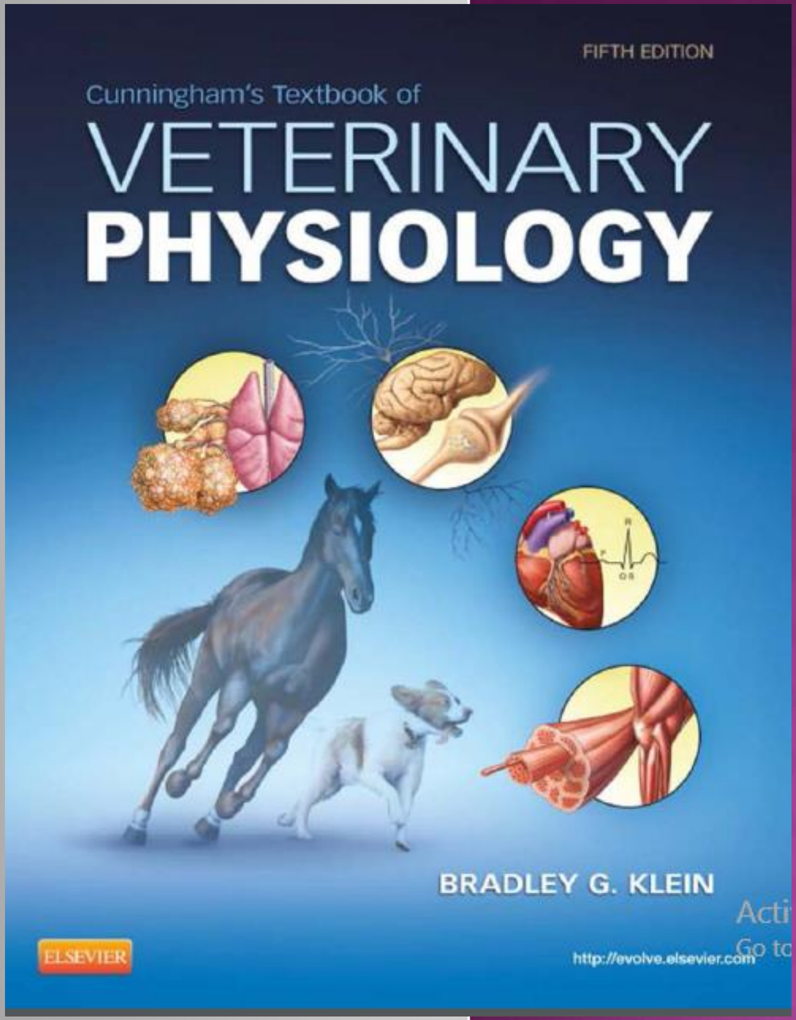
CELL PHYSIOLOGY

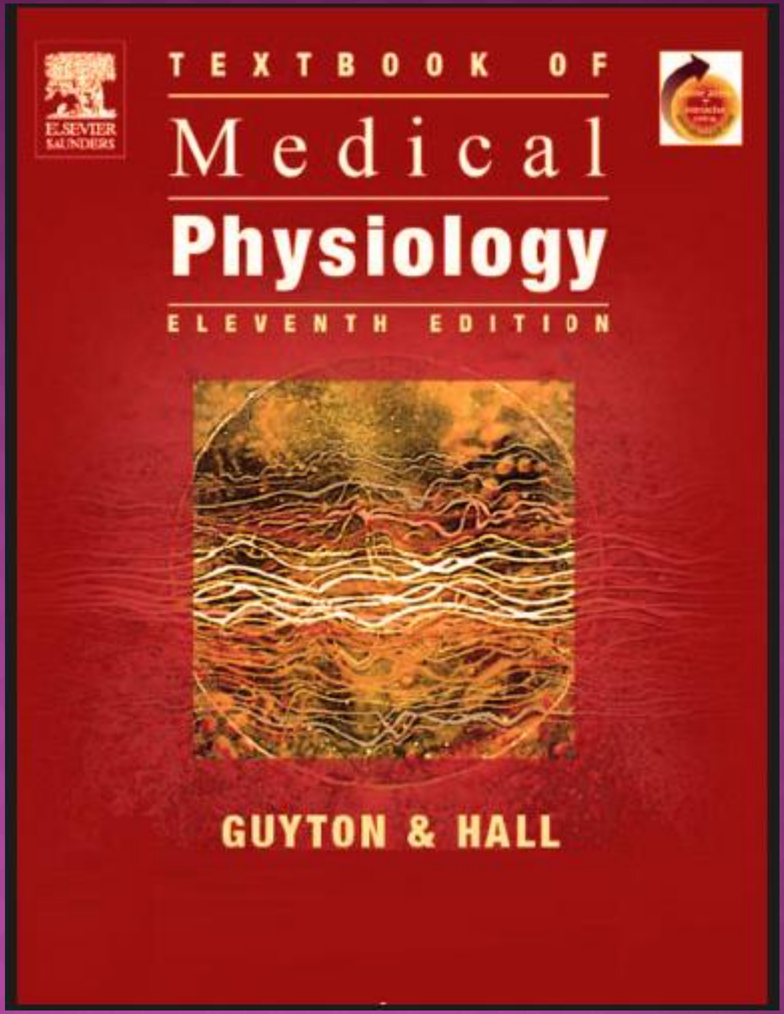
Dr. A. K.Goudrazi , D.V.M. Ph.D

Department of basic sciences

Faculty of veterinary medicine

I.A.University

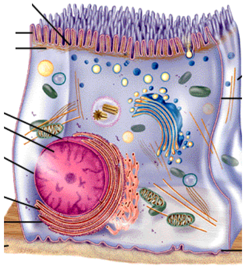




For PDF files, visit: www.kajalpetclinic.com

CONTENTS:

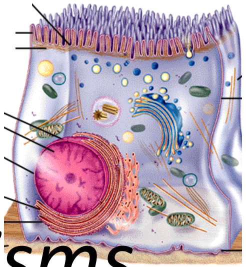
- *body cells*
- *plasma (cell) membrane*
- *cytoplasm and organelles*
- *cell nucleus*
- *body fluids*
- *transport through cell membrane*



Part 1:

BODY CELLS

BODY CELLS

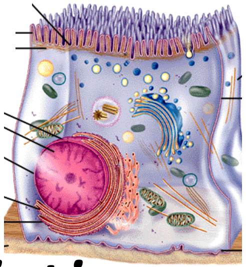


Physiology is the study of the regulation of change within organisms, in this case higher animals.

Cells are basic living unit of structure & function of the body.

