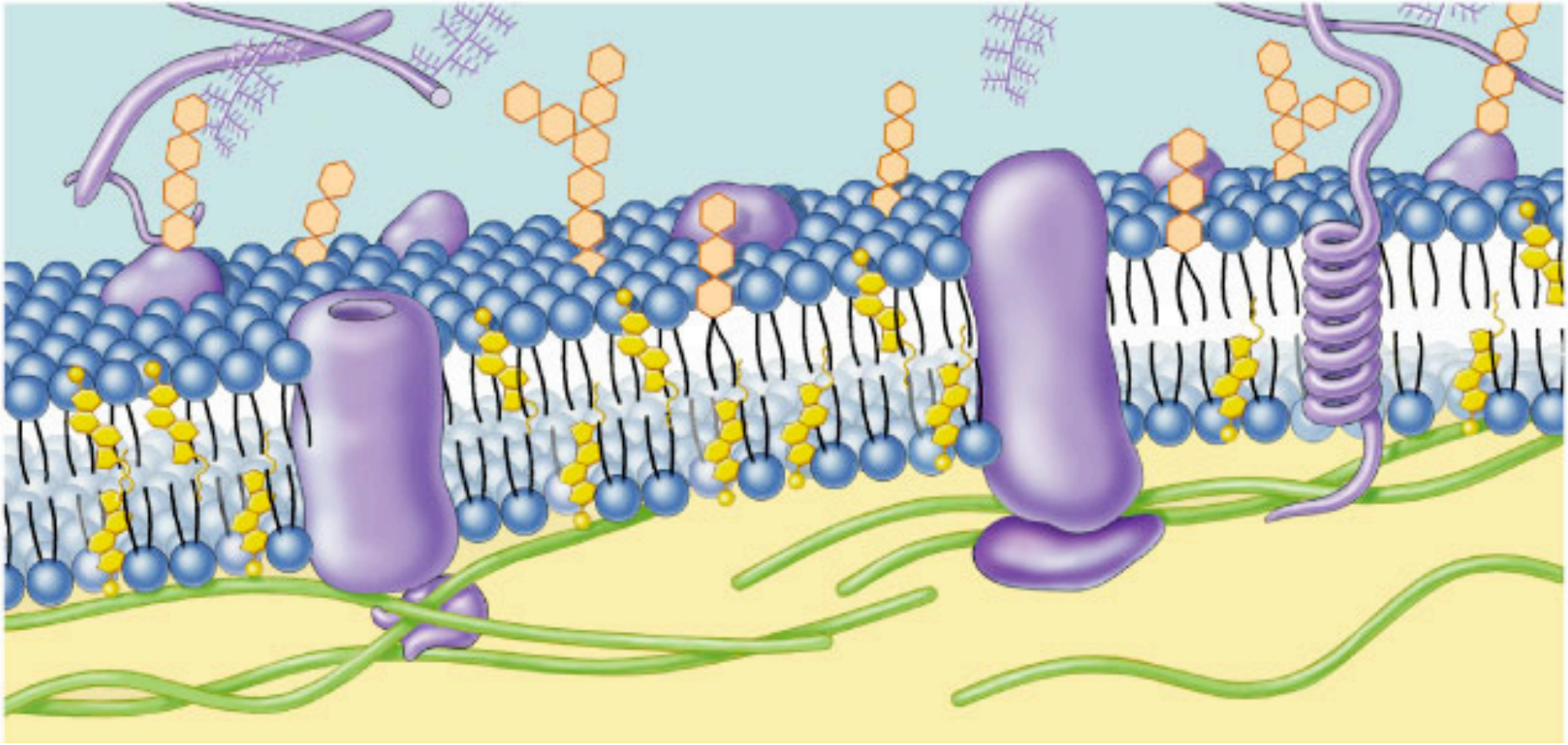
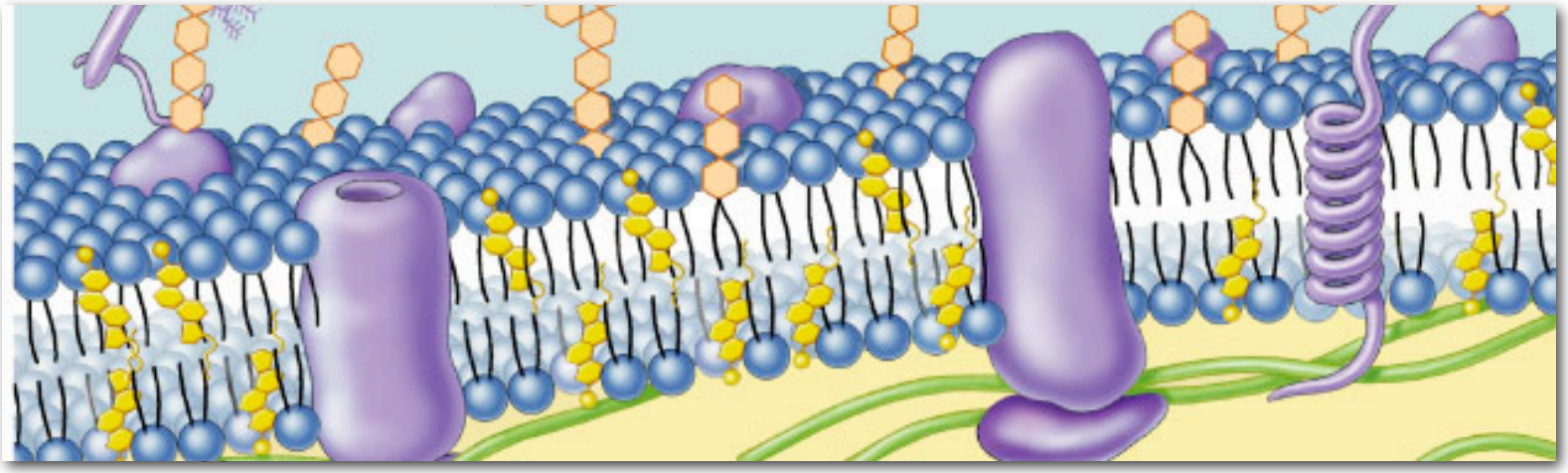
The Cell Membrane: Structure and Function



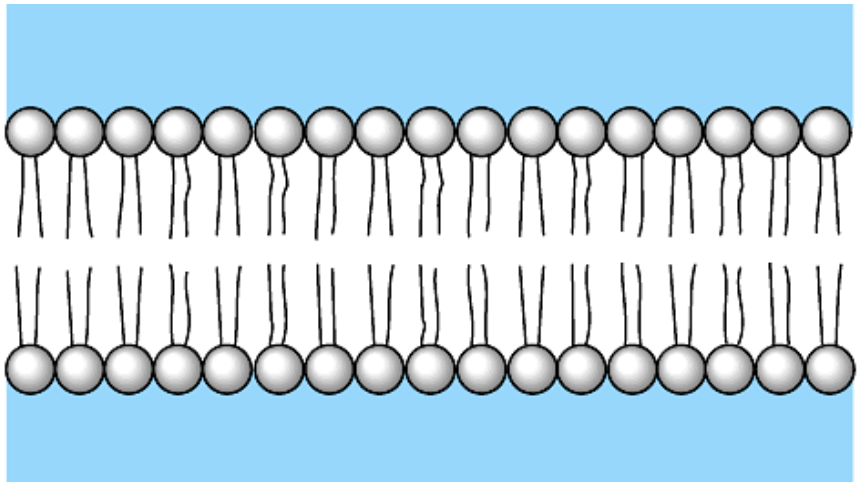
Overview of the Cell Membrane

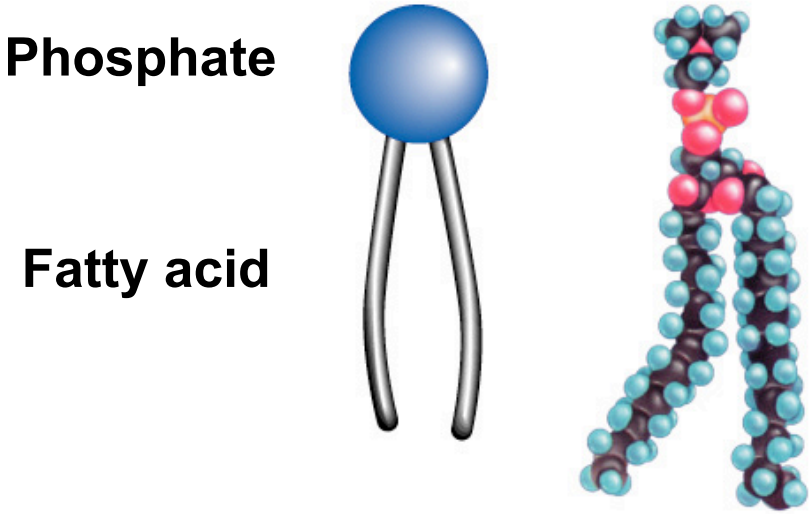
- All cells have a cell membrane
- Separates living cell from nonliving surroundings
- Mainly made of **phospholipids**
  - proteins & other macromolecules too
- It is **selectively permeable**
  - allows some substances to cross more easily than others

