Animal Physiology
Third stage
Lect-1-

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Membrane Transport and the Membrane Potential

Extracellular Environment

- Includes all parts of the body outside of cells
  - Cells receive nourishment
  - Cells release waste
  - Cells interact (through chemical mediators)

Body Fluids

Two compartments:
Intracellular (~67% of body's H20)
Extracellular (~33% of body's H20):-
Blood plasma: about 20% of this
Tissue fluid (or interstitial fluid)
Includes extracellular matrix
Lymph

Extracellular matrix

Connective tissue
Fibers
Collegen
about 15 kinds
In the basal lamina bind to carbo on plasma membrane
Then binds to matrix of CT
Proteoglycans and glycoproteins   Binds ET to CT
Elastin

Transport across cell membrane

- Plasma (cell) membrane
  - Is selectively permeable
    - Generally not permeable to
      - Proteins
      - Nucleic acids
    - Selectively permeable to
      - Ions
      - Nutrients
      - Waste
  - It is a biological interface between the two compartments

Plasma (cell) membrane
Site of chemical reactions
Enzymes located in it
Receptors: can bond to molecular signals
Transporter molecules
Recognition factors: allow for cellular adhesion

Transport across cell membrane

- Transport categories
  - Based on structure
    - Carrier-mediated
      - Facilitated diffusion
      - Active transport
    - Non-carrier mediated
      - Diffusion
      - Osmosis
      - Bulk flow

        (pressure gradients)
    - Vesicle mediated
      - Exocytosis
      - Endocytosis
        - Pinocytosis
        - phagocytosis

- Based on energy requirements

Passive transport :

Based on concentration gradient

Does not use metabolic energy

Active transport

Against a gradient

Uses metabolic energy

Involves specific carriers

Diffusion and Osmosis

- Cell membrane separates ICF from ECF.
- Cell membrane is selectively permeable.
- Mechanisms to transport molecules and ions through the cell membrane:
  - Carrier mediated transport
  - Non-carrier mediated transport

Energy requirements for transport through the cell membrane:

Passive transport:

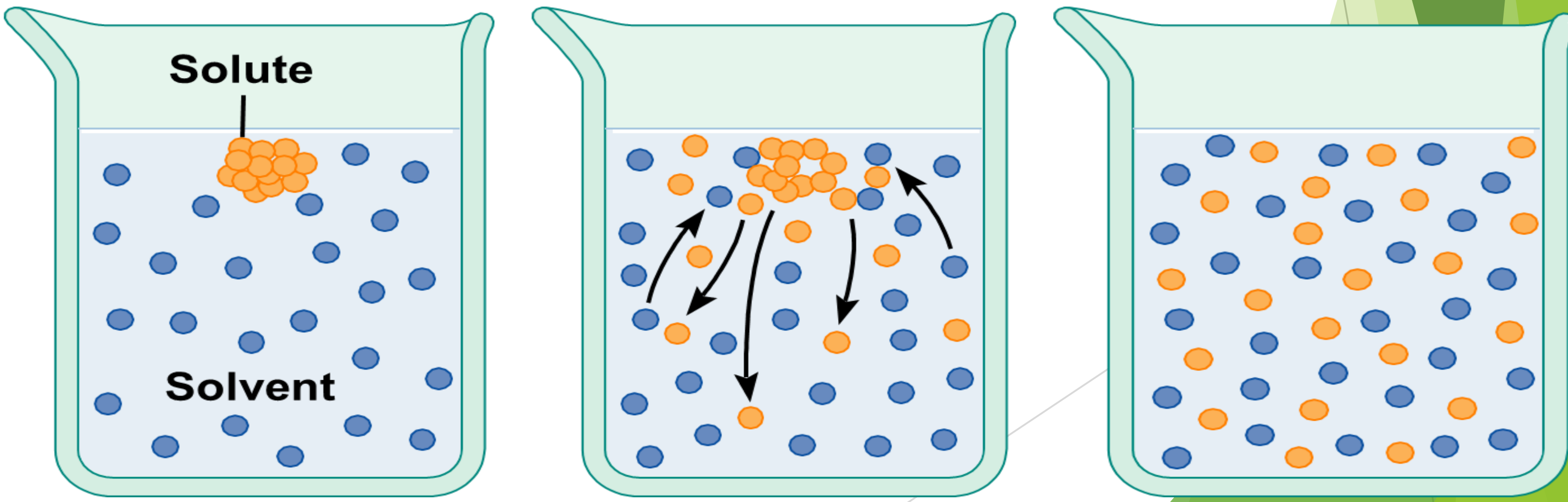
Net movement down a concentration gradient.

Active transport:

Net movement against a concentration gradient.
Requires energy.

Diffusion

- Physical process that occurs:
  - **Concentration difference** across the membrane
  - **Membrane is permeable** to the diffusing substance.
- Molecules/ions are in constant state of random motion due to their thermal energy.
  - Eliminates a concentration gradient and distributes the molecules uniformly.



Diffusion Through Cell Membrane

- Cell membrane permeable to:
  - Non-polar molecules (0_2)
  - Lipid soluble molecules (steroids)
  - Small polar covalent bonds ($C0_2$)
  - H_20 (small size, lack charge)
- Cell membrane impermeable to:
  - Large polar molecules (glucose)
  - Charged inorganic ions (Na^+)

Rate of Diffusion

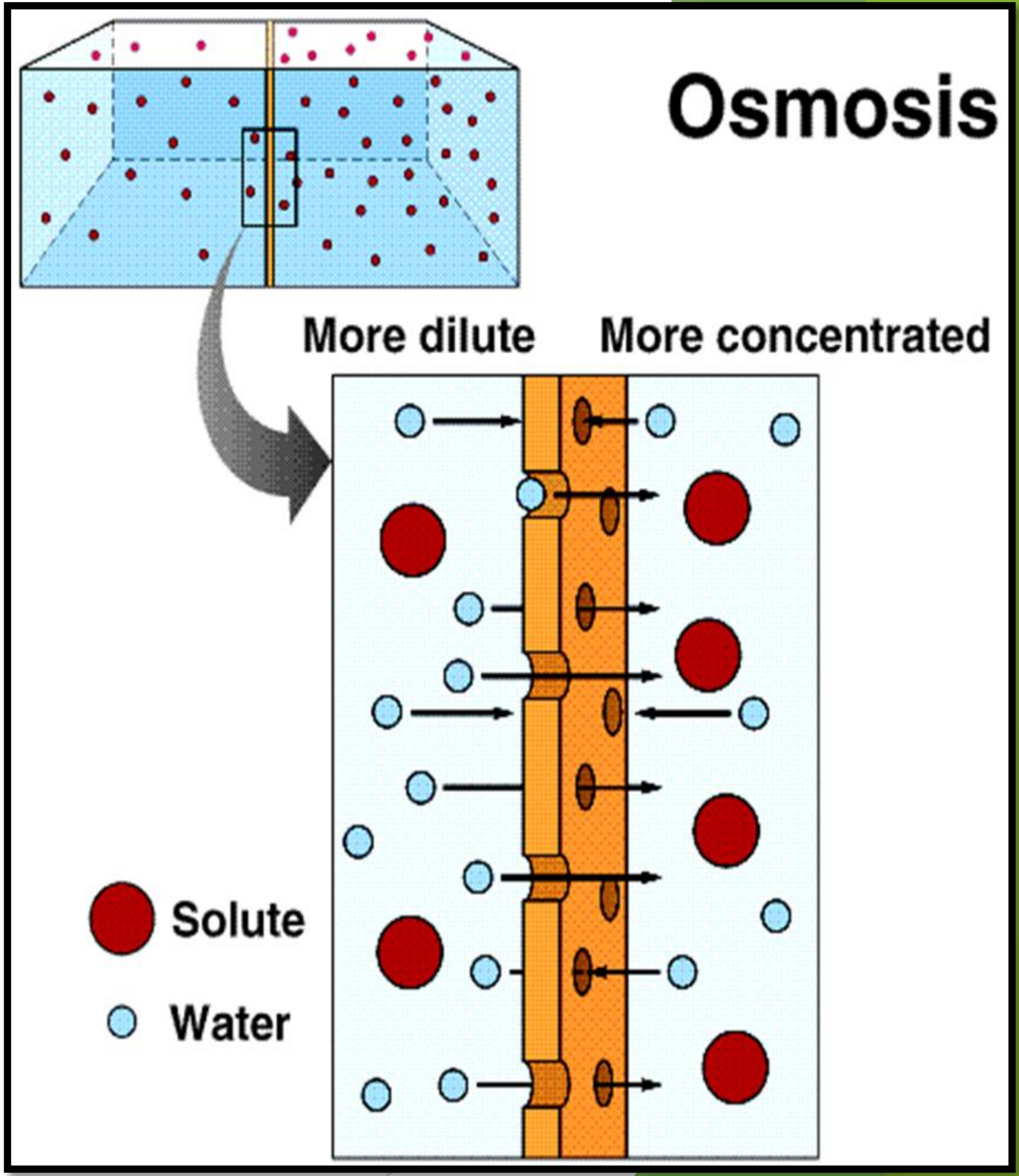
- Dependent upon:
  - The magnitude of concentration gradient.
    - Driving force of diffusion.
  - Permeability of the membrane.
    - Neuronal cell membrane 20 x more permeable to K^+ than Na^+.
  - Temperature.
    - Higher temperature, faster diffusion rate.
  - Surface area of the membrane.
    - Microvilli increase surface area