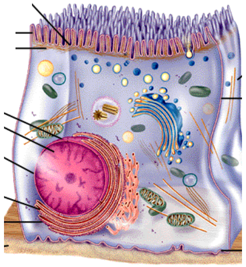
- *> 100 trillion cells in body.*
- *very small (10^{-5} m in diameter).*
- *highly organized.*
- *variety of shapes & sizes.*
- *each type of cells has a special fx.*

BODY CELLS

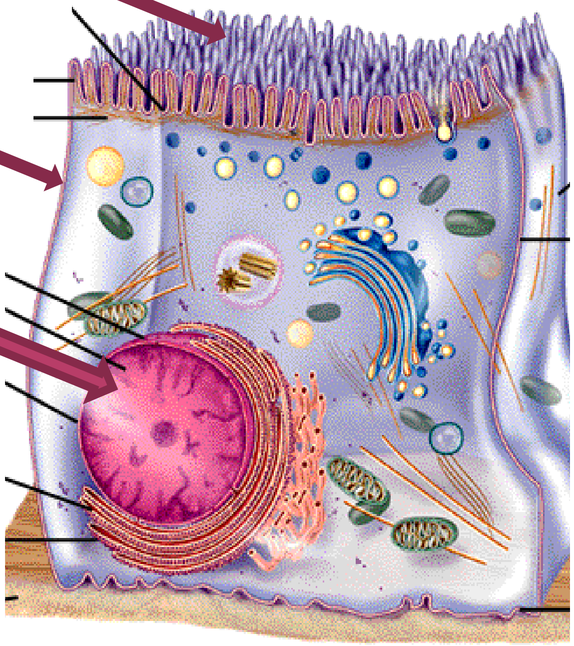


- *All Cells share certain characteristics:*
  - *general cell structure & components.*
  - *general mechanisms for changing nutrients to Energy.*
  - *deliver end products into their surrounding fluid.*
  - *almost all have the ability to reproduce.*

BODY CELLS



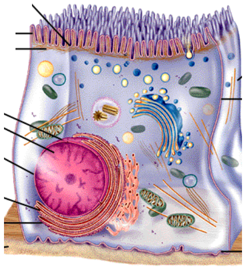
- 3 *principal parts:*
  - *Plasma (cell) membrane.*
  - *Cytoplasm & organelles.*
  - *Nucleus.*



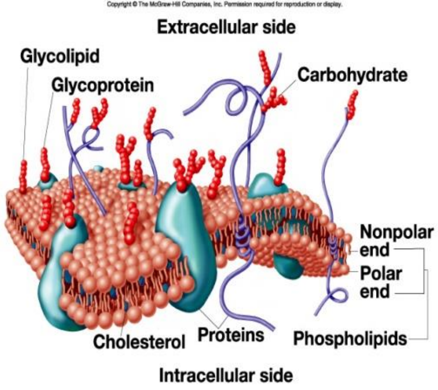
The cell has two major compartments: the nucleus & the cytoplasm.

The cytoplasm contains the major cell organelles & a fluid called cytosol.

GENERAL CELL STRUCTURE & FUNCTION



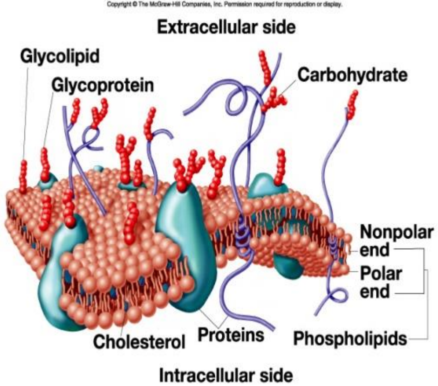
Component	Structure	Function
Plasma (cell) membrane	Membrane composed of double layer of phospholipids in which proteins are embedded	Surrounds, holds cell together & gives its form; controls passage of materials into & out of cell
Cytoplasm	Fluid, jellylike substance b/w cell membrane & nucleus in which organelles are suspended	Serves as matrix substance in which chemical reactions occur.
Nucleus:		
- Nuclear envelope	Double-layered membrane that surrounds nucleus, composed of protein & lipid molecules	Supports nucleus & controls passage of materials b/w nucleus & cytoplasm
- Nucleolus	Dense nonmembranous mass composed of protein & RNA molecules	Produces ribosomal RNA for ribosomes
- Chromatin	Fibrous strands composed of protein & DNA	Contains genetic code that determines which proteins (including enzymes) will be manufactured by the cell



Part 2:

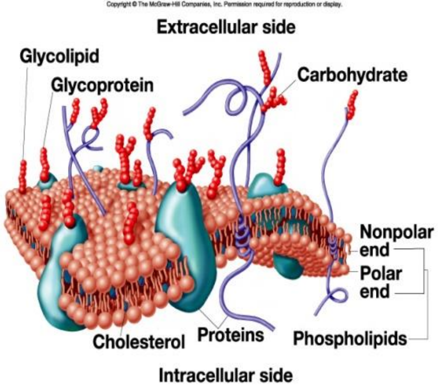
PLASMA (CELL) MEMBRANE

PLASMA (CELL) MEMBRANE

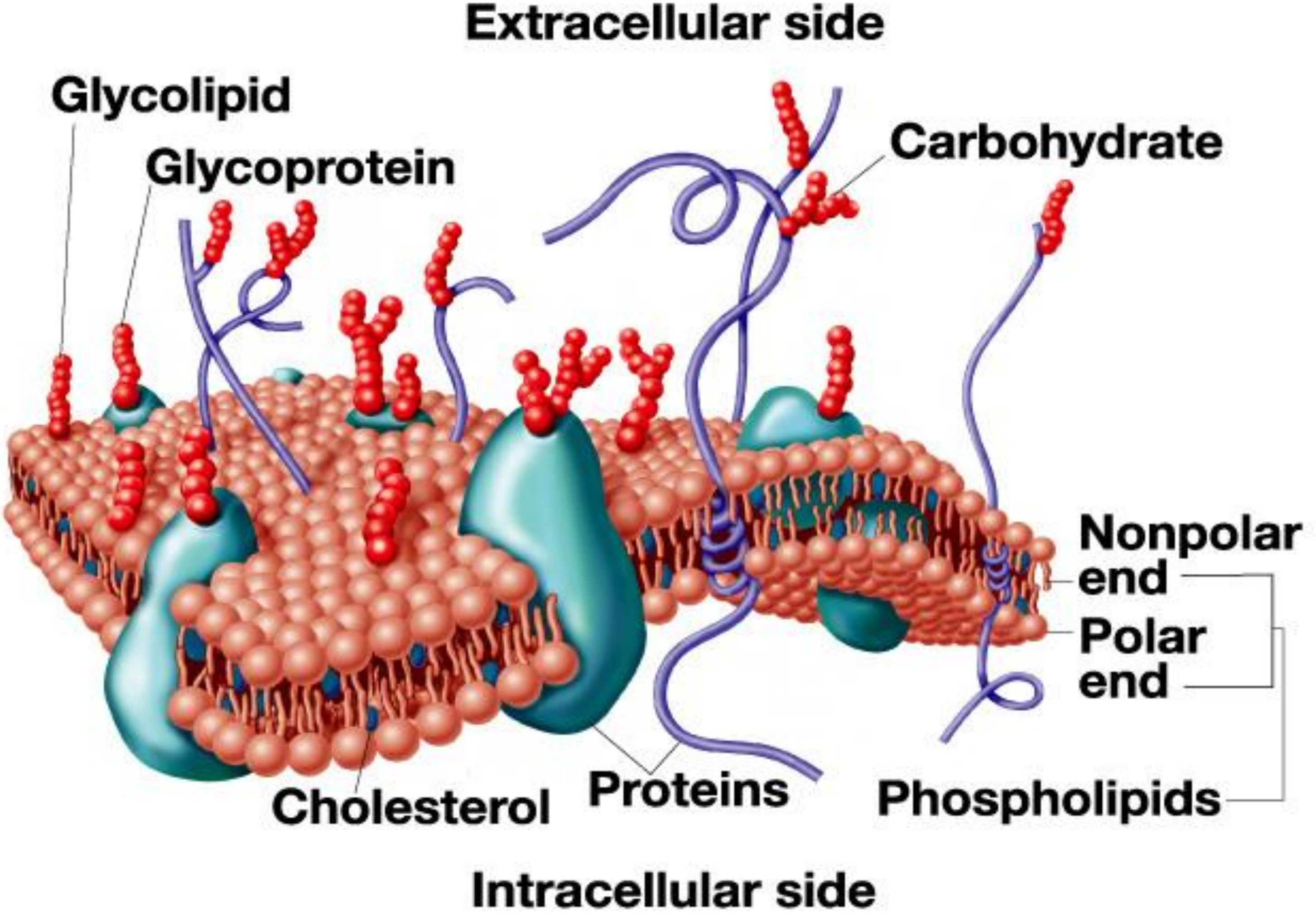


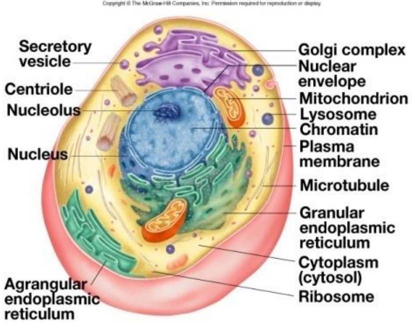
- *Surrounds, holds cell together & gives its form.*
- *10 nanometer thick.*
- *Not solid.*
- *Separates cell's internal structures from extracellular environment.*
- *Is selectively permeable, & controls passage of materials into & out of cell.*
- *Participates in intracellular communication.*

PLASMA (CELL) MEMBRANE



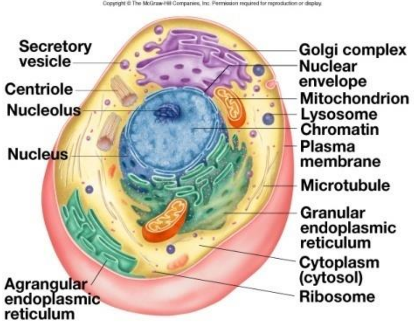
- *Composed of:*
  - *Double layer of phospholipids (hydrophobic/ hydrophilic parts).*
  - *Proteins span, or partially span the membrane.*
  - *Negatively charged carbohydrates attach to the outer surface.*


Extracellular side
Glycolipid
Glycoprotein
Carbohydrate
Nonpolar end
Polar end
Cholesterol
Proteins
Phospholipids
Intracellular side



Part 3:

CYTOPLASM & ORGANELLES



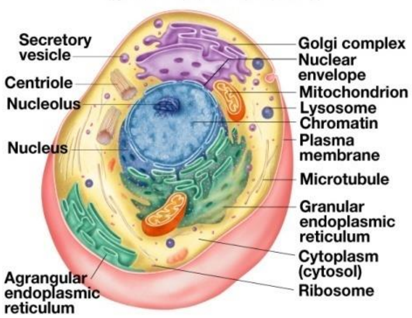
CYTOPLASM & ORGANELLES

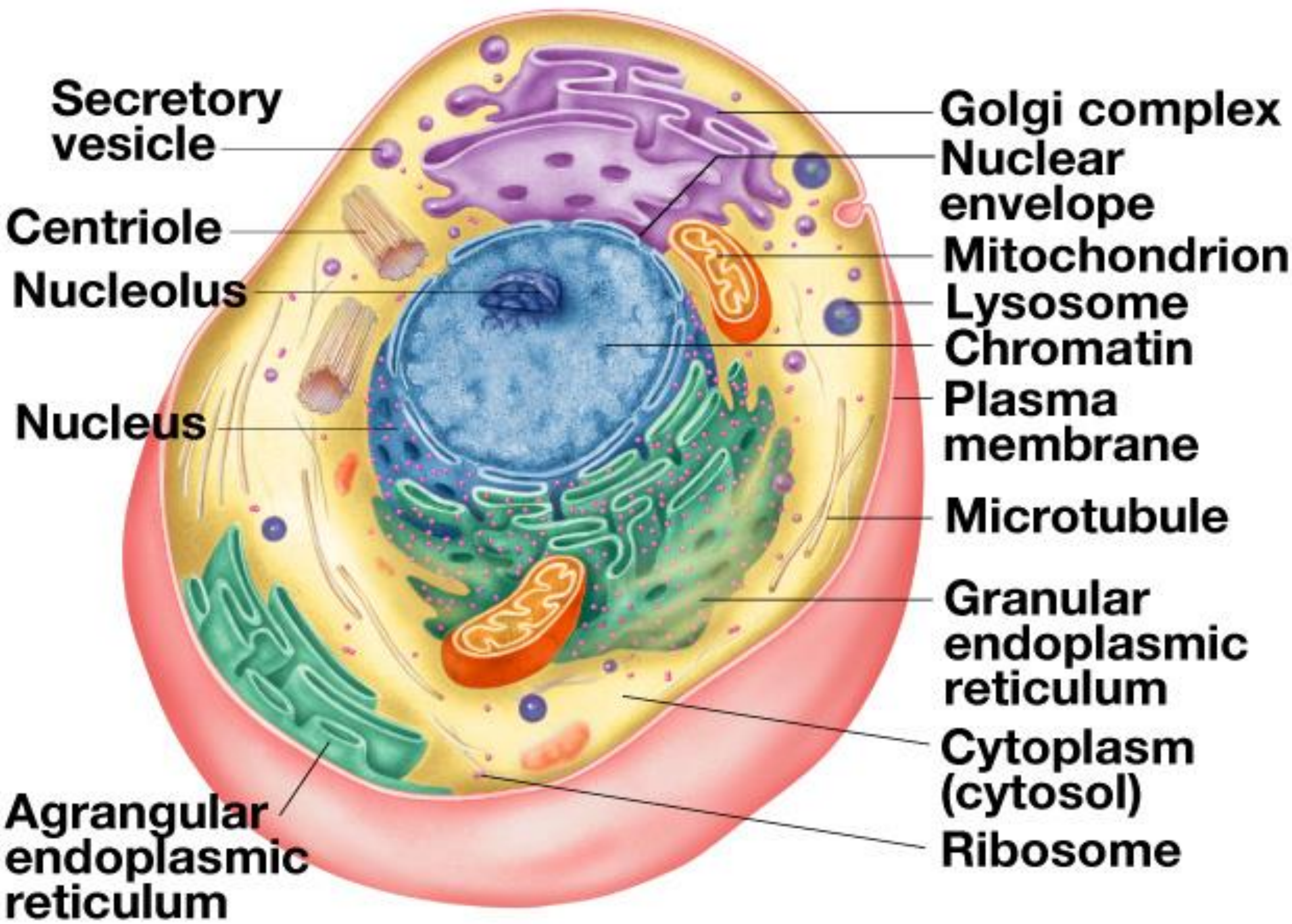
- *The aqueous content of a cell (fluid, jellylike substance), that lies b/w cell membrane & nucleus in which organelles are suspended.*