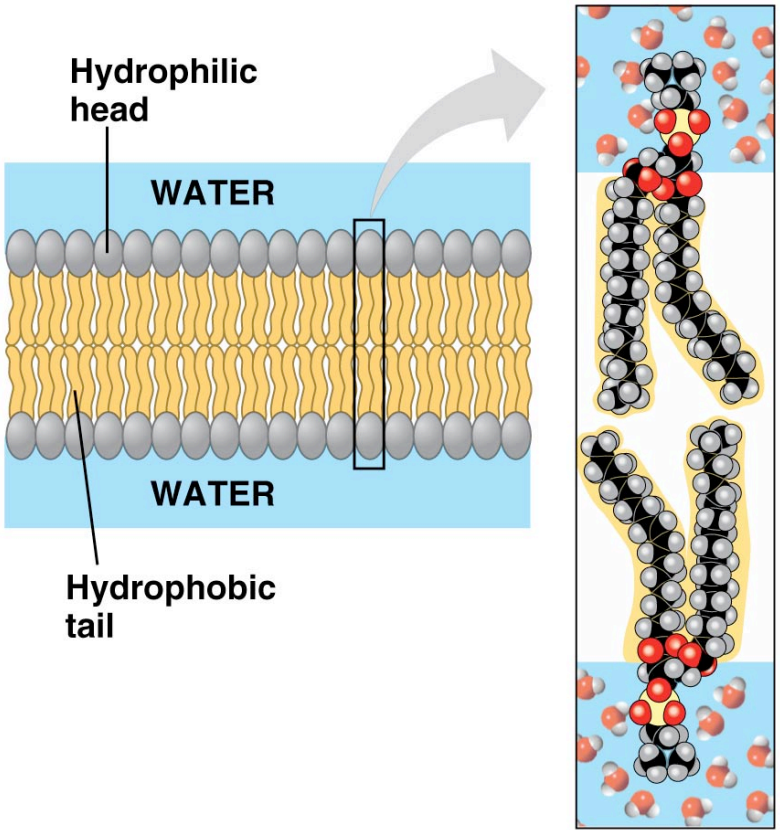


Phospholipids

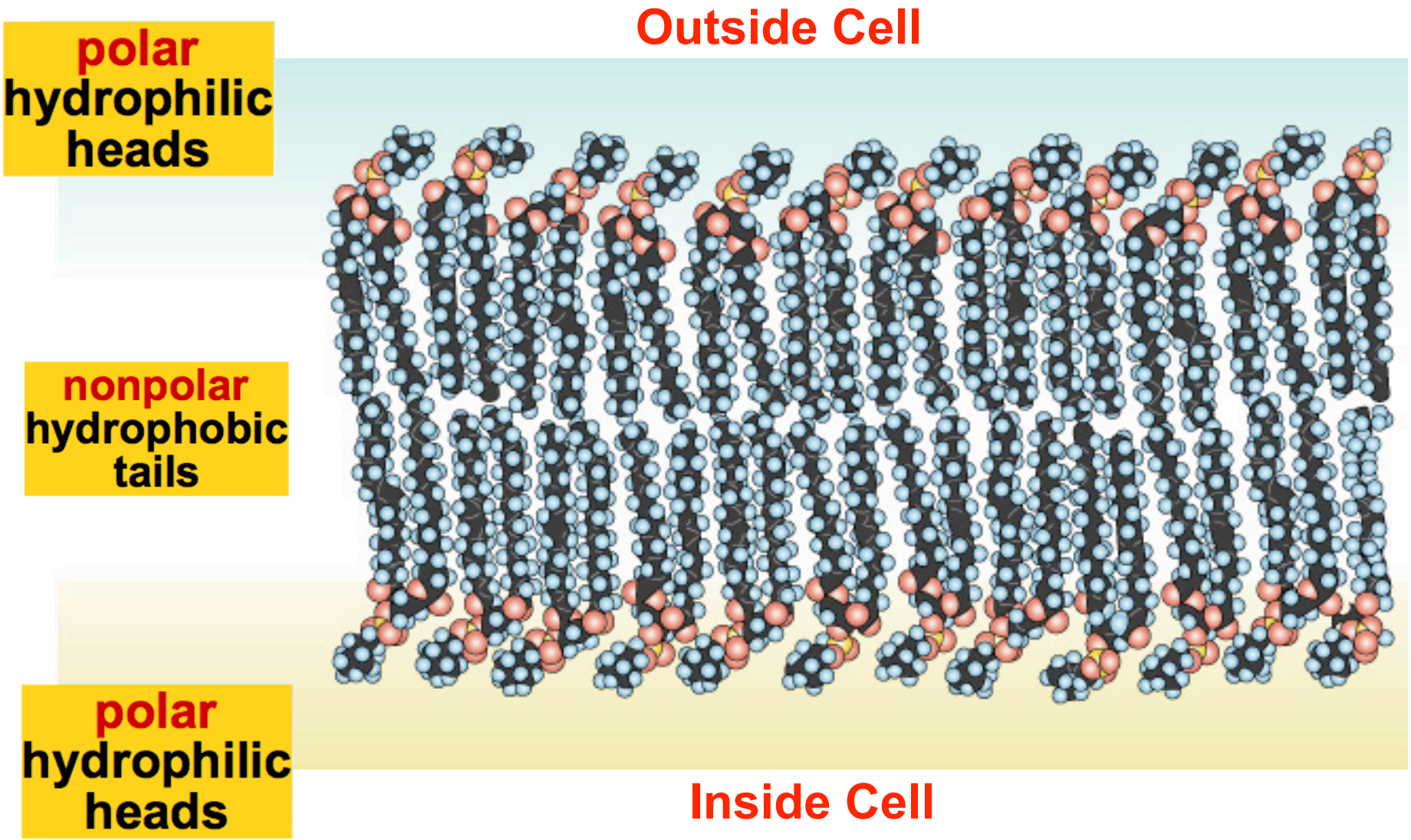
- **Hydrophilic** "heads"
  - Phosphate group
  - face the water
- **Hydrophobic** "tails"
  - Fatty acids
  - face each other (to avoid the water)
- Arranged as a **bilayer**



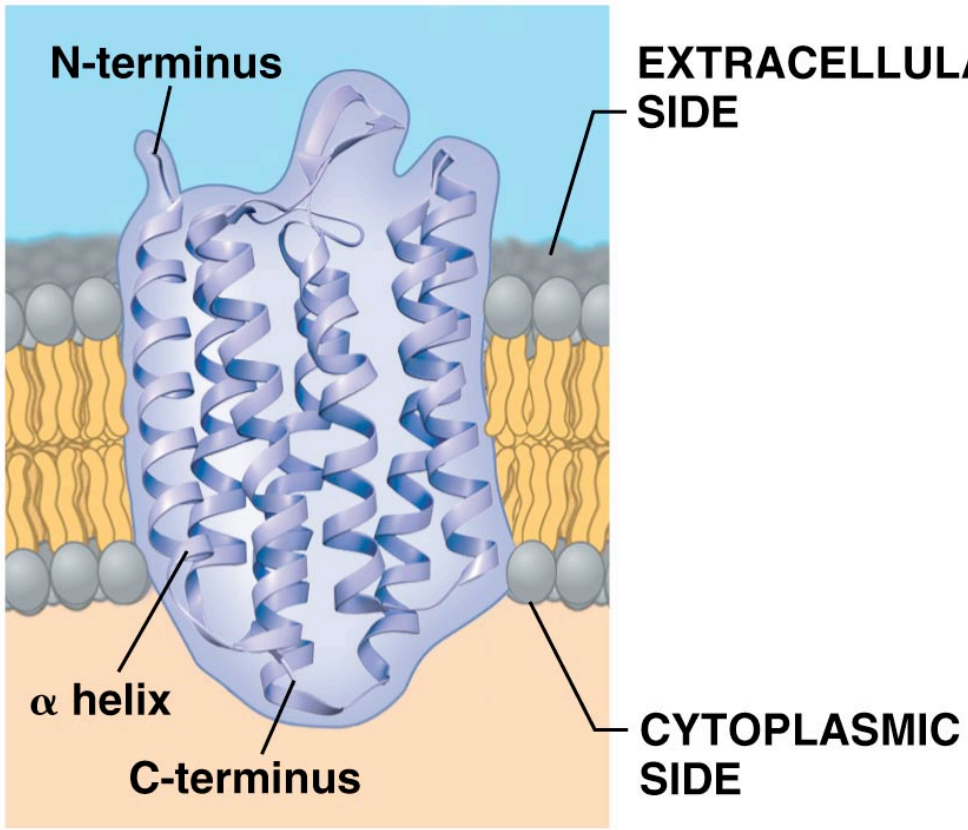


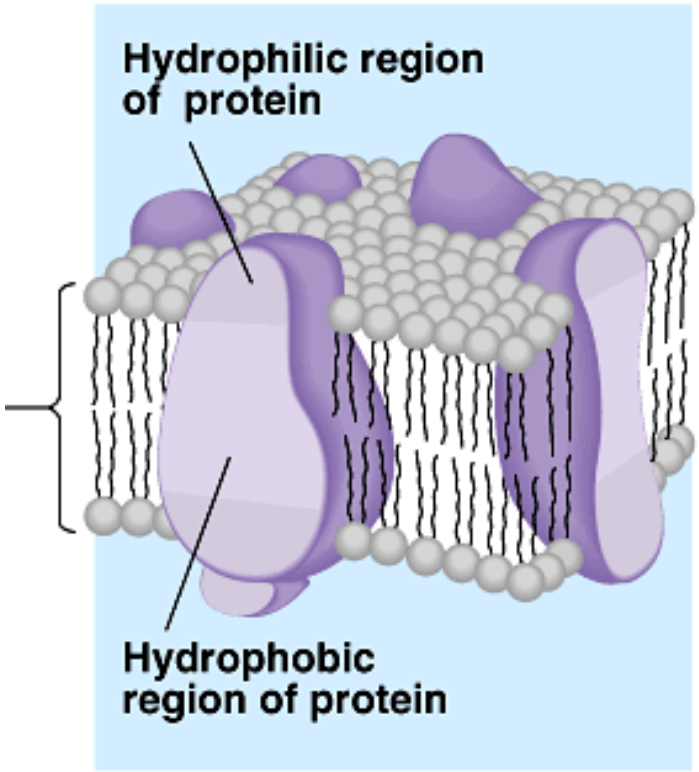


Phospholipid bilayer



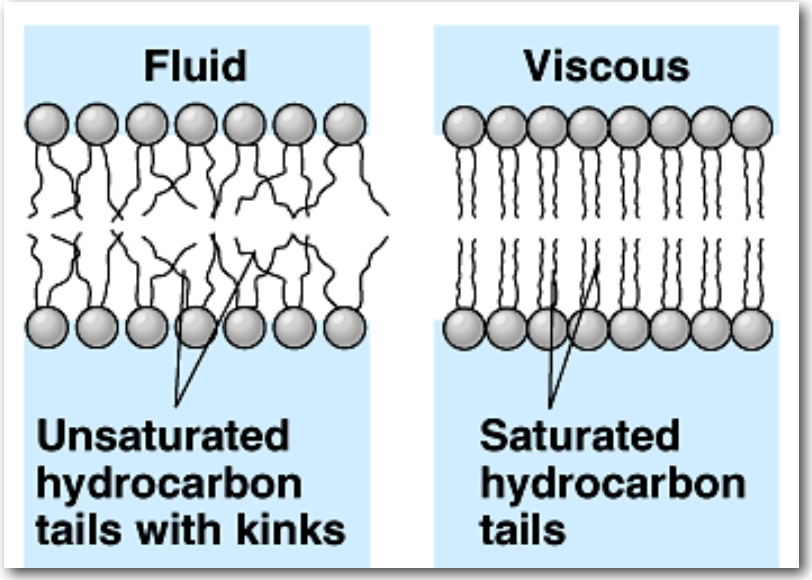
But wait, there is more. . .
Proteins in the Cell Membrane!

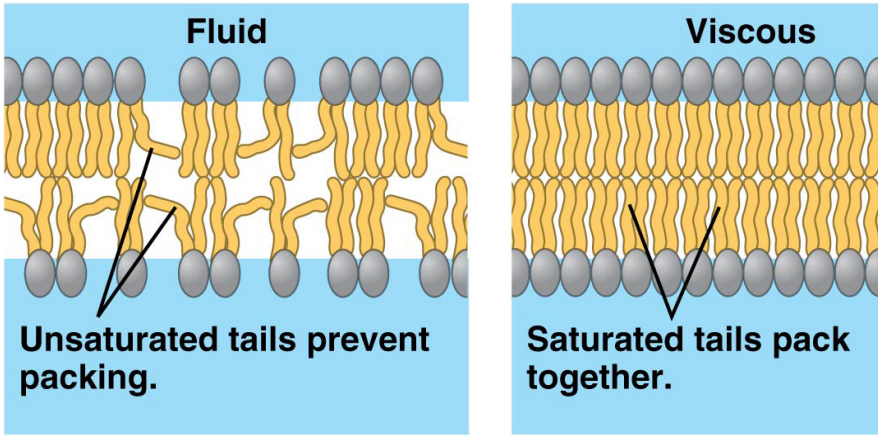


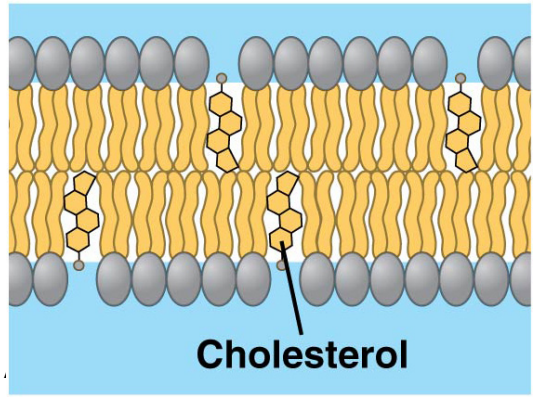


Membranes are "Fluid"

- Unsaturated fatty acid tails increase fluidity
  - prevents close packing
- Saturated fatty acid tails decrease fluidity (more viscous)
  - allows for close packing
- Cholesterol
  - Decrease fluidity at higher temperatures
  - Decreases solidification at lower temps
  - Therefore, it resists changes in fluidity when temperature changes