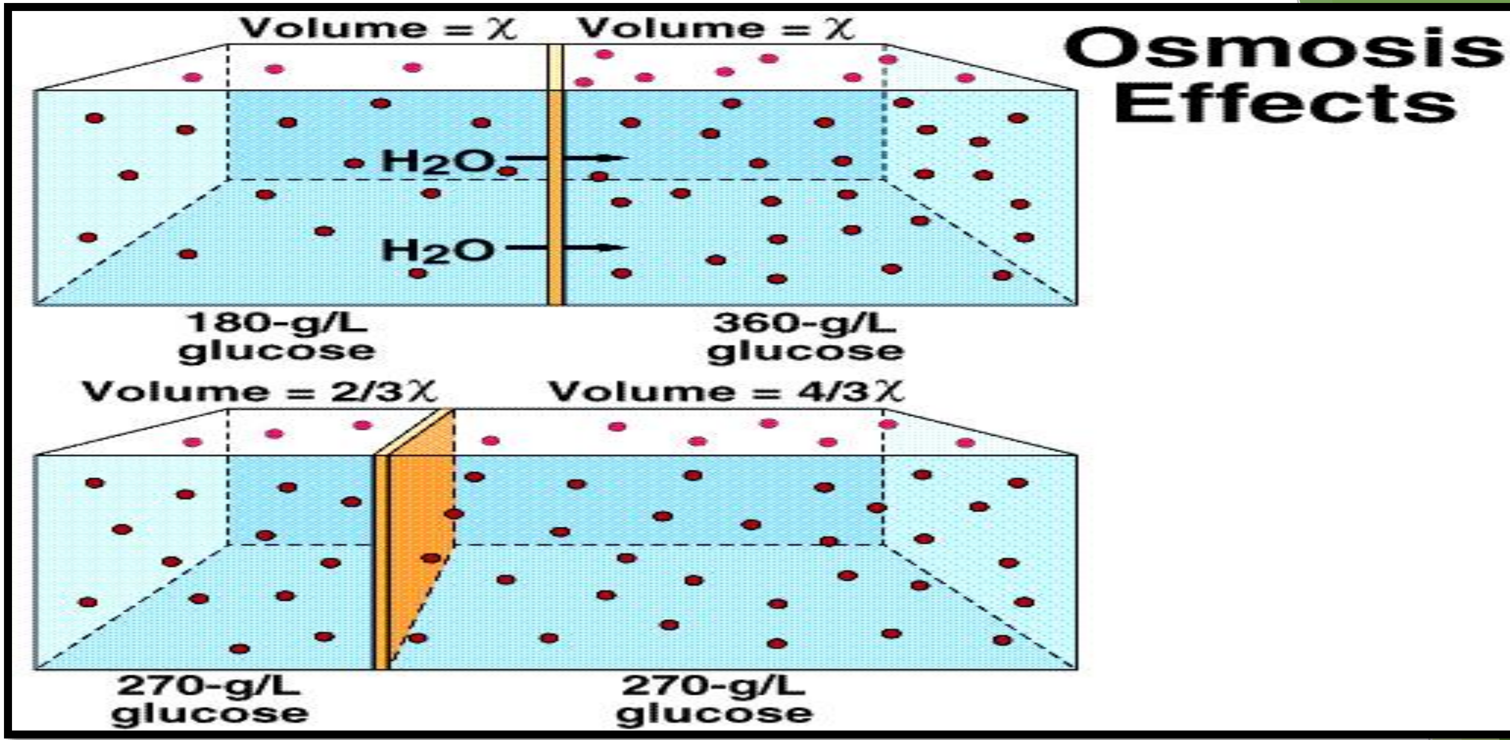
Osmosis

- Net diffusion of H_20 across a selectively permeable membrane.
- 2 requirements for osmosis:
  - Must be difference in solute concentration on the 2 sides of the membrane.
  - Membrane must be impermeable to the
  - solute.
  - Osmotically active solutes: solutes that cannot pass freely through the membrane.

Effects of Osmosis

Movement of H20 form high concentration of H20 to lower concentration of H20.