- *Serves as matrix substance in which chemical reactions occur.*

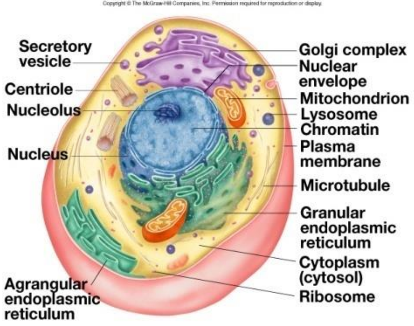
- *'cytosol' is the term used to describe fluid portion of the cytoplasm.*

ORGANELLES (EXCLUDING NUCLEUS)



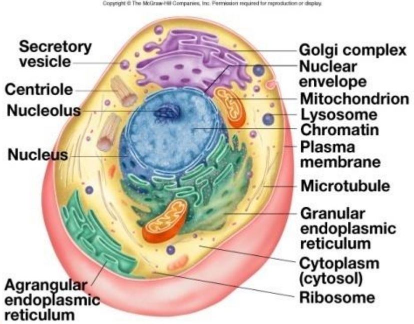


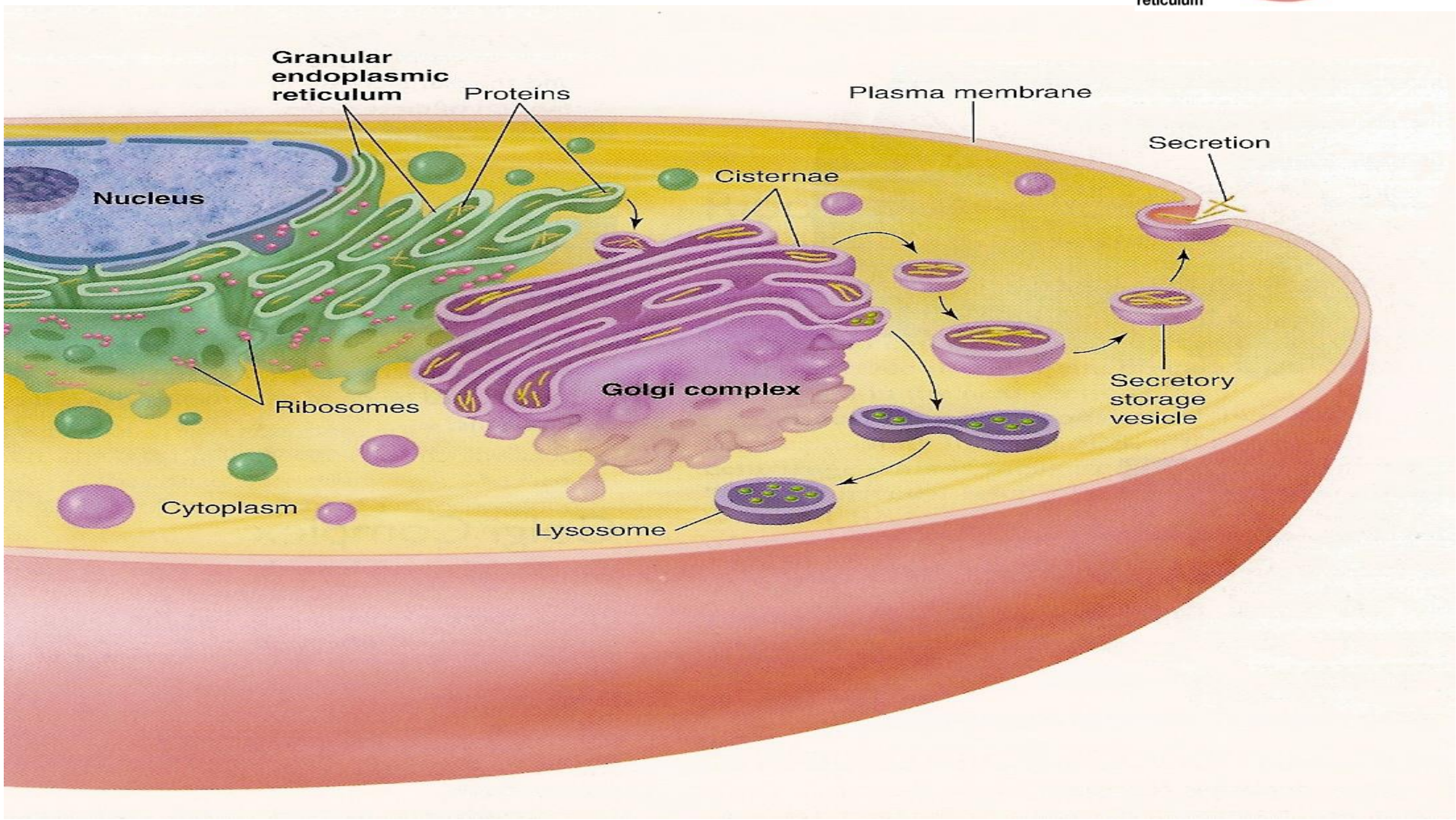
ORGANELLES
(EXCLUDING NUCLEUS)



Component	Structure	Function
Endoplasmic reticulum	System of interconnected membrane-forming canals & tubules	**Agranular** (smooth) ER metabolizes nonpolar compounds & stores Ca^{2+} in striated muscle cells; **granular** (rough) ER assists in protein sysnthesis
Ribosomes	Granular particles composed of protein & RNA	Synthesize proteins
Golgi complex	Cluster of flattened membranous sacs	Synthesizes carbohydrates & packages molecules for secretion. Secretes lipids & glycoproteins
Mitochondria	Membranous sacs w folded inner partitions	Release energy from food molecules & transform energy into usable ATP
Lysosomes	Membranous sacs	Digest foreign molecules & damaged organelles