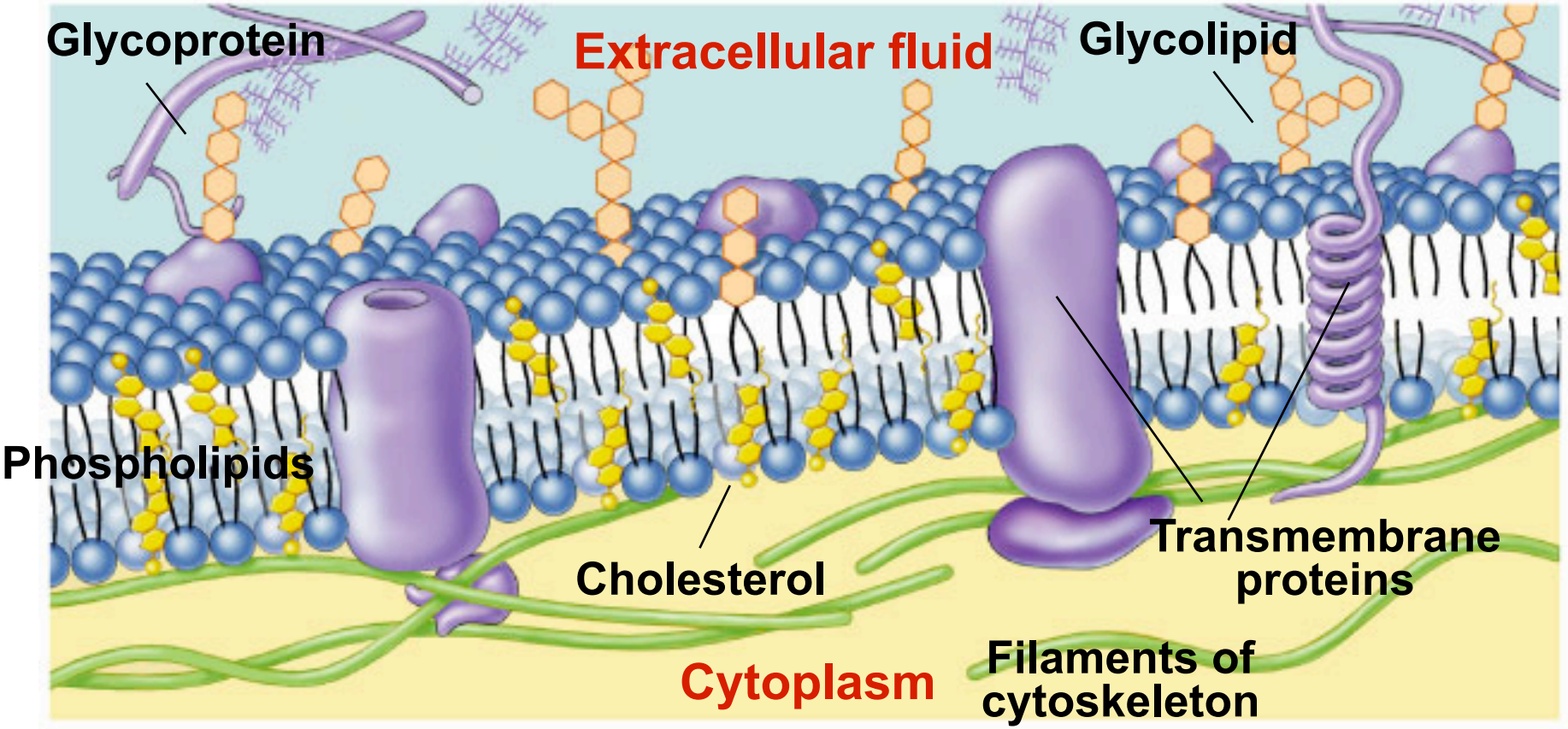




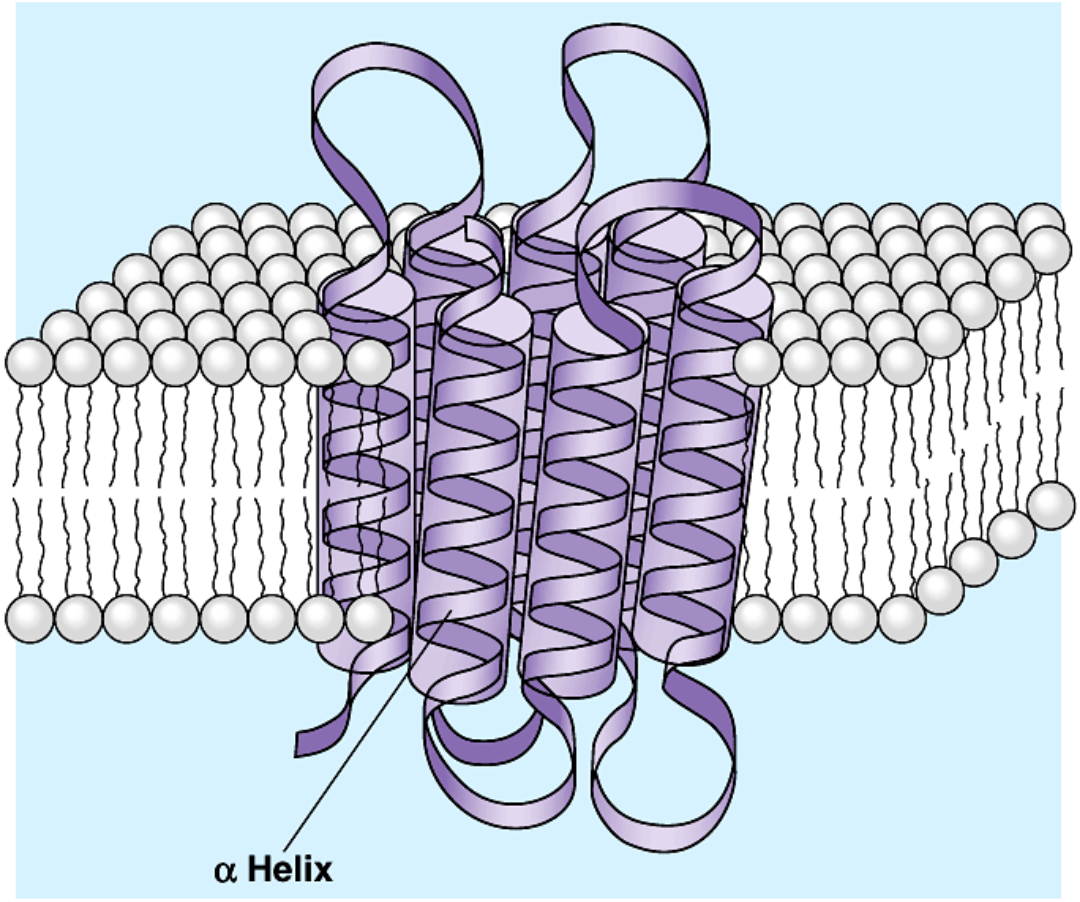


Fluid Mosaic Model

- **Phospholipid Bilayer** provides main structure of cell
- **Proteins** provide function of cell
  - -For example: Red Blood cells have 50 different membrane proteins
- **Carbohydrates** allow for cell to cell recognition
  - -Glycolipids
  - -Glycoproteins
- It is a **mosaic** of different molecules: lipids, proteins, carboydrates, etc.
- Fluid Mosaic Animation: Click on "At the Cell Surface"

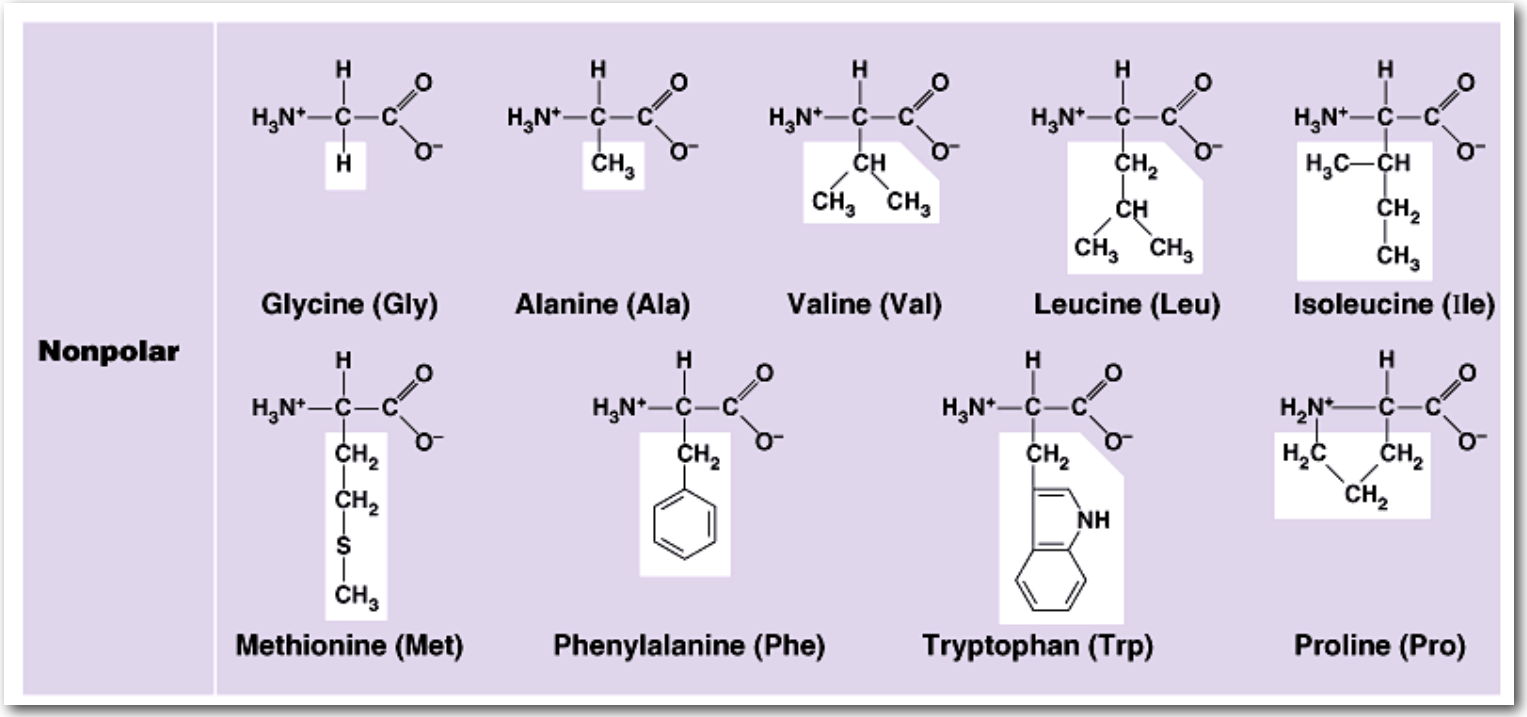


How Do Proteins Become Embedded in the Cell Membrane?