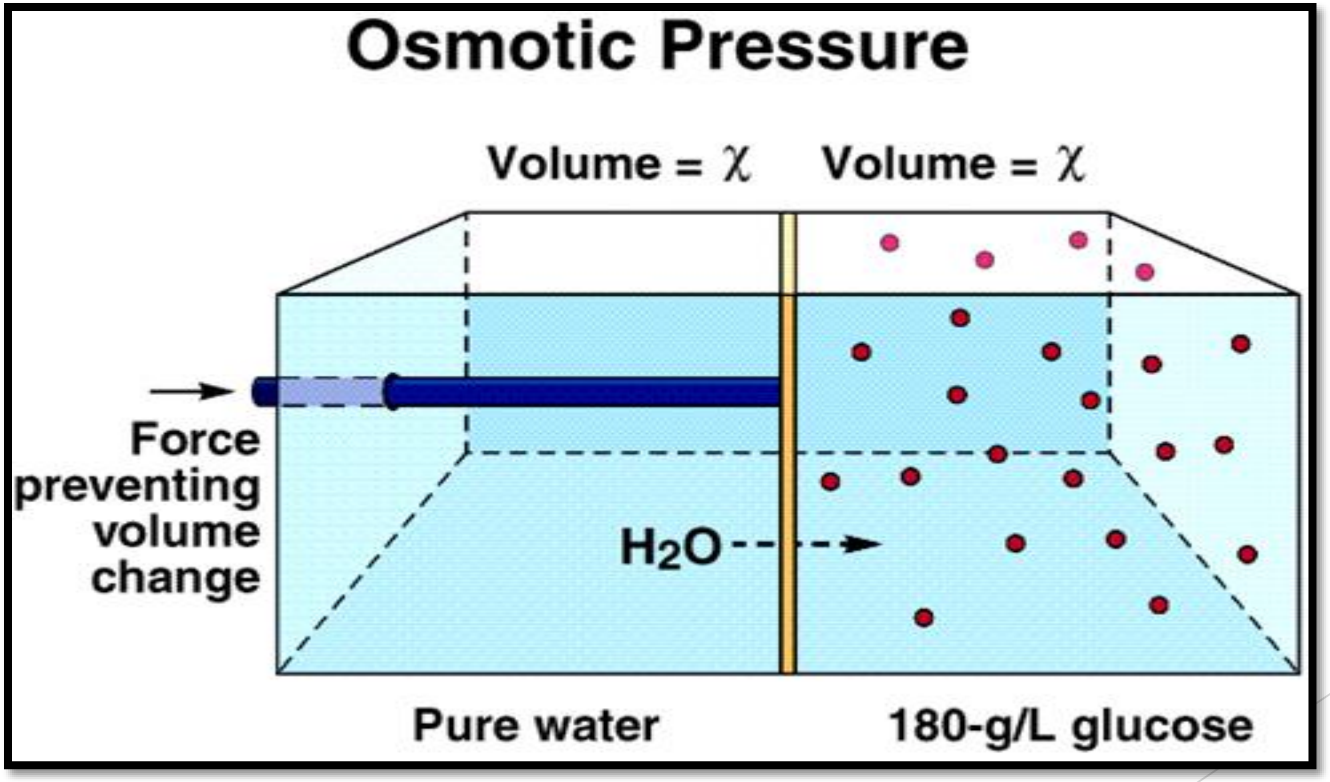


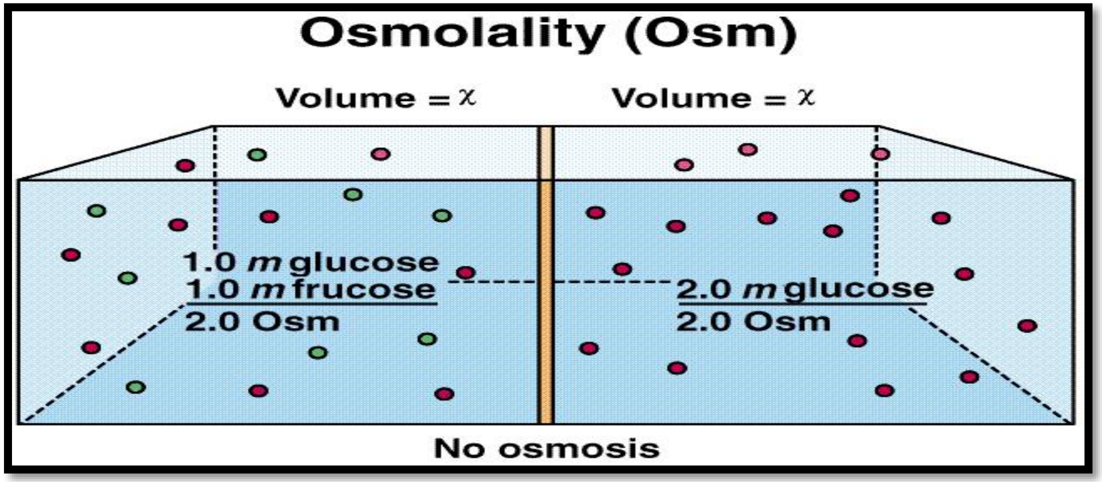


$H_2 0$ moves by osmosis into the lower $H_2 0$ concentration until equilibrium is reached (270 g/l glucose).

The force that would have to be exerted to prevent osmosis.

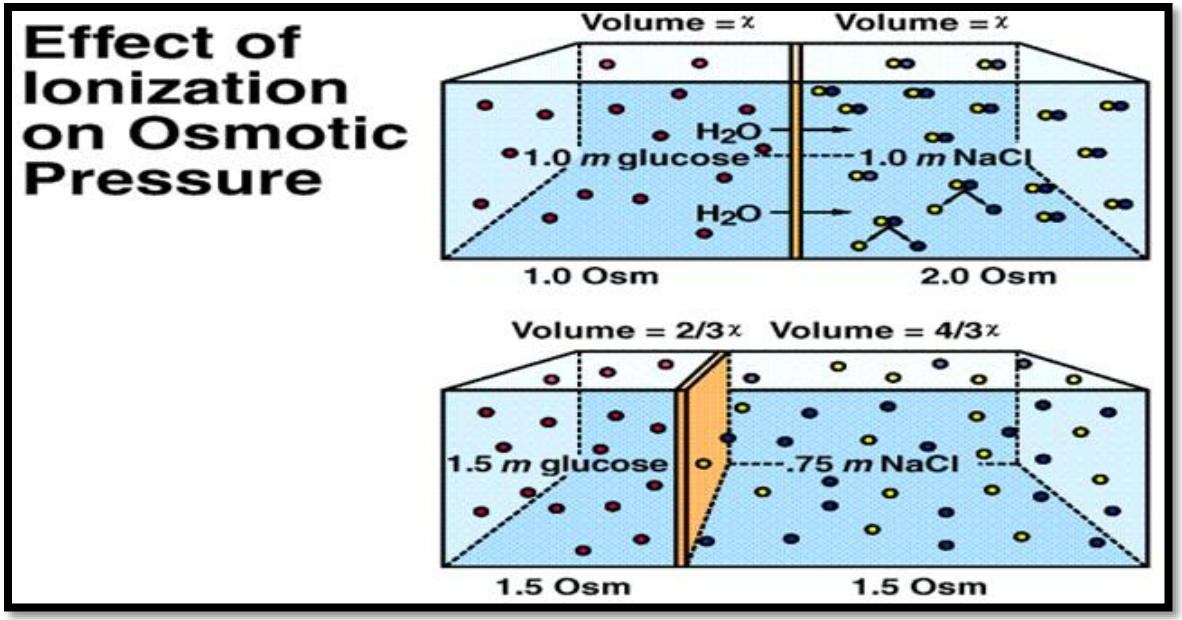
Indicates how strongly the solution "draws" H20 into it by osmosis.





Molality and Osmolality

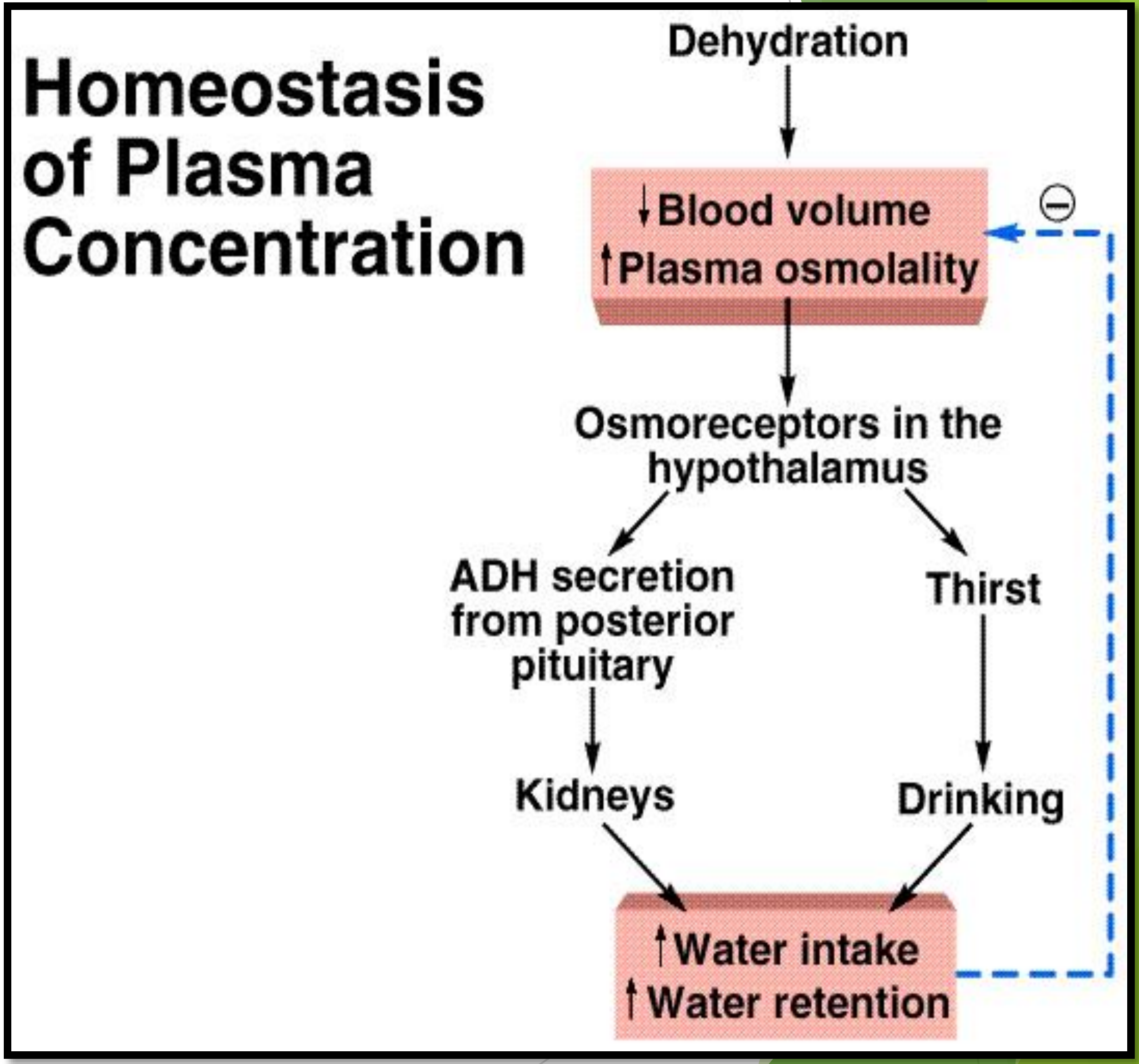
- Ratio of solute to H_20 critical to osmosis.
- Use molality (1.0 m):
  - 1 mole of solute is dissolved in 1 kg H_20.
- Osmolality (Osm):
  - Total molality of a solution.
- Plasma osmolality = 300 mOsm/l.