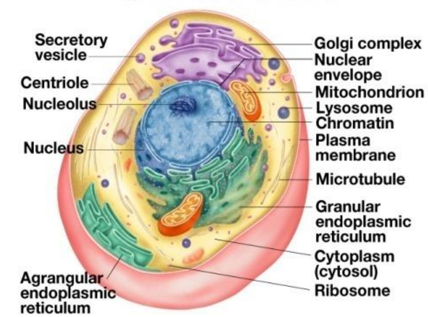
ORGANELLES (EXCLUDING NUCLEUS)

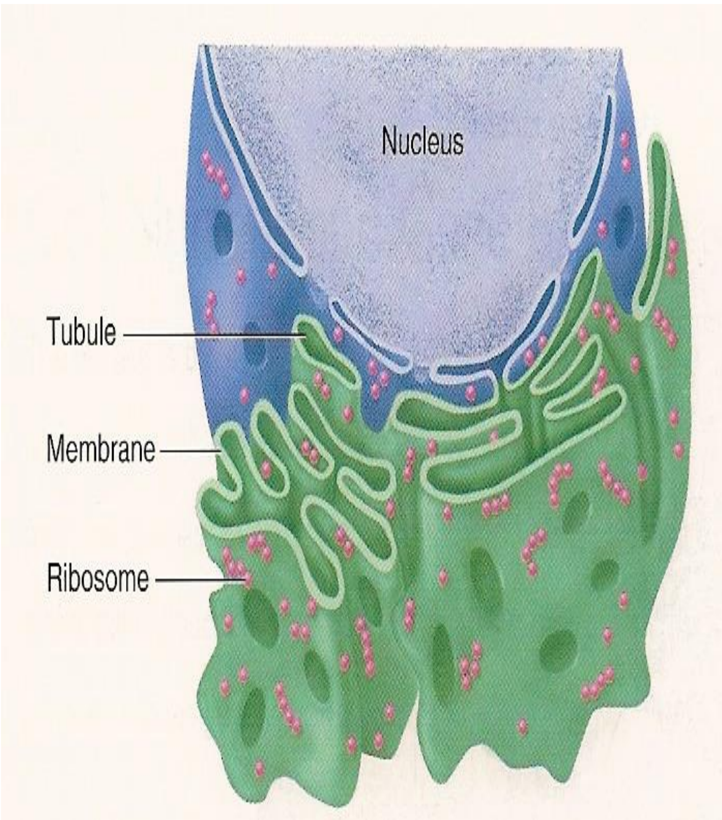


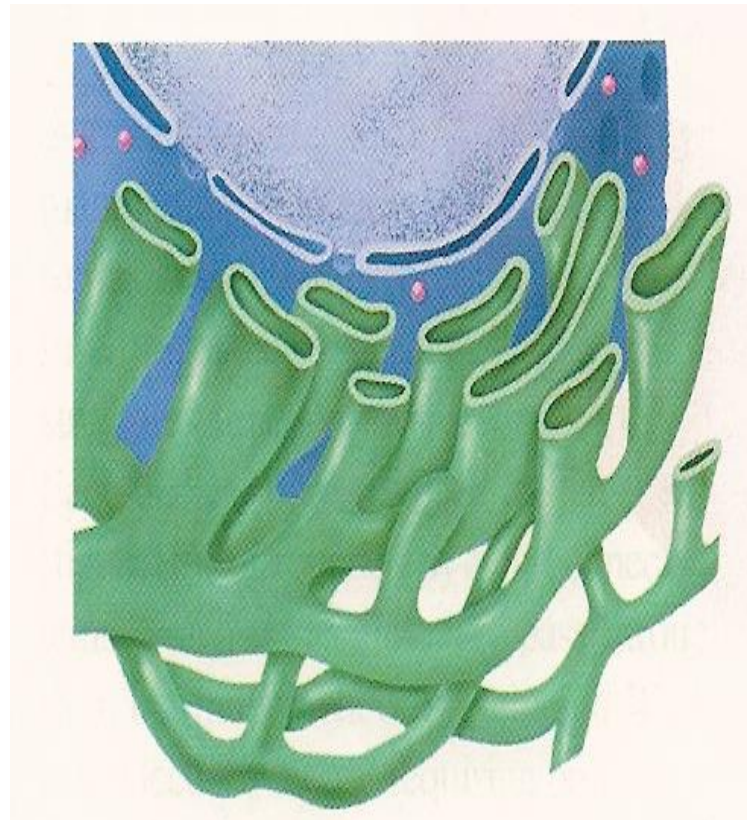


An illustration of the processing of proteins by the granular endoplasmic reticulum & Golgi complex. Notice the formation of vesicles at the ends of some of the flattened sacs of the Golgi complex.

ORGANELLES
(EXCLUDING NUCLEUS)