Classes of amino acids

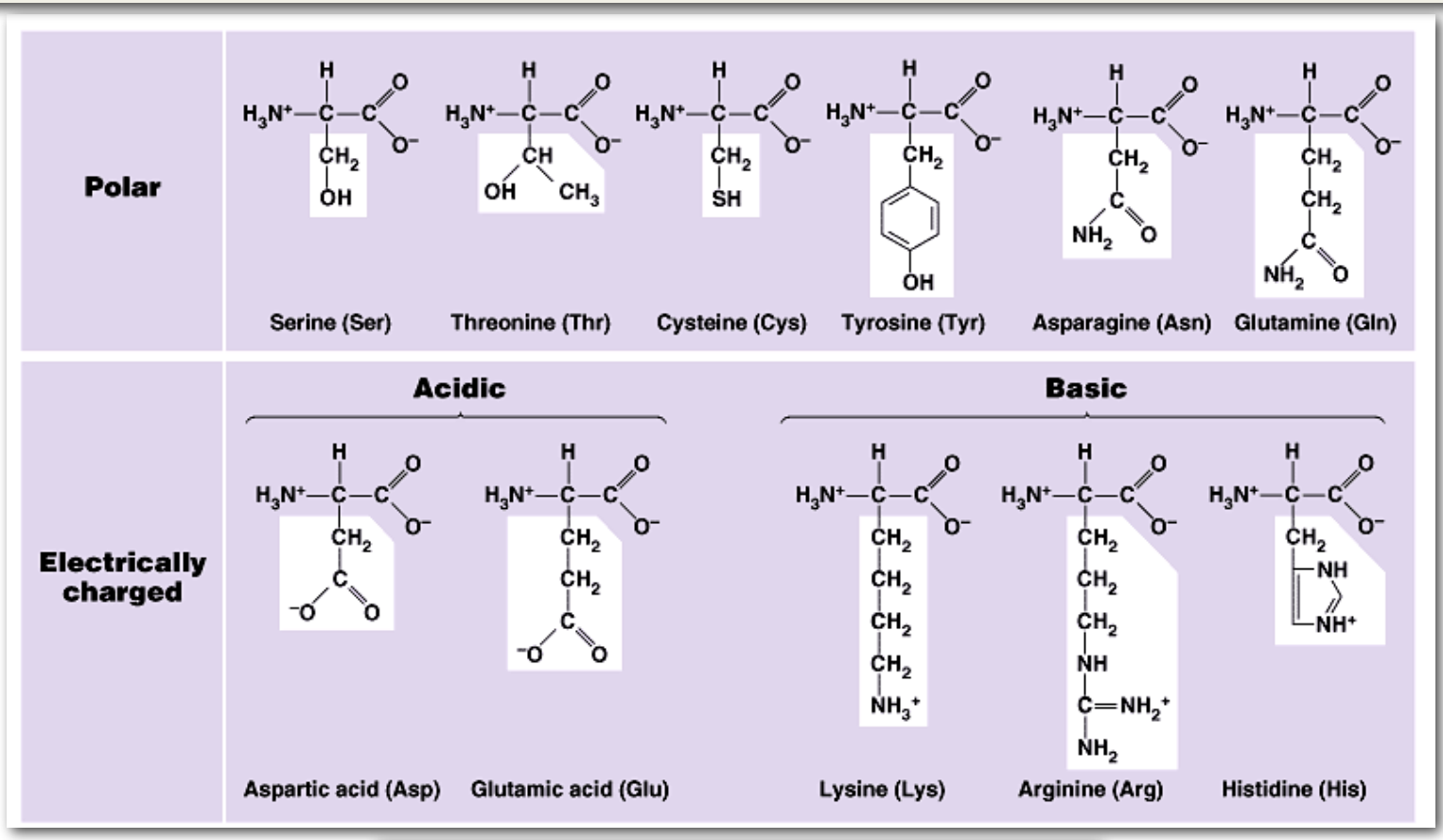
What do these amino acids have in common?



nonpolar & hydrophobic

Classes of amino acids

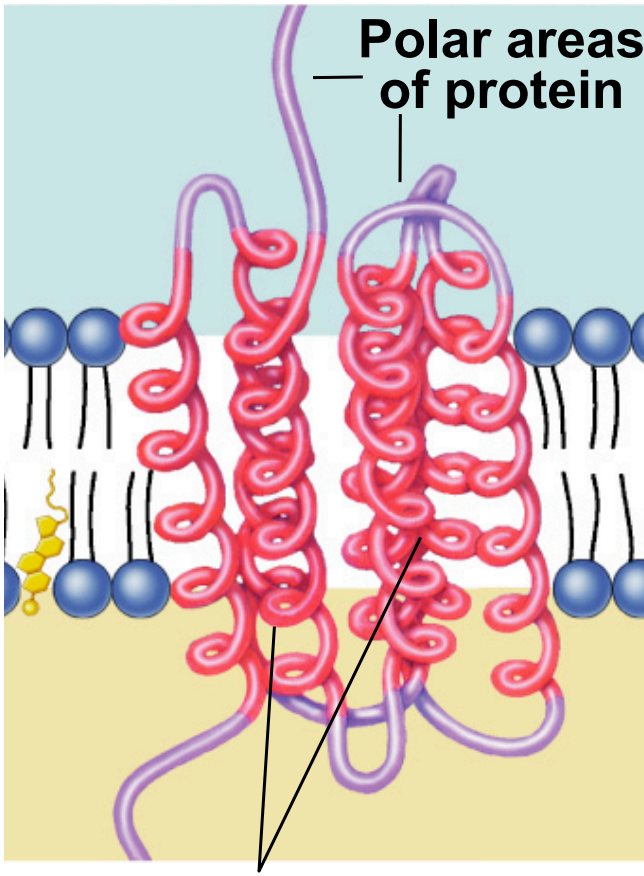
What do these amino acids have in common?



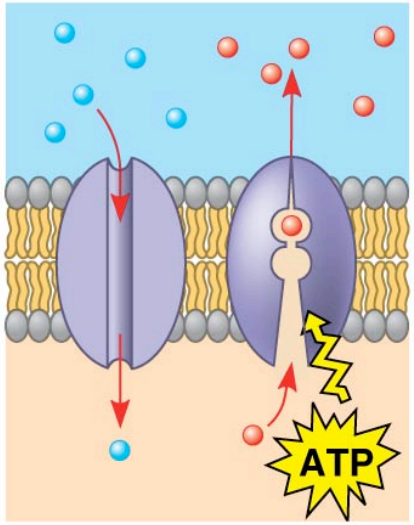
polar & hydrophilic

Protein "R" Groups help anchor molecule

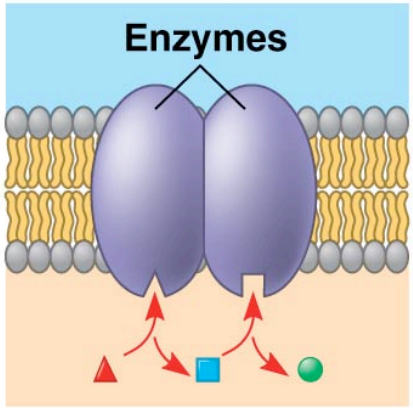
- Within the lipid bilayer
  - fatty acid tails provide a **hydrophilic** environment
  - **nonpolar** amino acids
    - hydrophobic
    - anchors protein into membrane
- On outer surfaces of membrane
  - **polar** amino acids
    - hydrophilic
    - extend into extracellular fluid & into cytosol



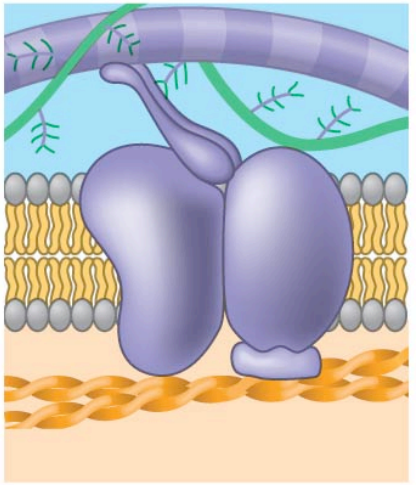
Functions of Membrane Proteins



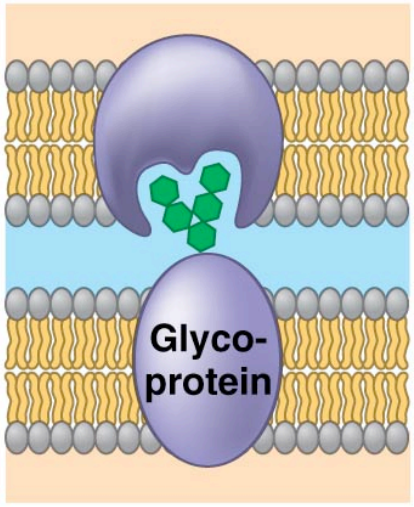
(a) Transport



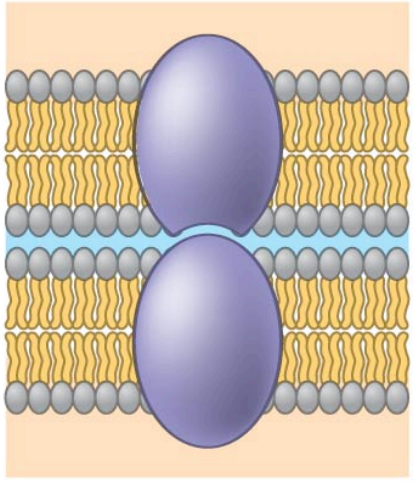
(b) Enzymatic activity



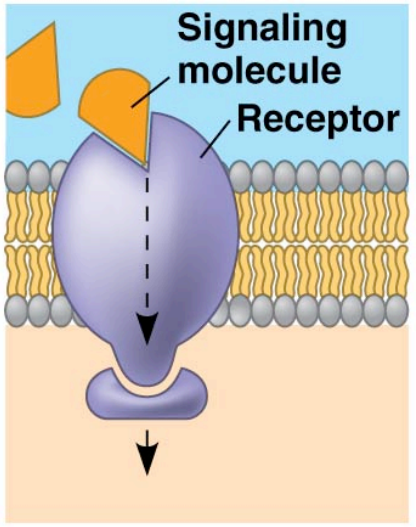
(c) Attachment to the cytoskeleton and extra-cellular matrix (ECM)