- **NaCl ionized when dissolved in H_20 forms 1 mole of Na^+ and 1 mole of Cl^-, thus has a concentration of 2 Osm.**
- **Glucose when dissolved in H_20 forms 1 mole, thus has a concentration of 1 Osm.**

Regulation of Plasma Osmolality

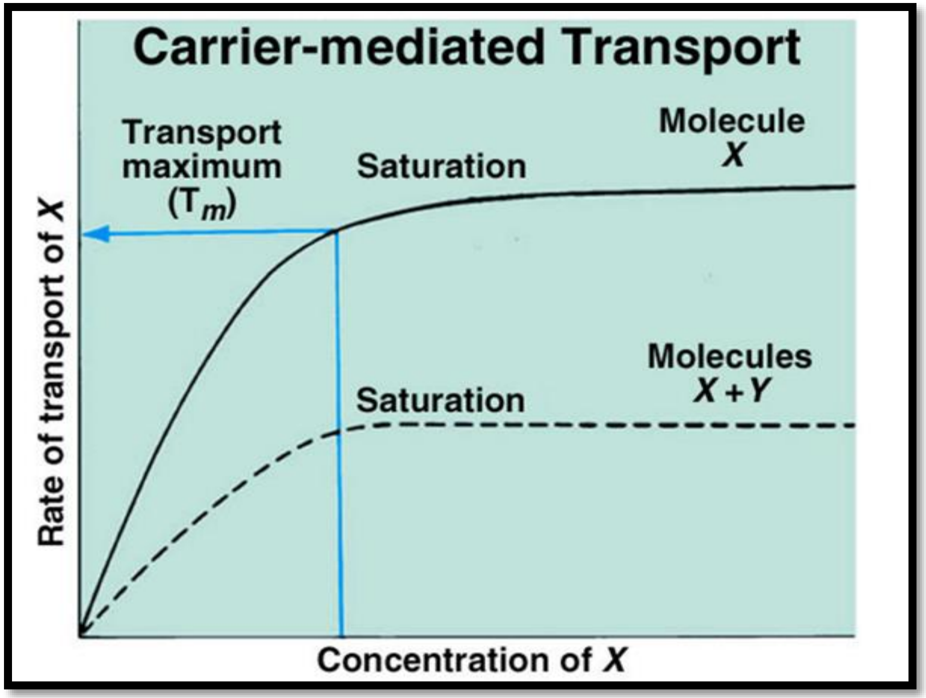
- Maintained in narrow range.
- Reguatory Mechanisms:
- Osmoreceptors stimulate hypothalamus:
  - ADH released.
  - Thirst increased.



Tonicity

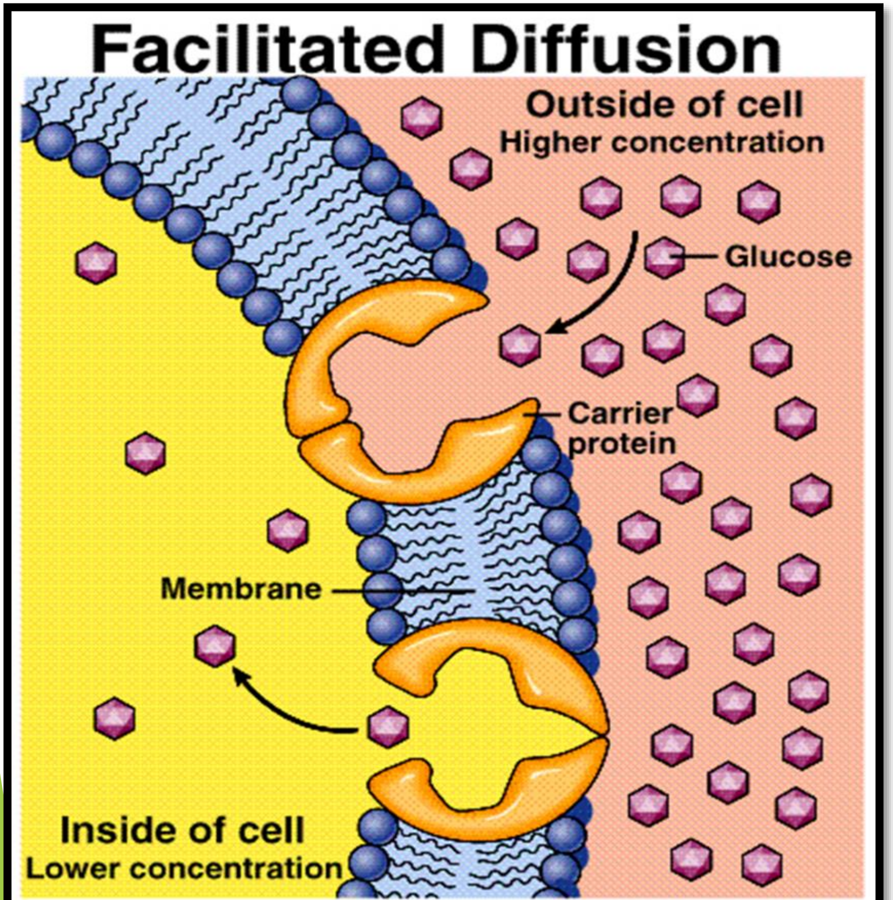
- The effect of a solution on the osmotic movement of H_20.
- Isotonic:
  - Equal tension to plasma.
  - RBCs will not gain or lose H_20.
- Hypotonic:
  - Osmotically active solutes in a lower osmolality and osmotic pressure than plasma.
  - RBC will hemolyse.
- Hypertonic:
  - Osmotically active solutes in a higher osmolality and osmotic pressure than plasma.
  - RBC will crenate.