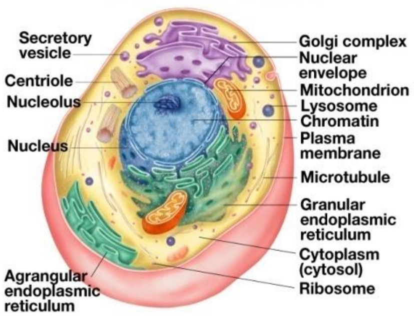


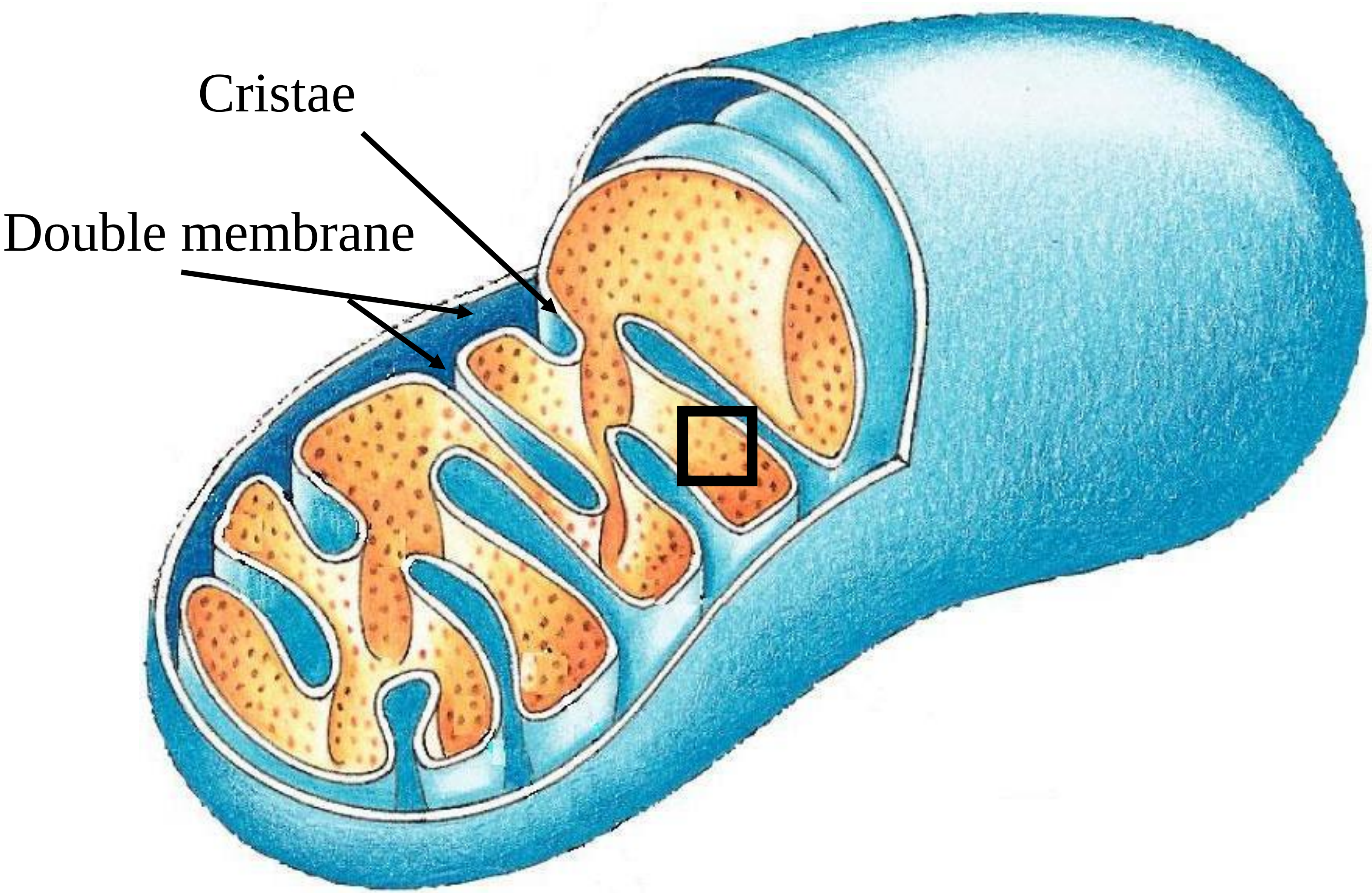




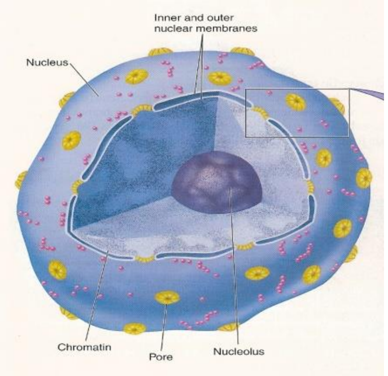
The endoplasmic reticulum. granular ER has ribosomes attached to its surface, whereas agranular ER lacks ribosomes.

ORGANELLES
(EXCLUDING NUCLEUS)





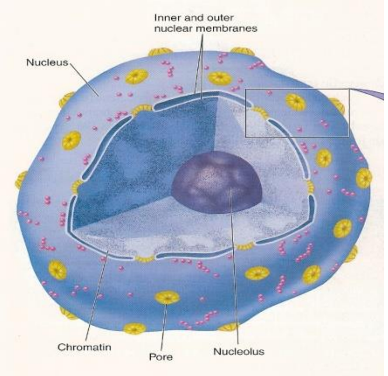

MATRIX



Part 4:

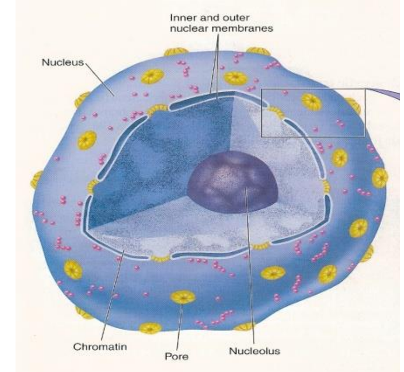
CELL NUCLEUS

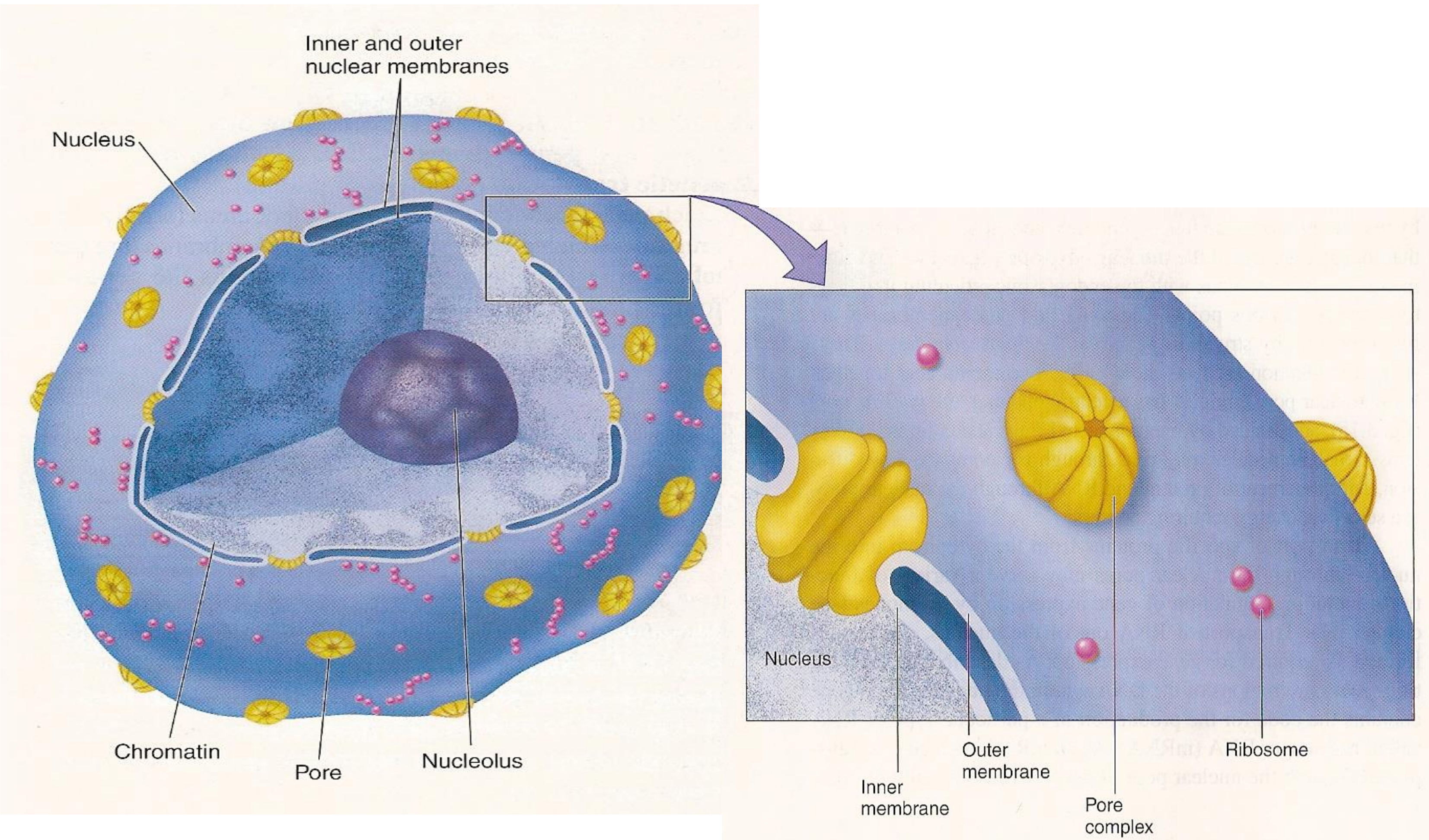
CELL NUCLEUS



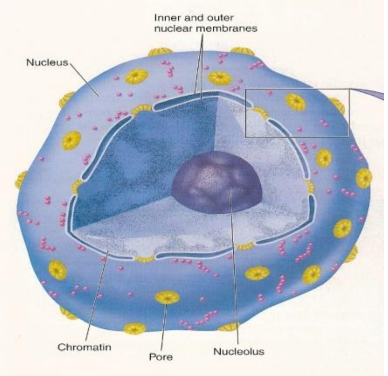
- *Is a large spheroid body.*
- *Largest of organelles.*
- *Contains the genetic material (DNA).*
- *Most cells have a single nucleus.*
- *Enclosed by inner & outer membrane (nuclear envelope).*
  - *Outer membrane is continuous w ER.*
- *Nuclear pore complexes fuse inner & outer membranes together.*
  - *Selective active transport of proteins & RNA.*

CELL NUCLEUS

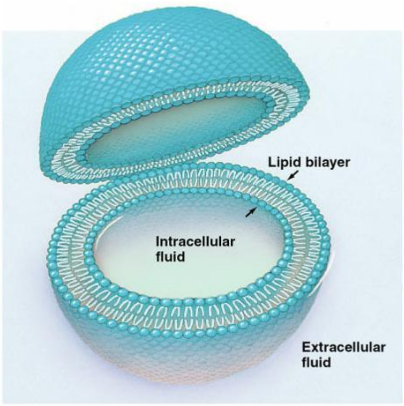




CELL NUCLEUS



- *Nucleoli:*
  - *Dark areas within the nucleus, not surrounded by membrane.*
  - *Centers for production of ribosomes.*
- *Chromatin:*
  - *Threadlike material that makes up chromosomes.*

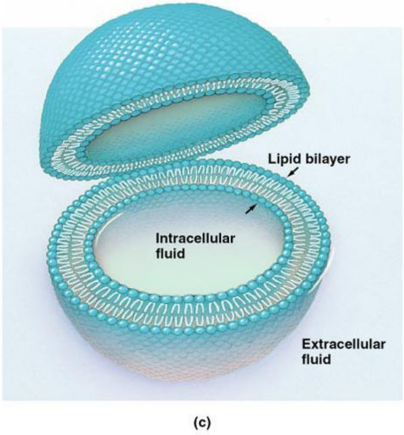


(c)

Part 5:

BODY FLUIDS

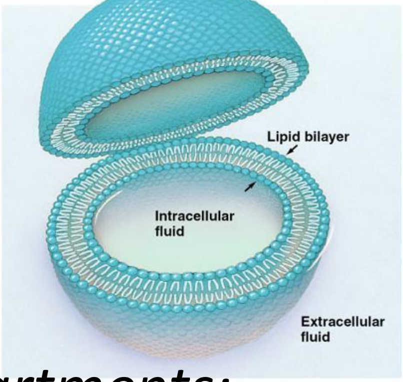
BODY FLUIDS



- *In average young adult male:*

Body composition	% of body weight
Protein, & related substances	**18%**
Fat	**15%**
Mineral	**7%**
Water	**60%**

BODY FLUIDS



- *Water content in body is divided into 2 compartments:*

  1. ***Extracellular fluid (ECF):*** *(internal environment or the milieu intérieur)*

     - fluid outside the cells.

     ≈1/3 volume of fluids in body (≈33% of total body water).

     - contains ions & nutrients needed for cellular life.

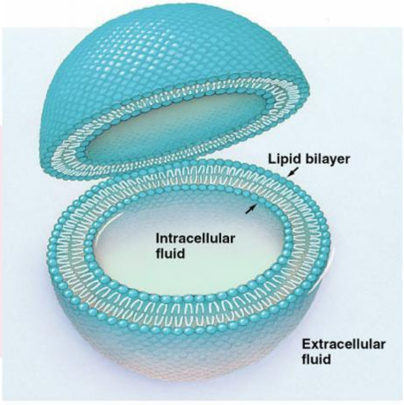
  2. ***Intracellular fluid (ICF):***

     - fluid inside the cells.

     ≈2/3 volume of fluids in body (≈67% of total body water).

FLUID COMPARTMENTS

≈ 60% OF BODY WEIGHT



(c)

Extracellular fluid
(≈ 1/3)
≈ 33% of TBW
≈ **20% of body wt**

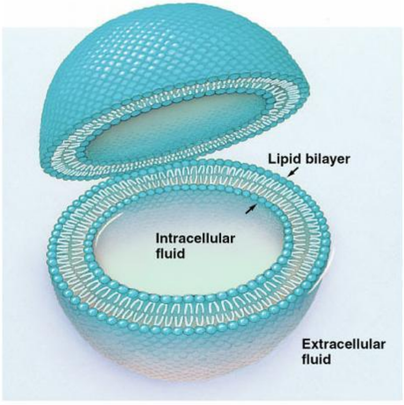
Intracellular fluid
(≈ 2/3)
≈ 67% of TBW
≈ **40% of body wt**

Plasma
≈ 25% of ECF
≈ **5% of body wt**

Interstitial fluid
≈75% of ECF
≈ **15% of body wt**

Transcellular fluid
- CSF
- Intraocular
- Pleural
- Peritoneal
- Pericardial
- Synovial
- Digestive secretions

BODY FLUIDS

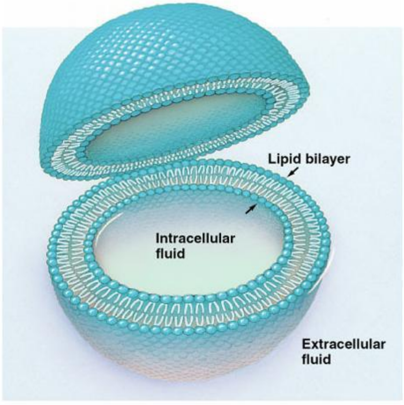


- *Example:*
  How to calculate total body water (TBW)?