(d) Cell-cell recognition



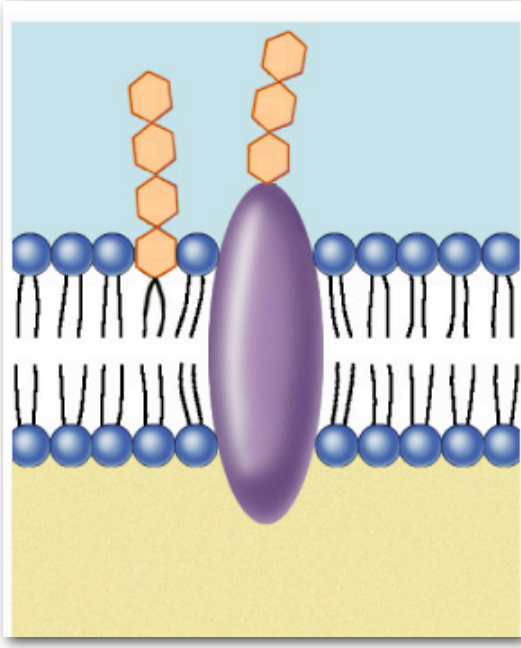
(e) Intercellular joining

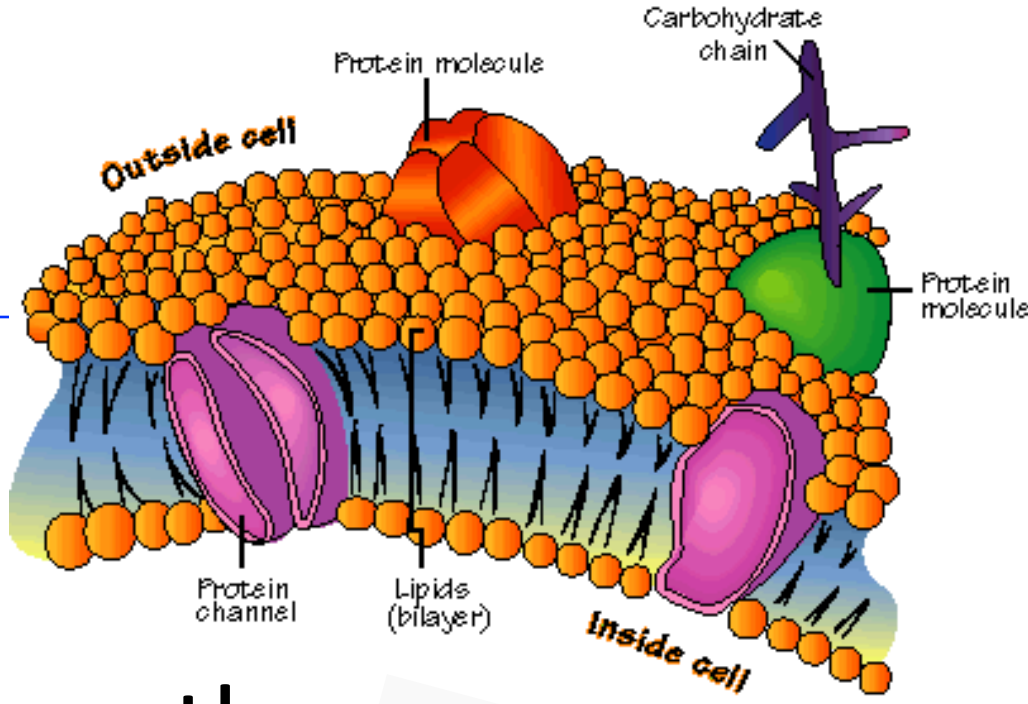


(f) Signal transduction

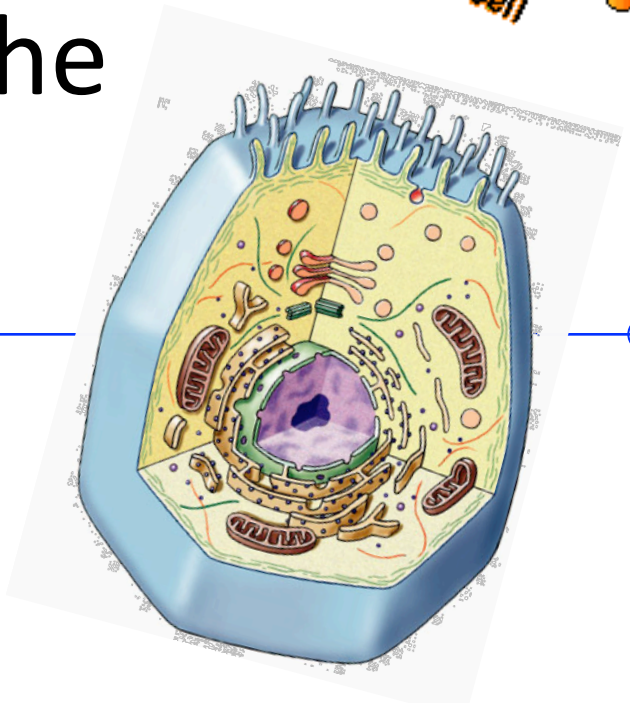
Membrane Carbohydrates

- **Glyco**: refers to carbohydrate
  - Glycolipid: Carbohydrate bound to a lipid
  - Glycoprotein: Carbohydrate bound to a protein (more common)
- Play a key role in **cell-cell recognition**
  - ability of a cell to distinguish one cell from another
  - A,B,AB,O Blood groups are due to different carbohydrates as part of the glycoproteins of red blood cells





Movement across the Cell Membrane



Movement of Molecules across the Cell Membrane

- The cell membrane (AKA plasma membrane) is "**selectively permeable**"
  - Certain molecules are allowed to pass through the membrane while others are blocked.
- To understand the movement of molecules across membranes one must understand the following processes:
  - Simple Diffusion (Diffusion)
  - Osmosis
  - Facilitated Diffusion
  - Active Transport
  - Exocytosis
  - Endocytosis

Diffusion

- Molecules are constantly moving if not at absolute zero. . .
  - Because they have Kinetic Energy
  - This random motion of molecules results in **Diffusion**
  - Diffusion is a **passive process** (i.e. no energy is required aside from the kinetic energy of the molecules)
  - Animation of Diffusion
    - Notice how all the molecules are originally clumped together in one place and then they slowly start to randomly move away from each other. This is diffusion.
    - http://cronodon.com/images/DiffusionAnim.gif

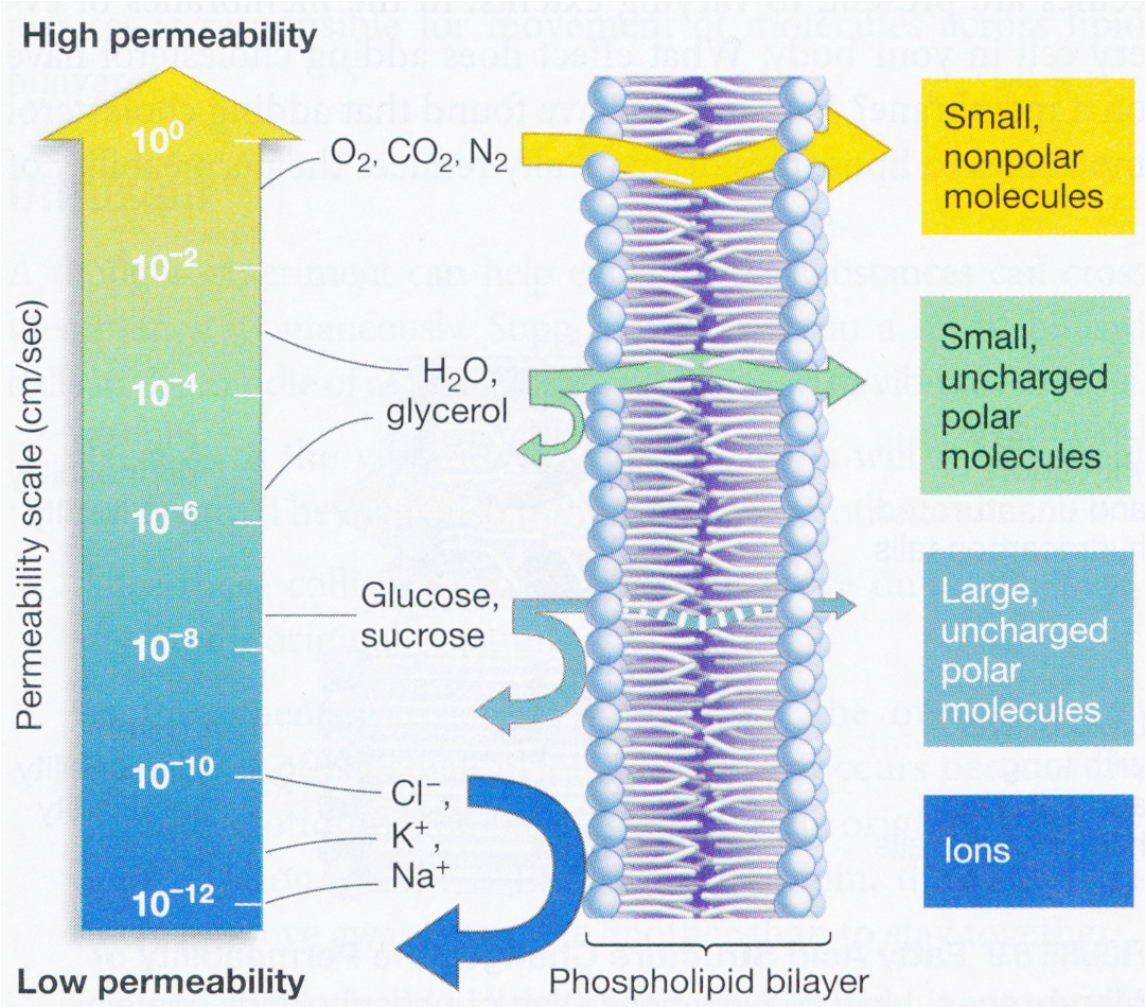
Summary of Diffusion

- **Diffusion is movement of molecules from high concentration → low concentration**

Diffusion across cell membranes

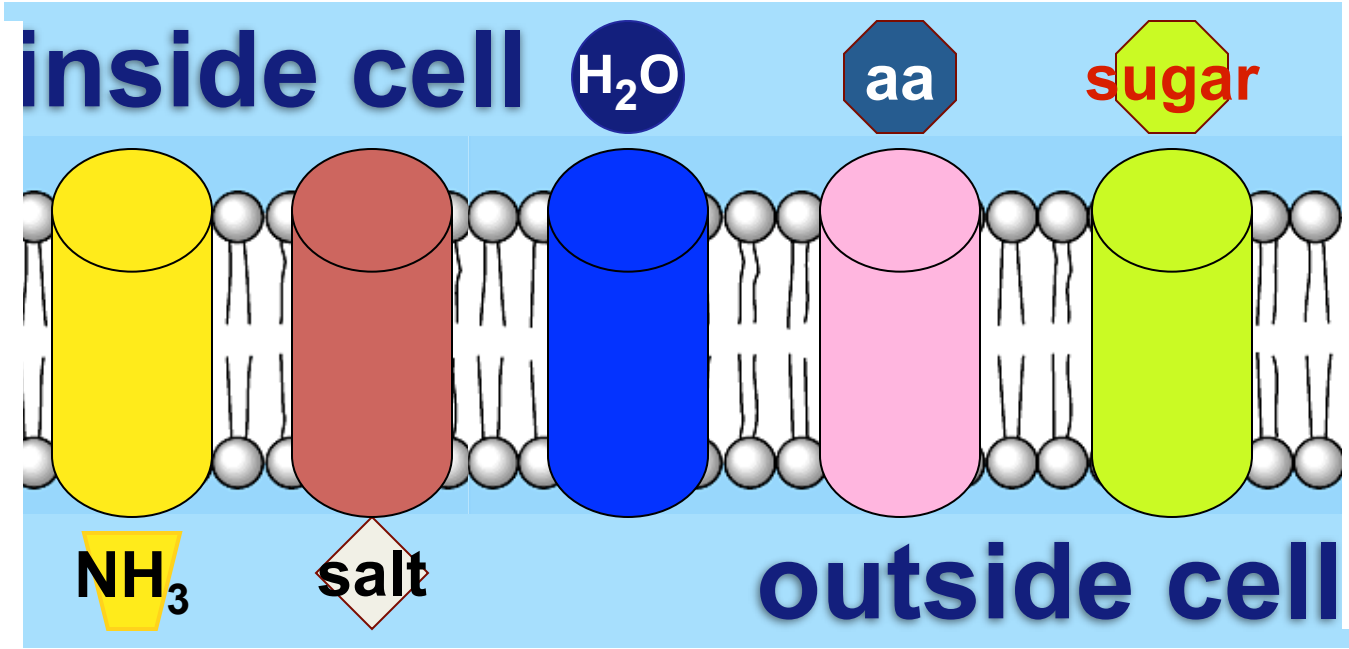
- There is a range of **cell membrane permeability** depending on the chemical characteristics of the molecules.