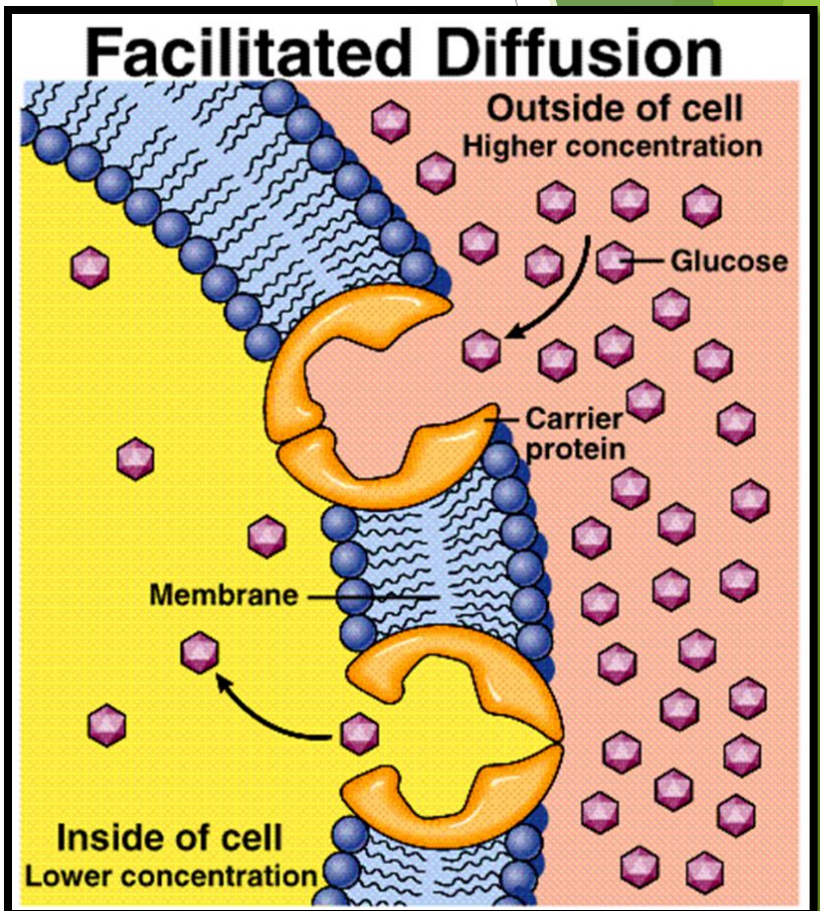
- **Transport across cell membrane by protein carriers.**
- Characteristics of protein carriers:
  - Specificity:
    - Interact with specific molecule only.
  - Competition:
    - Molecules with similar chemical structures compete for carrier site.
  - Saturation:
    - Carrier sites filled.



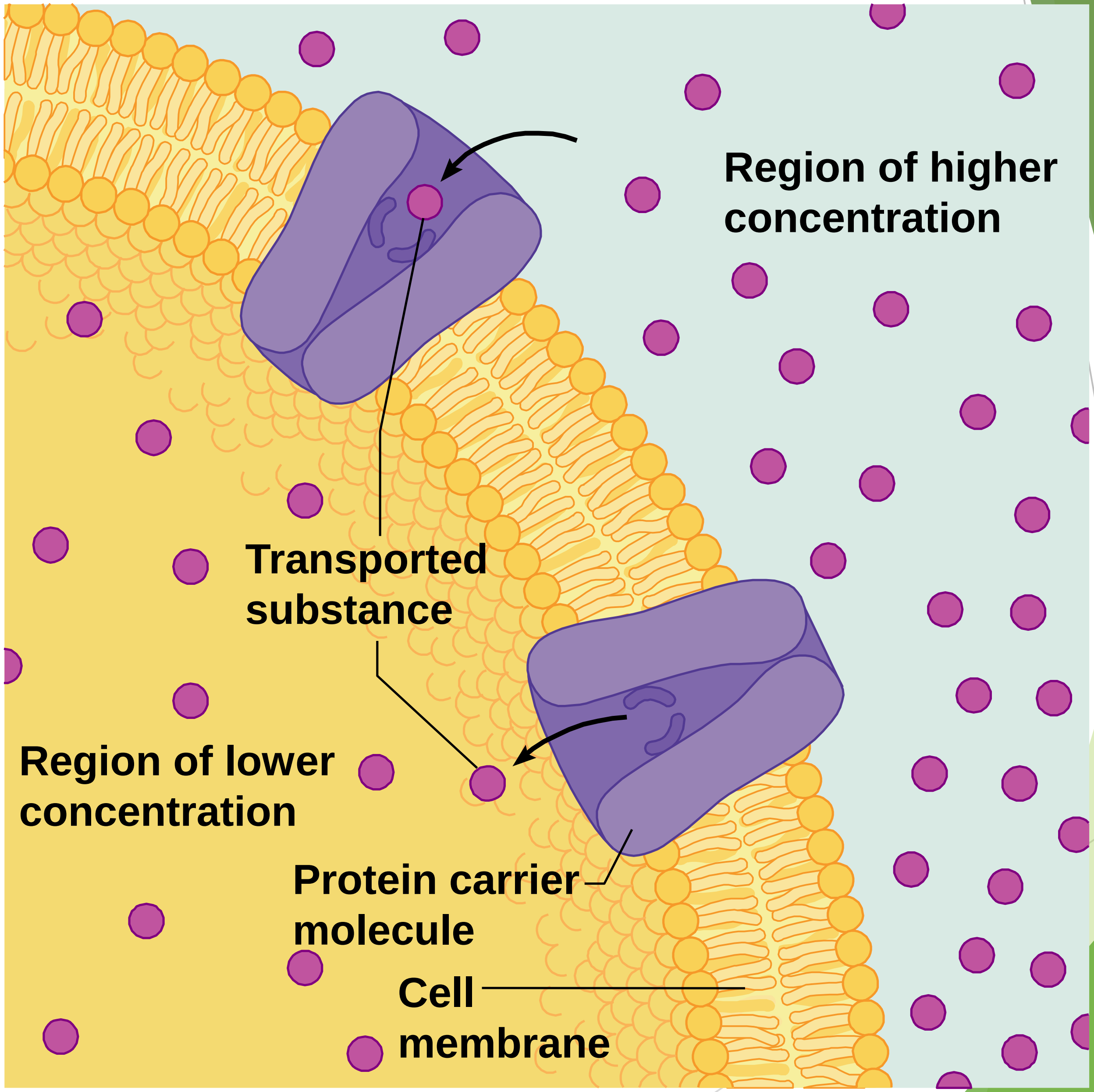
- **Transport maximum (Tm):**
  Carriers have become saturated.
- **Competition:**
  Molecules X and Y compete for same carrier.

- **Facilitated diffusion:**
- **Passive:**
  - ATP not needed. Powered by thermal energy.
  - Involves transport of substance through cell membrane from higher to lower concentration.



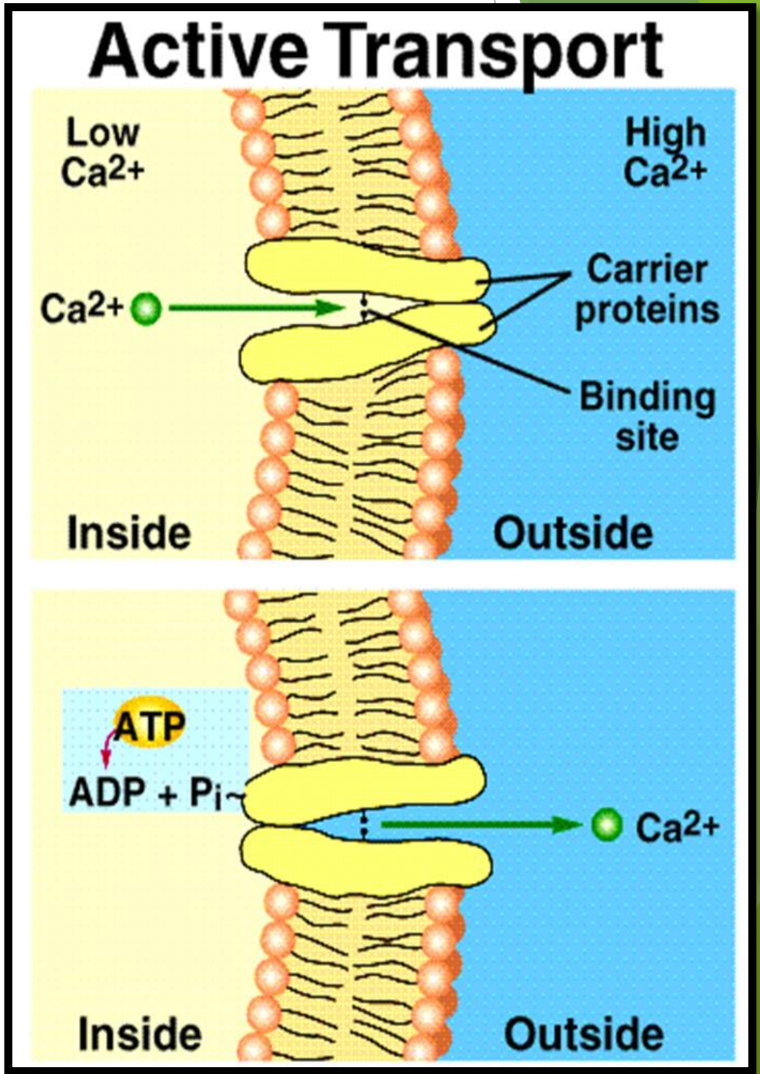


Facilitated diffusion



Active Transport

- Movement of molecules and ions against their concentration gradients.
  - From lower to higher concentrations.
- Requires ATP.
- 2 Types of Active Transport:
  - Primary
  - Secondary