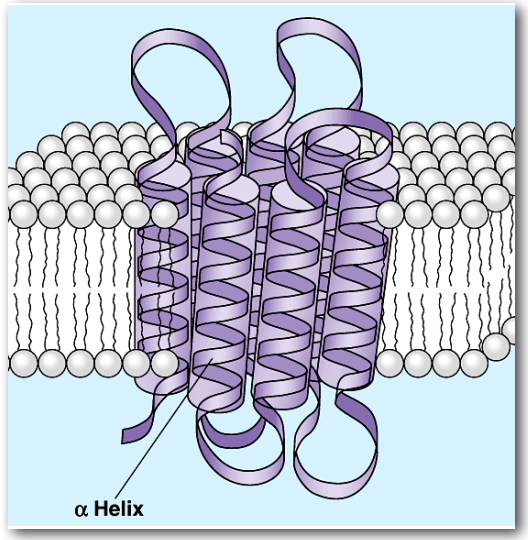
•High Permeability
  -small, nonpolar molecule
    -O_2, CO_2,N_2
•Medium/High Permeability
  -small, uncharged polar molecules
  -H_2O, glycerol
•Medium/Low Permeability
  -large, uncharged polar molecules
  -glucose, sucrose
•Low Permeability
  -Ions (charged molecules)
  -Cl^-, K^+,Na^+



Channels through cell membranes

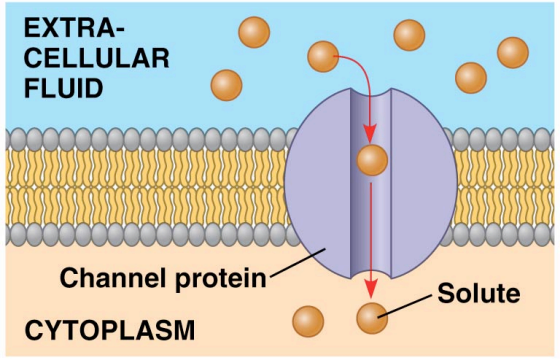
- Membranes becomes semi-permeable with protein channels
  - specific channels allow specific material across cell membranes



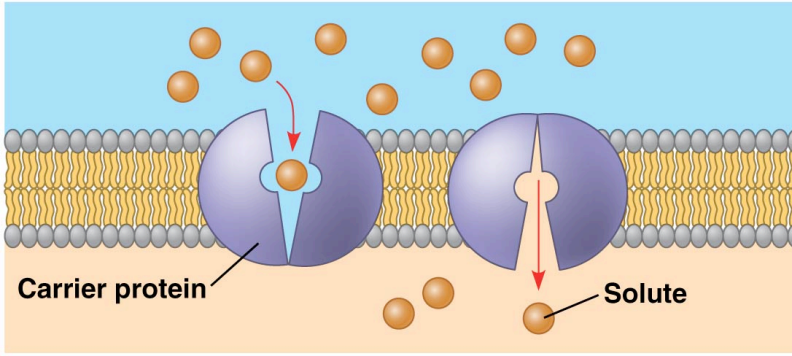


Facilitated Diffusion

- Movement of a molecule across the plasma membrane (AKA cell membrane) that normally cannot move through the lipid bilayer.
- Requires no energy (i.e. it is a passive process)
- Diffusion is "**facilitated**" (i.e. helped) by using a membrane bound protein
- The protein acts like a "bouncer" at a club- only certain molecules are let into the cell.
- Movement from high concentration to low concentration.
- Two Types of Proteins:
  - **Channel Protein**: provides corridors allowing molecules to pass through the membrane, down their concentration gradient.
  - **Carrier Protein**: A molecule binds to the protein, the protein changes shape, allowing the molecule to move through the membrane, down it's concentration gradient.
    - Animation of a carrier protein allowing facilitated diffusion



(a) A channel protein



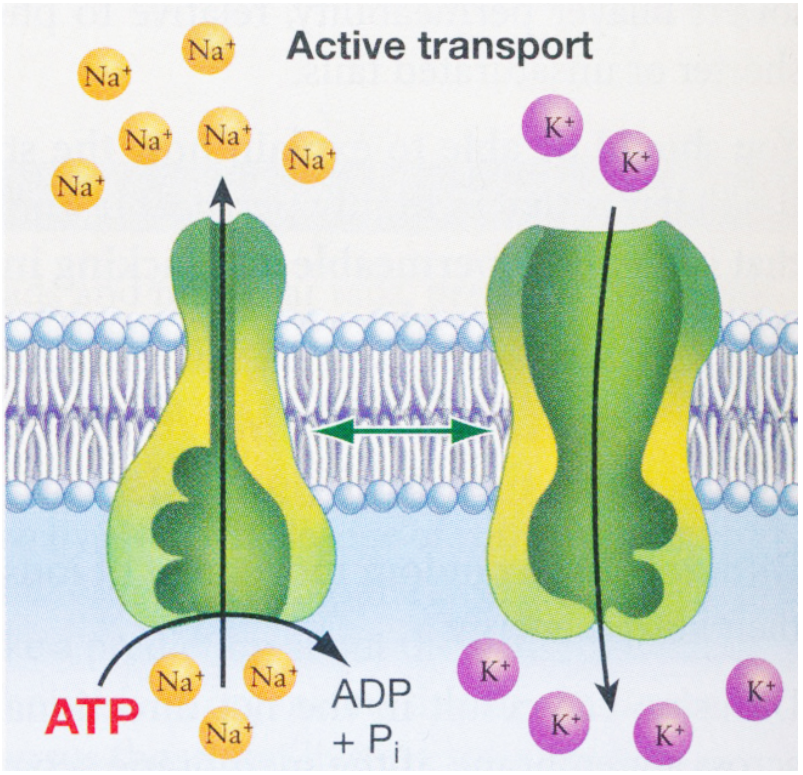
(b) A carrier protein

Active Transport

- Molecules are moved across a membrane **against** their concentration gradient
- Requires energy (ATP)
- Most famous example: Sodium-Potassium Pump
- Animation

HIGH Concentration of Na^+

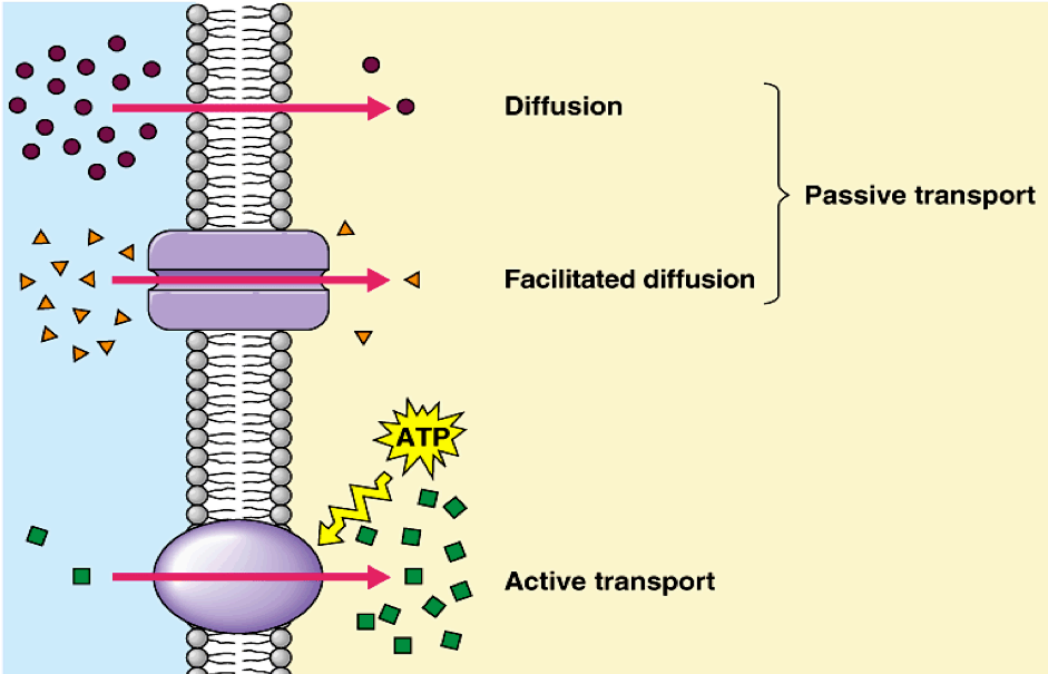
Concentration Gradient



LOW Concentration of Na^+

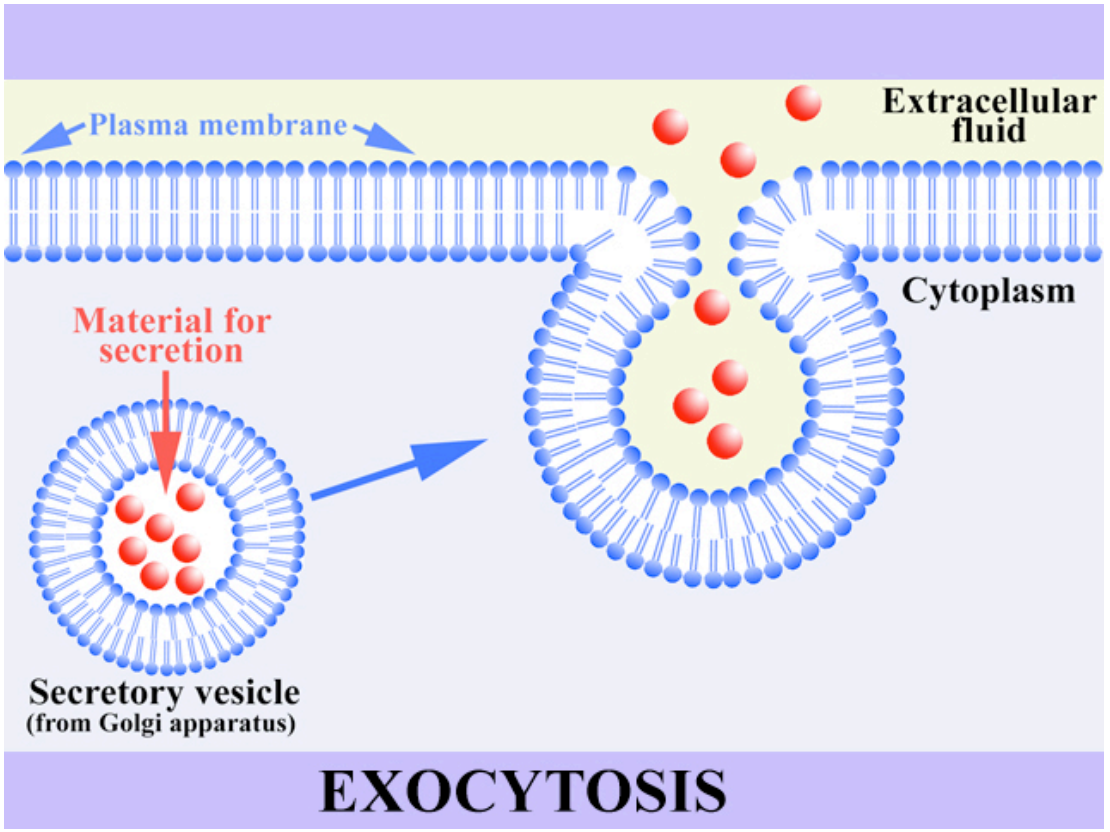
Getting through the cell membrane

- **Passive Transport**
  - **Simple Diffusion**
    - diffusion of nonpolar, hydrophobic molecules
      - high → low concentration gradient
  - **Facilitated Diffusion**
    - diffusion of polar, hydrophilic molecules
    - through a protein channel
      - high → low concentration gradient
- **Active transport**
  - diffusion *against* concentration gradient
    - low → high concentration gradient



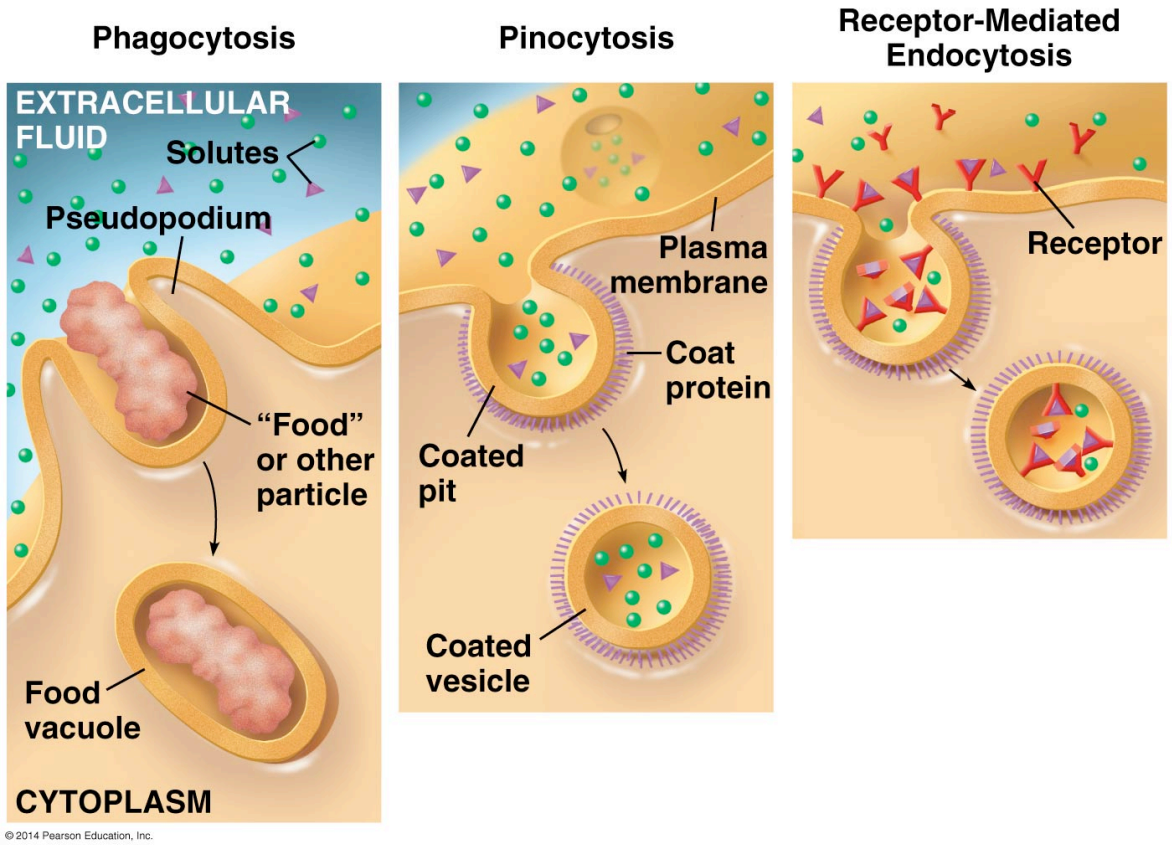
How about large molecules?