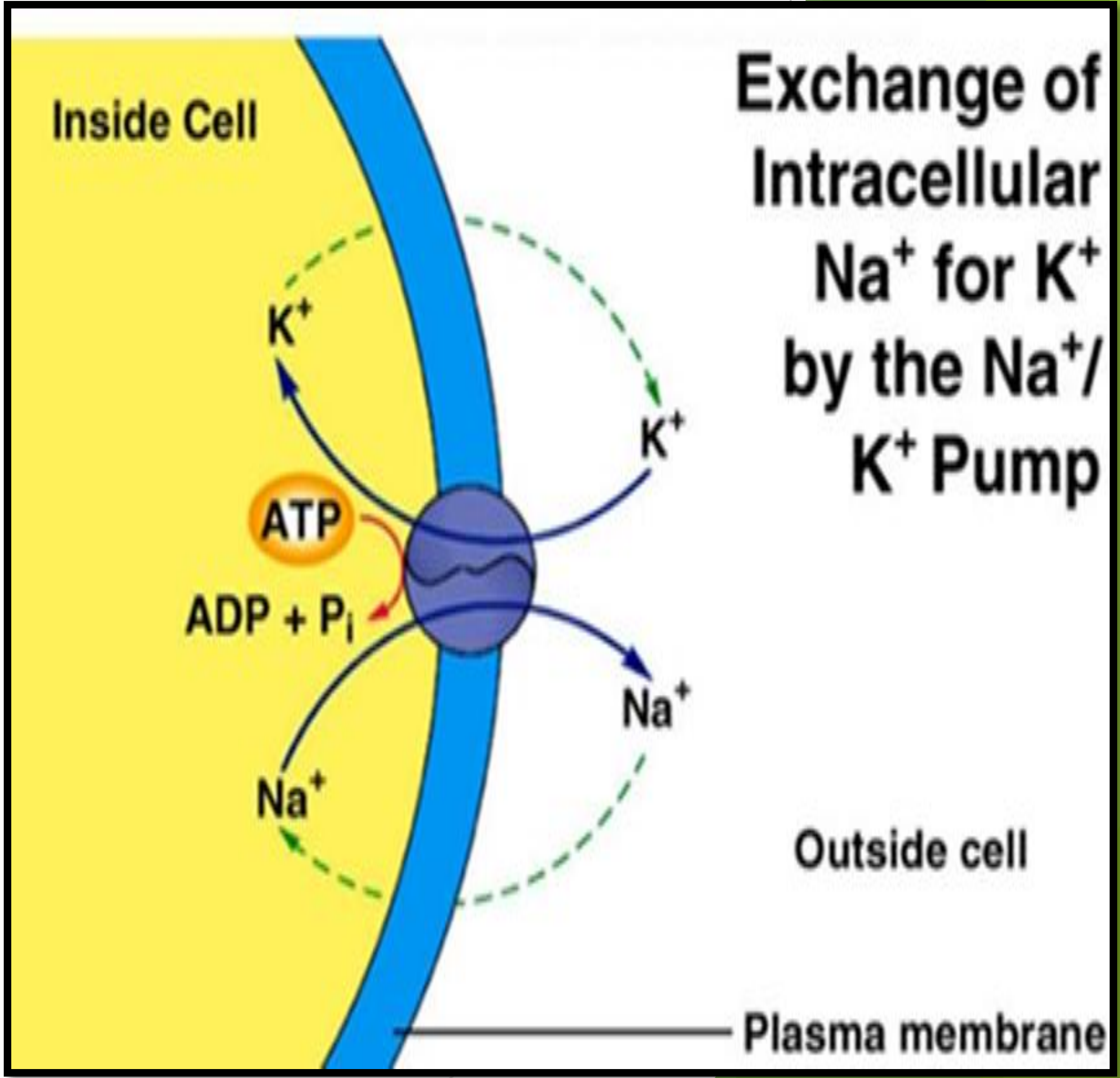


Primary Active Transport

- **ATP directly required for the function of the carriers.**
- **Molecule or ion binds to carrier site.**
- **Binding stimulates phosphorylation (breakdown of ATP).**
- **Conformational change moves molecule to other side of membrane.**

Na^+ - K^+ ATP-ase Pump

- Primary active transport.
- Carrier protein is also an
- ATP enzyme that converts
- ATP to ADP and p1



1. Three sodium ions (Na^+) and adenosine triphosphate (ATP) bind to the carrier protein.

2. The ATP breaks down to adenosine diphosphate (ADP) and a phosphate (P) and releases energy.

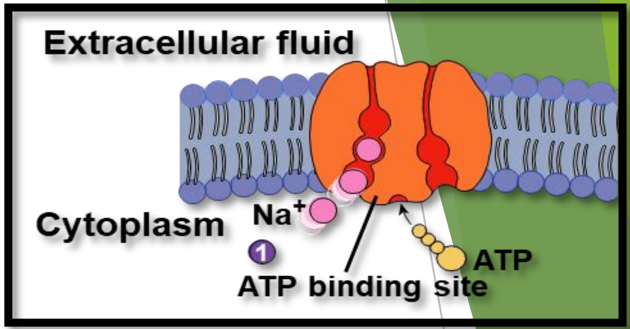
3. The carrier protein changes shape, and the Na^+ are transported across the membrane.

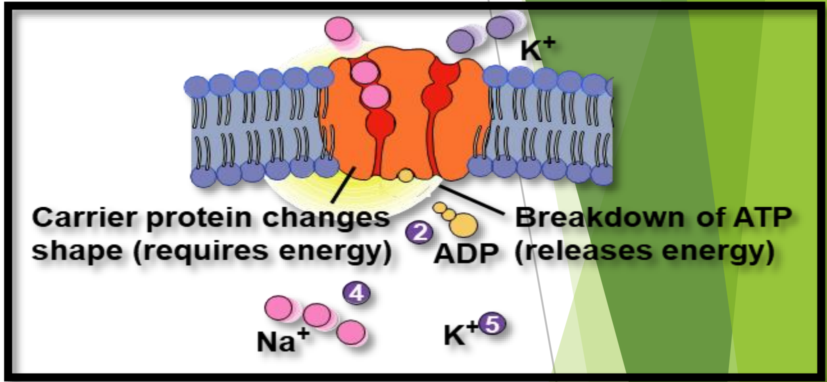
4. The Na^+ diffuse away from the carrier protein.

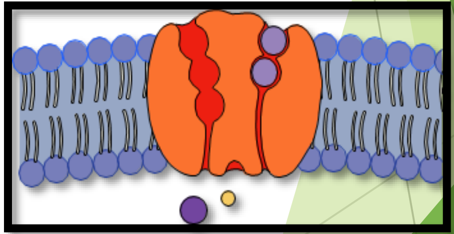
5. Tpotassium ions (K^+) bind to the carrier protein.wo

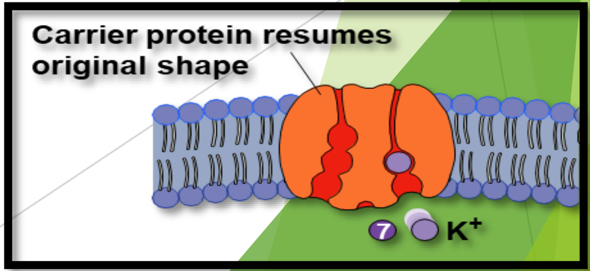
6. The phosphate is released.