- **Exocytosis**
  - Secretion of macromolecules from the cell by fusing with the cell membrane



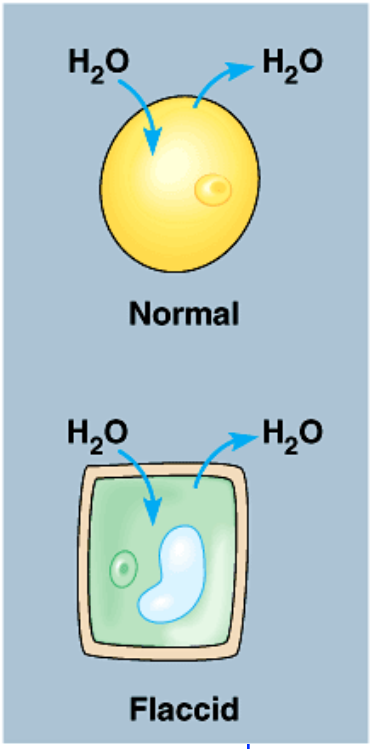
How about large molecules?

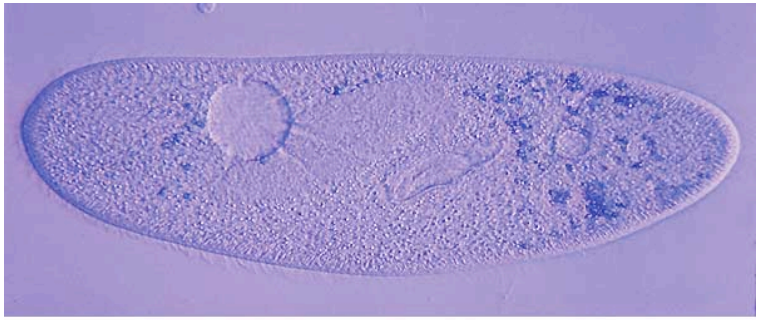
- **Edocytosis**
  - Cell takes in macromolecules by forming new vesicles from the plasma membrane (AKA cell membrane)
  - Three Types
    - **Phagocytosis**: Cellular eating
    - **Pinocytosis**: Cellular drinking
    - **Receptor-mediated endocytosis**: allows the cell to acquire specific molecules
  - Exocytosis and Edocytosis Animations

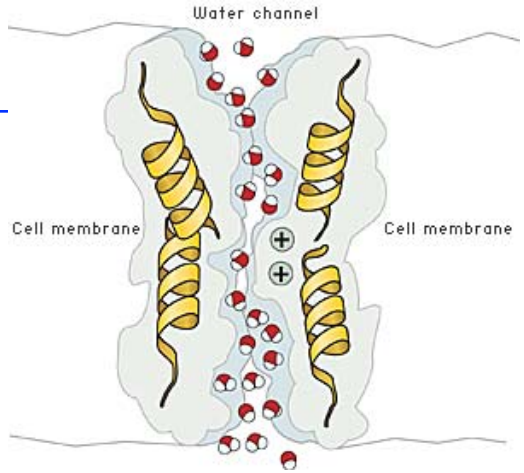


The Special Case of Water

Movement of water across the cell membrane

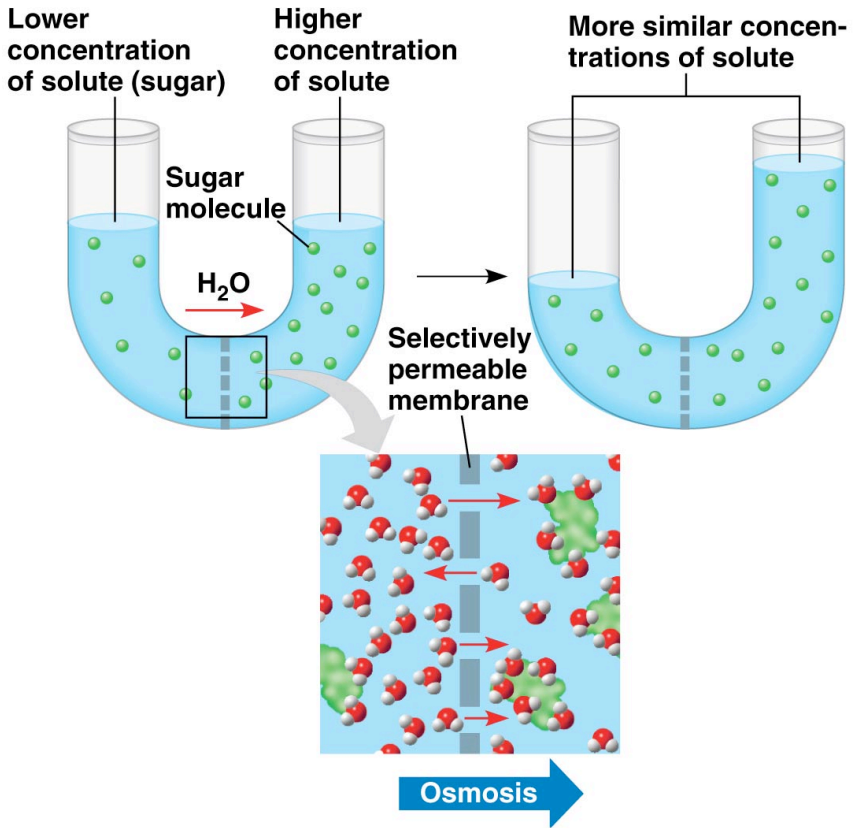


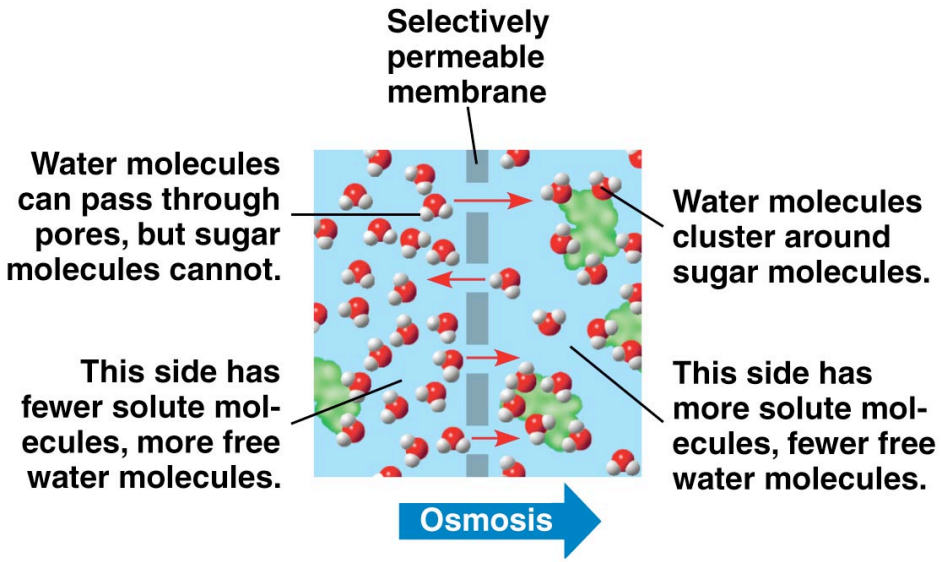




Osmosis is Diffusion of Water

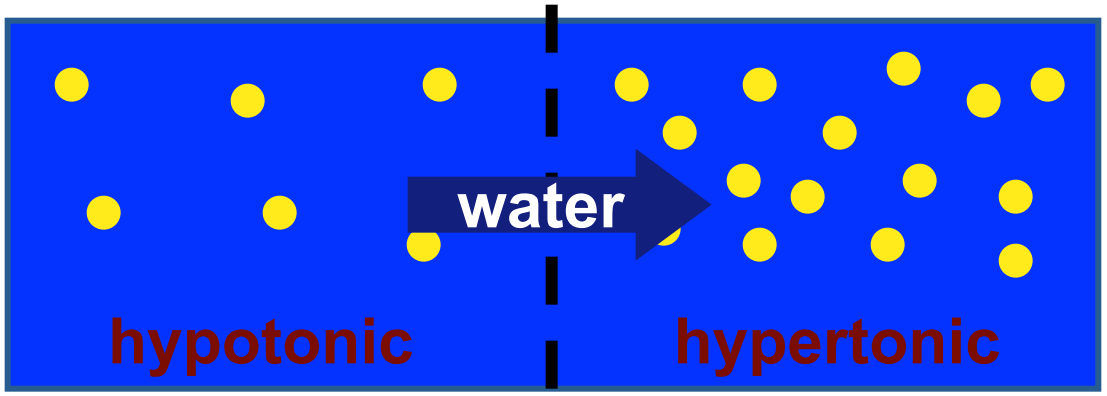
- Water is very important to life, so we talk about water separately
- Diffusion of water from *high concentration* of <u>water</u> to *low concentration* of <u>water</u>
  - across a semi-permeable membrane (i.e selectively permeable membrane)
  - When the solute concentration (e.g. sugar) is higher on one side of a semi-permeable membrane, the water concentration is lower on that side of the membrane because the solute is taking the place that the water would have taken.
    - Therefore an easy way to remember which side of the membrane has the **lower water concentration** is the side with the higher solute concentration. Alternatively, the side with the **higher water concentration** is the side with the lower solute concentration.