7. The carrier protein changes shape, transporting K^+ across the membrane, and the K^+ diffuse away from the carrier protein. The carrier protein can again bind to Na^+ and ATP.





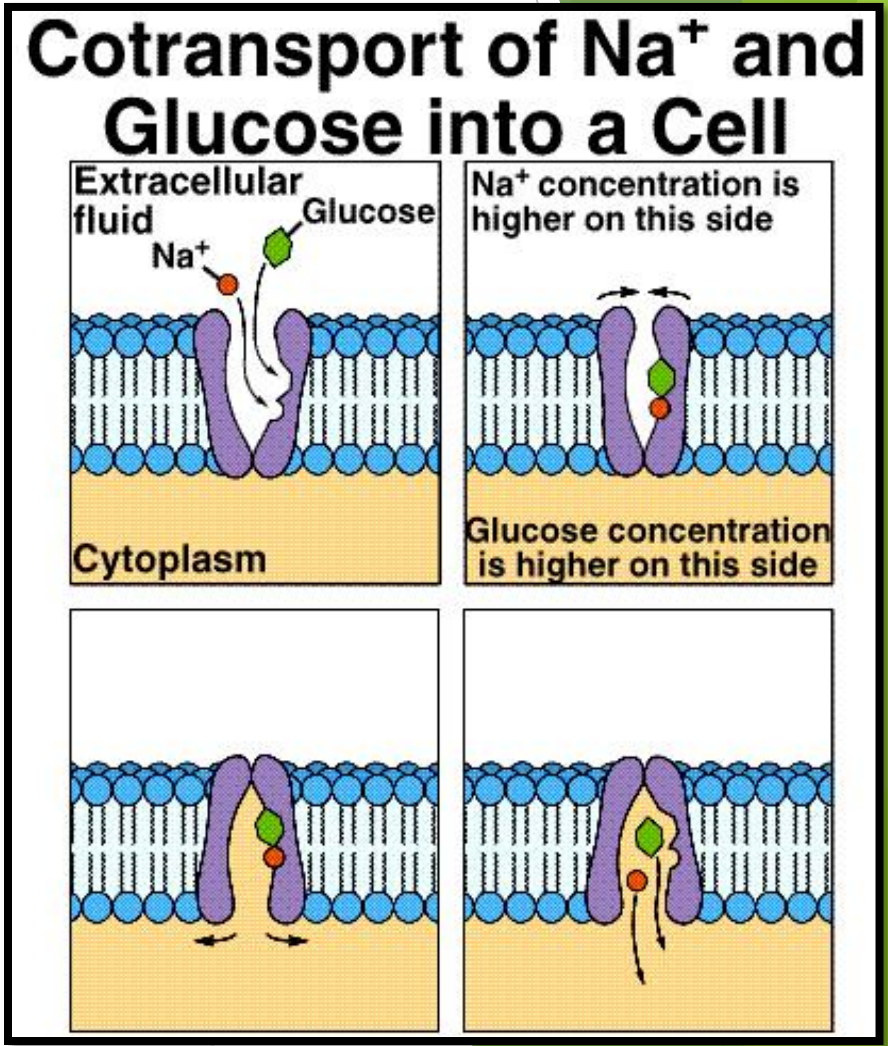




Secondary Active Transport

- Coupled transport.
- Energy needed for uphill movement obtained from downhill transport of Na^+.

- **Cotransport (symport):**
  - **Molecule or ion moving in the same direction.**
- **Countertransport (antiport):**
  - **Molecule or ion is moved in the opposite direction.**

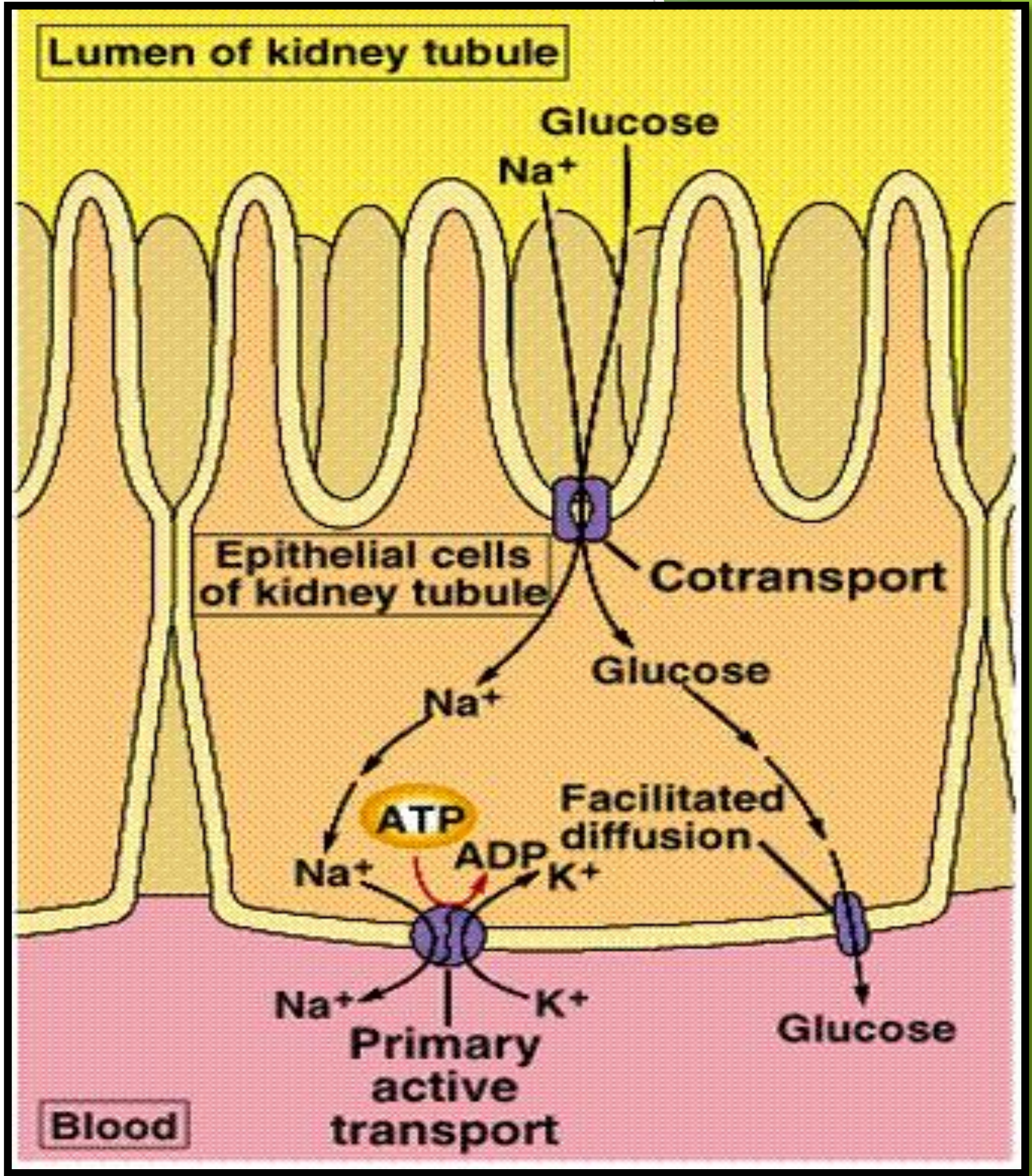


Membrane Transport of Glucose

- Glucose transport is an example of:
  - Cotransport
  - Primary active transport
  - Facilitated diffusion