Concentration of water

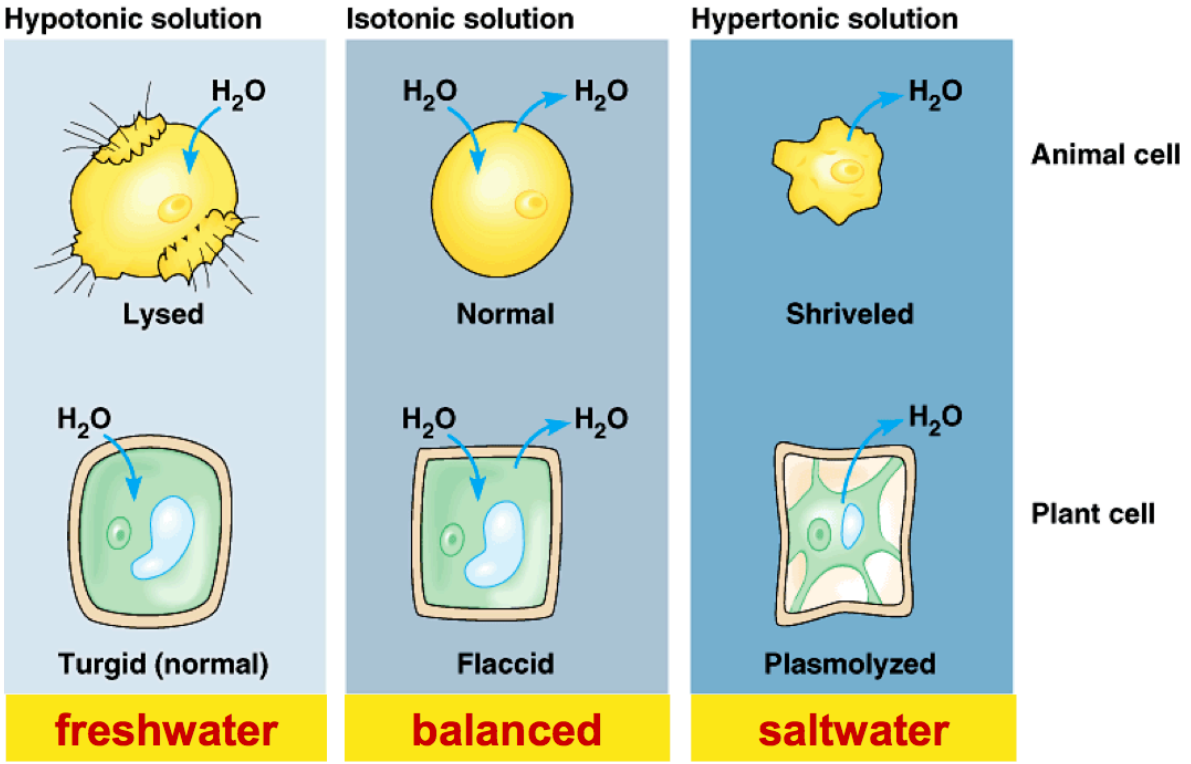
- Direction of osmosis is determined by comparing total solute concentrations
  - Hypertonic - more solute, less water
  - Hypotonic - less solute, more water
  - Isotonic - equal solute, equal water



net movement of water

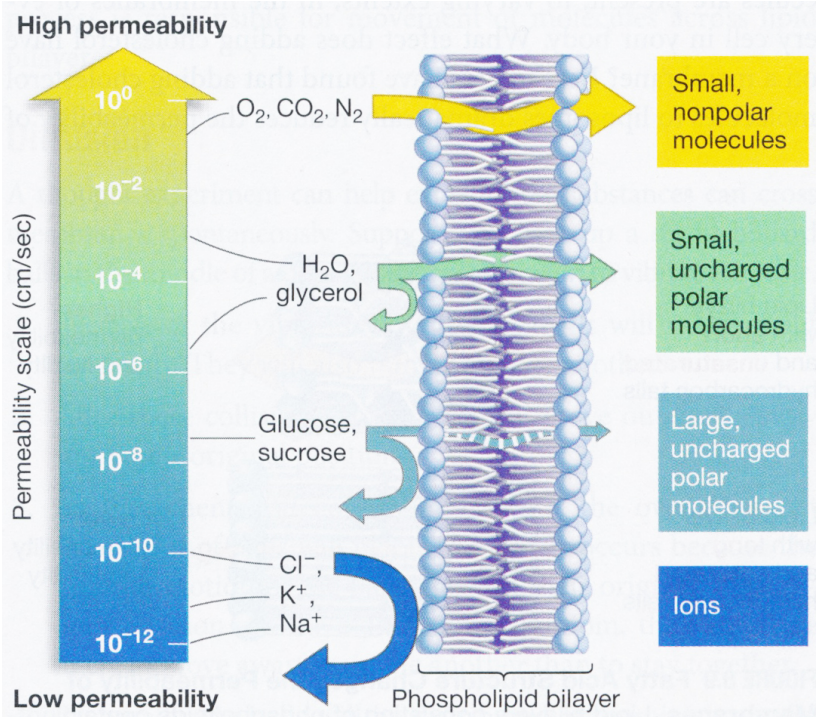
Managing water balance

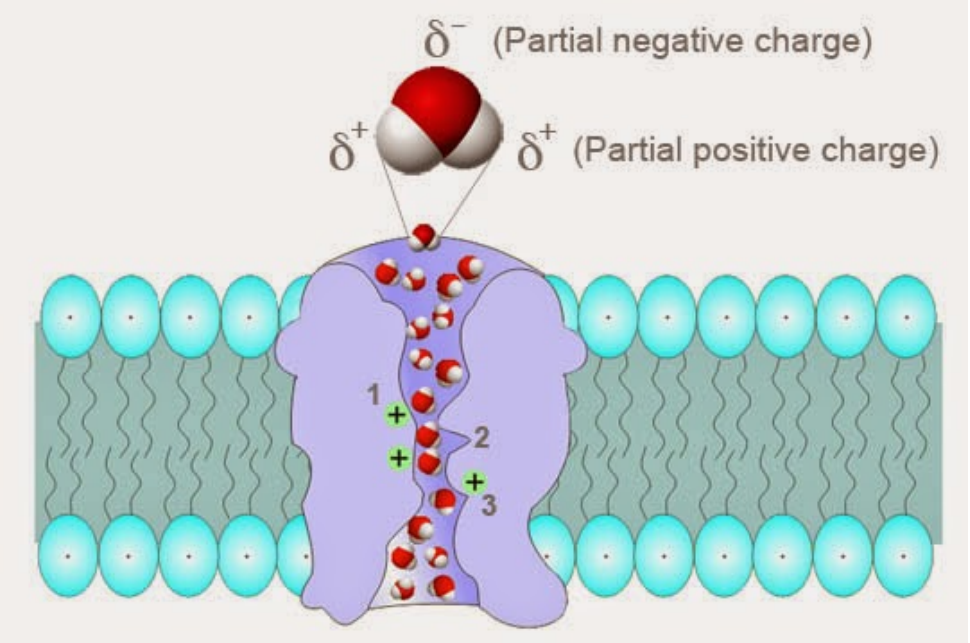
- Cell survival depends on balancing water uptake & loss
  - In the examples below an animal and plant cell are placed in three different solutions
  - **Hypotonic solution** (freshwater)
    - This is hypotonic because it does not have many dissolved solutes in it. The cells have more dissolved solutes in them than the freshwater outside them. Therefore the water concentration outside the cell is greater than it is inside the cell. Since the concentration gradient of the water is towards the inside of the cell the animal cell gains water and bursts. The plant cell doesn't burst because plant cells have a cell wall as well as a cell membrane.
  - **Isotonic solution** (the outside solution has the same number of solutes as the cell)
    - This is isotonic because it has the same number of dissolved solutes in it as the cells. Therefore the water concentration is the same outside and inside the cell. Since there is no concentration gradient for the water, the system is in equilibrium. The same amount of water enters as leaves the cell.
  - **Hypertonic** (saltwater)
    - This is hypertonic because it has more dissolved solutes in it. The cells have less dissolved solutes in them than the sewater outside them. Therefore the water concentration outside the cell is less than it is inside the cell. Since the concentration gradient of the water is towards the outside of the cell the animal cell loses water and shrivels. The plant cell pulls off the cell wall because plant cells have a cell wall as well as a cell membrane. This process occuring in a plant cell is called plasmolysis.
  - Osmosis Animation



Aquaporins

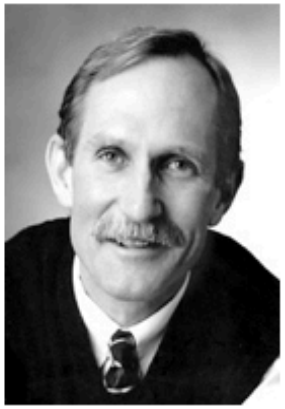
- Special membrane proteins that provide channels allowing water to move more easily across the membrane.
  - Since water is polar is doesn't move easily through the hydrophobic phospholipid bilayer
- Evidence that water channels existed
  - Water moves more rapidly than expected, into & out of cells





Are Aquaporins worth Studying?

The Nobel Prize in Chemistry 2003

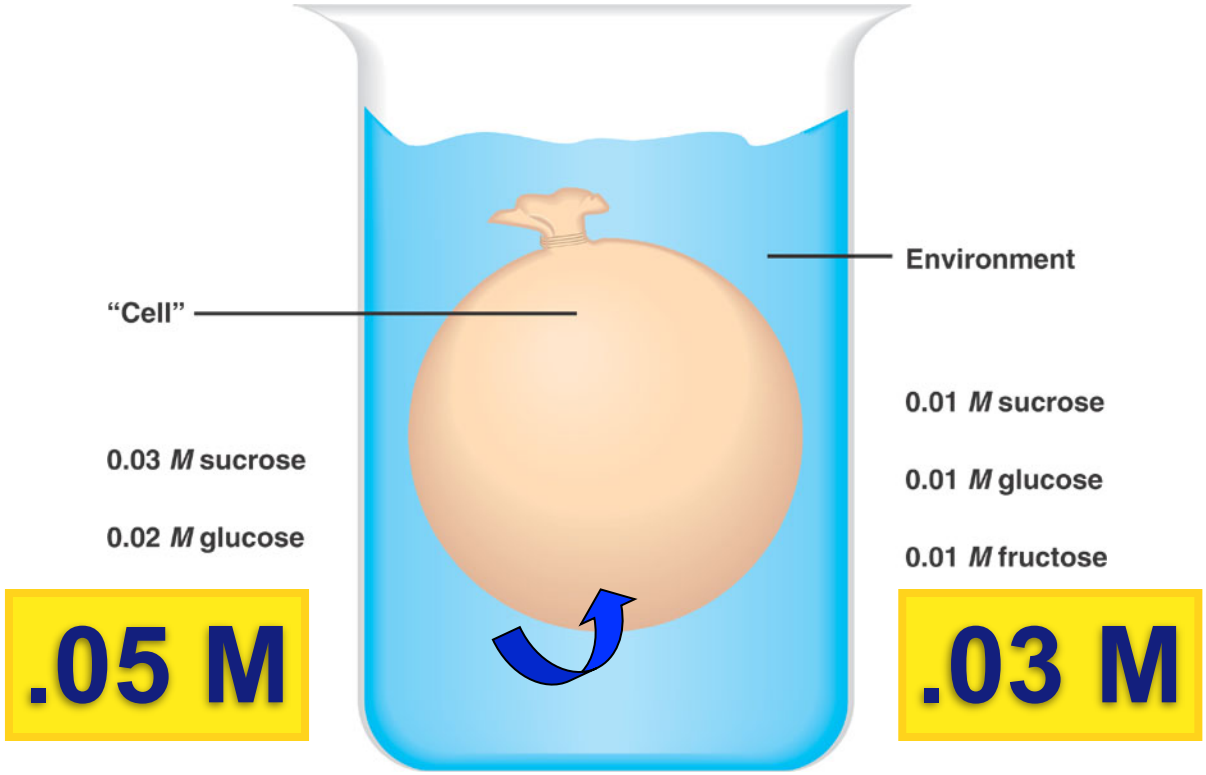


Peter Agre
Prize share: 1/2

Roderick MacKinnon
Prize share: 1/2

The Nobel Prize in Chemistry 2003 was awarded *"for discoveries concerning channels in cell membranes"* jointly with one half to Peter Agre *"for the discovery of water channels"* and with one half to Roderick MacKinnon *"for structural and mechanistic studies of ion channels"*.

Osmosis…



Cell (compared to beaker) ---> hypertonic or hypotonic?
Beaker (compared to cell) ---> hypertonic or hypotonic?
Which way does the water flow? ---> in or out of cell?