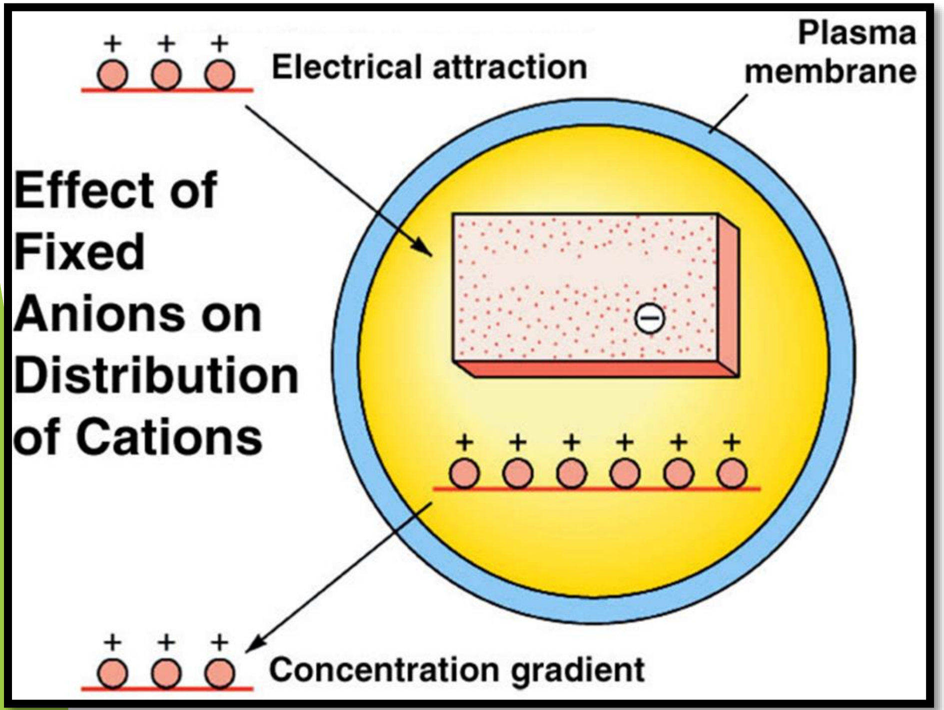
Bulk Transport

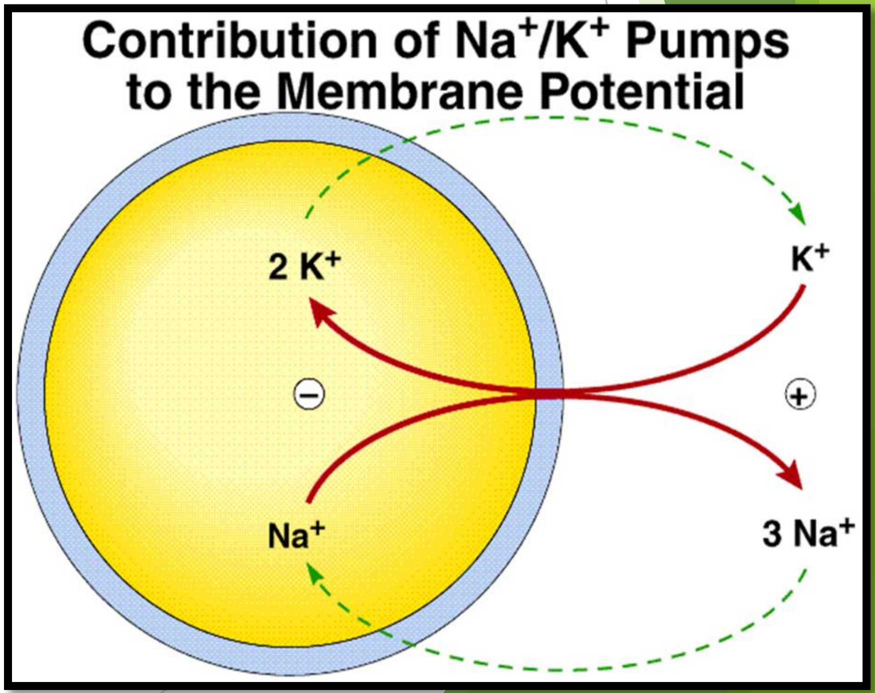
- Many large molecules are moved at the same time.
  - Exocytosis
  - Endocytosis



Membrane Potential

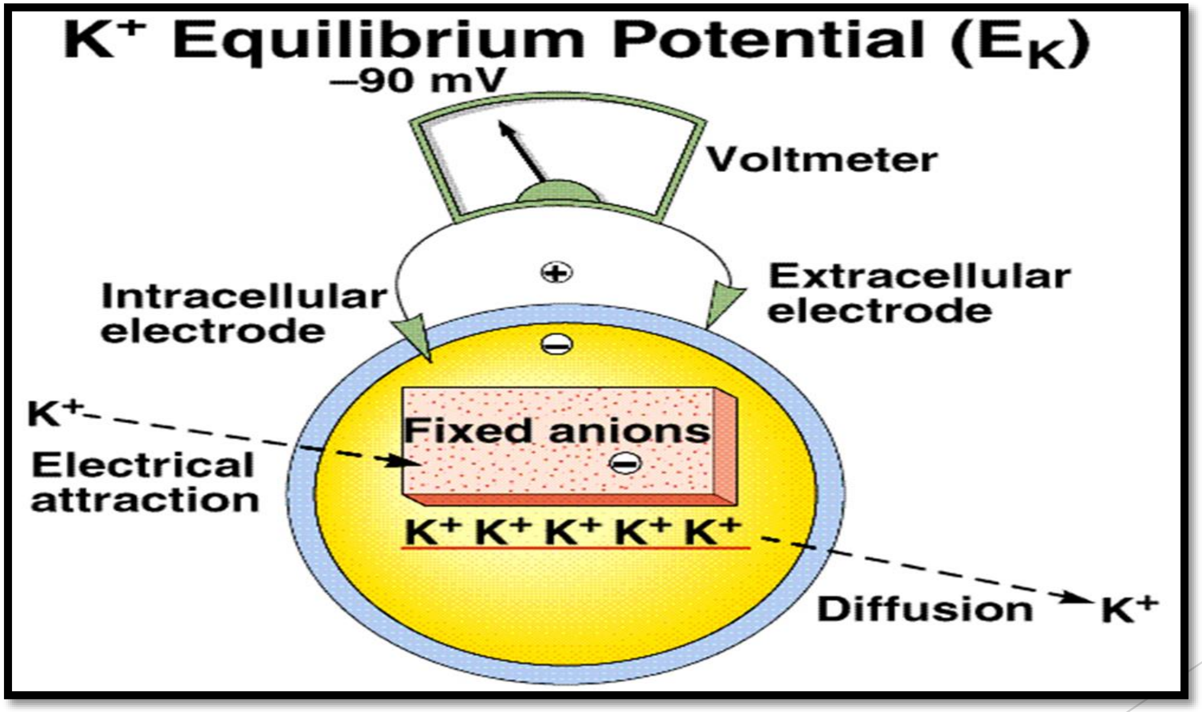
- Proteins and phosphates are negatively charged at normal cellular pH.
- These anions attract positively charged cations that can diffuse through the membrane pores.
- Membrane more permeable to K^+ than Na^+.
  - Concentration gradients for Na^+ and K^+.
- Na^+/ K^+ATP pump 3 Na^+ out for 2 K^+ in.
- All contribute to unequal charge across the membrane.





Equilibrium Potentials

- Theoretical voltage produced across the membrane if only 1 ion could diffuse through the membrane.
- Potential difference:
- Magnitude of difference in charge on the 2 sides of the membrane.



- **Potential difference of – 90 mV, if K^+ were the only diffusible ion.**

Nernst Equation

- Membrane potential that would exactly balance the diffusion gradient and prevent the net movement of a particular ion.
- Equilibrium potential for K^+ = - 90 mV.
- Equilibrium potential for Na^+ = + 65 mV.

Resting Membrane Potential

- Resting membrane potential is less than E_k because some Na^+ can also enter the cell.
- The slow rate of Na^+ efflux is accompanied by slow rate of K^+ influx.
- - 65 mV