Q. Calculate TBW for a 70 kg man.

- *TBW = 60% of body weight*
- *TBW = 60% X 70 = 42 L of water*

BODY FLUIDS



(c)

- *Differences between ECF & ICF*

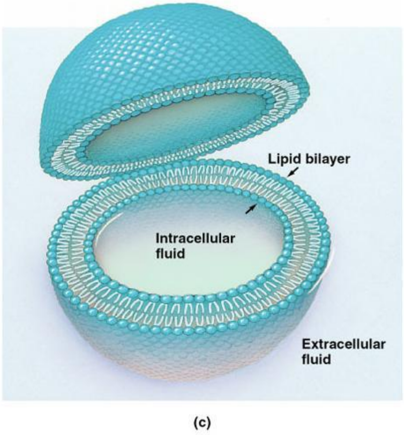
ECF	
Cations: Na$^+$ (142mmol/L) K$^+$ (4.2) Mg^{2+} (0.8)	**Anions:** Cl$^-$ (108) HCO_3^- (24)
Nutrients: O_2, glucose, fatty acids, & amino acids.	
Wastes: CO_2, Urea, uric acid, excess water, & ions.	

ICF	
Cations: Na$^+$ (14) K$^+$ (140) Mg^{2+} (20)	**Anions:** Cl$^-$ (4) HCO_3^- (10) **Phosphate ions**
Nutrients: High concentrations of proteins.	

	EXTRACELLULAR FLUID	INTRACELLULAR FLUID
Na^+	142 mEq/L	10 mEq/L
K^+	4 mEq/L	140 mEq/L
Ca^{++}	2.4 mEq/L	0.0001 mEq/L
Mg^{++}	1.2 mEq/L	58 mEq/L
Cl^-	103 mEq/L	4 mEq/L
HCO_3^-	28 mEq/L	10 mEq/L
Phosphates	4 mEq/L	75 mEq/L
SO_4^{--}	1 mEq/L	2 mEq/L
Glucose	90 mg/dl	0 to 20 mg/dl
Amino acids	30 mg/dl	200 mg/dl ?
Cholesterol, Phospholipids, Neutral fat	0.5 g/dl	2 to 95 g/dl
PO_2	35 mm Hg	20 mm Hg ?
PCO_2	46 mm Hg	50 mm Hg ?
pH	7.4	7.0
Proteins	2 g/dl (5 mEq/L)	16 g/dl (40 mEq/L)

	Concentration (mmol/L)		
	Intracellular	Extracellular	Blood Plasma
Na^+	15	140	142
K^+	150	5	4
Ca^{2+}	0.0001	1	2.5
Mg^{2+}	12	1.5	1.5
Cl^-	10	110	103
HCO_3^-	10	30	27
Phosphate	40	2	1
Glucose	1	5.6	5.6
Protein	4.0	0.2	2.5

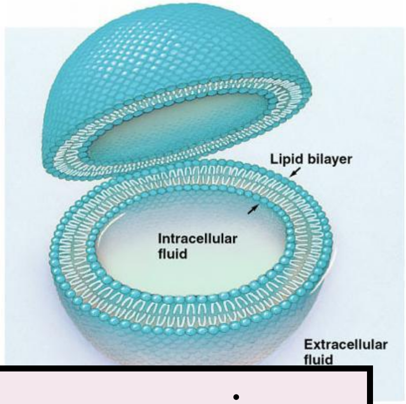
BODY FLUIDS



Factors affecting body fluids

- *Water intake & output*
- *Age:*
  - *infant: 73%*
  - *elderly: 45%*
- *Sex:*
  - *adult male: 60%*
  - *adult female: 40-50%*
- *Obesity*
- *Climate*
- *Habits*
- *Level of physical activity*

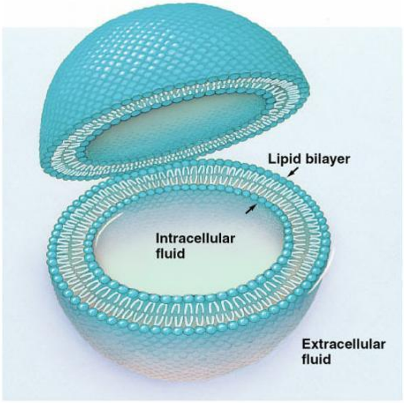
BODY FLUIDS



Daily intake & output of water (ml/day)

	Normal	Prolonged, heavy exercise
Intake:		
Fluids ingested (Drinking/in food)	2100	?
From metabolism	200	200
Total intake	**2300**	?
Output:		
Insensible – skin	350	350
Insensible – lungs	350	650
Sweat	100	5000
Feces	100	100
Urine	1400	500
Total output	**2300**	6600

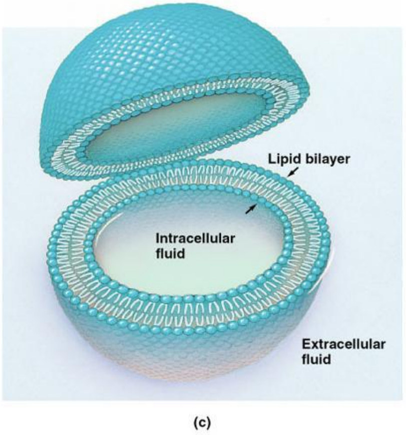
CONTROL OF BODY FLUIDS



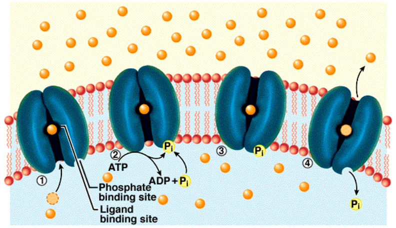
(c)

- *Thirst*
- *Sweating*
- *Renal control (aldosterone)*
- *Neuronal (osmoreceptors, baroreceptors)*

DEHYDRATION



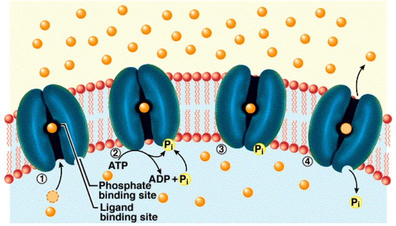
- *Loss of water from the body,*
  e.g. vomiting, diarrhea, sweating, & polyuria.
- *Leads to ↓in both ECF & ICF volumes.*
- *↑osmolarity in both ECF & ICF.*
- *General signs:*
  - *Dry tongue*
  - *loss of skin elasticity*
  - *soft eyeballs (due to lowering of intraocular tension)*
  - *↓blood pressure (if ≥4-6L loss)*
  - *↑Hb, & ↑Hct (packed cell volume)*
- *Treated w fluid replacement (orally, or IV).*



Part 6:

TRANSPORT THROUGH THE CELL MEMBRANE

TRANSPORT THROUGH THE CELL MEMBRANE

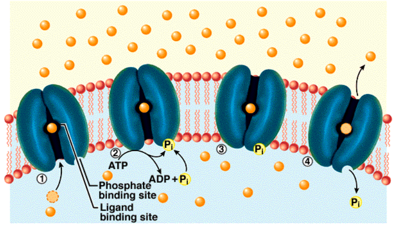


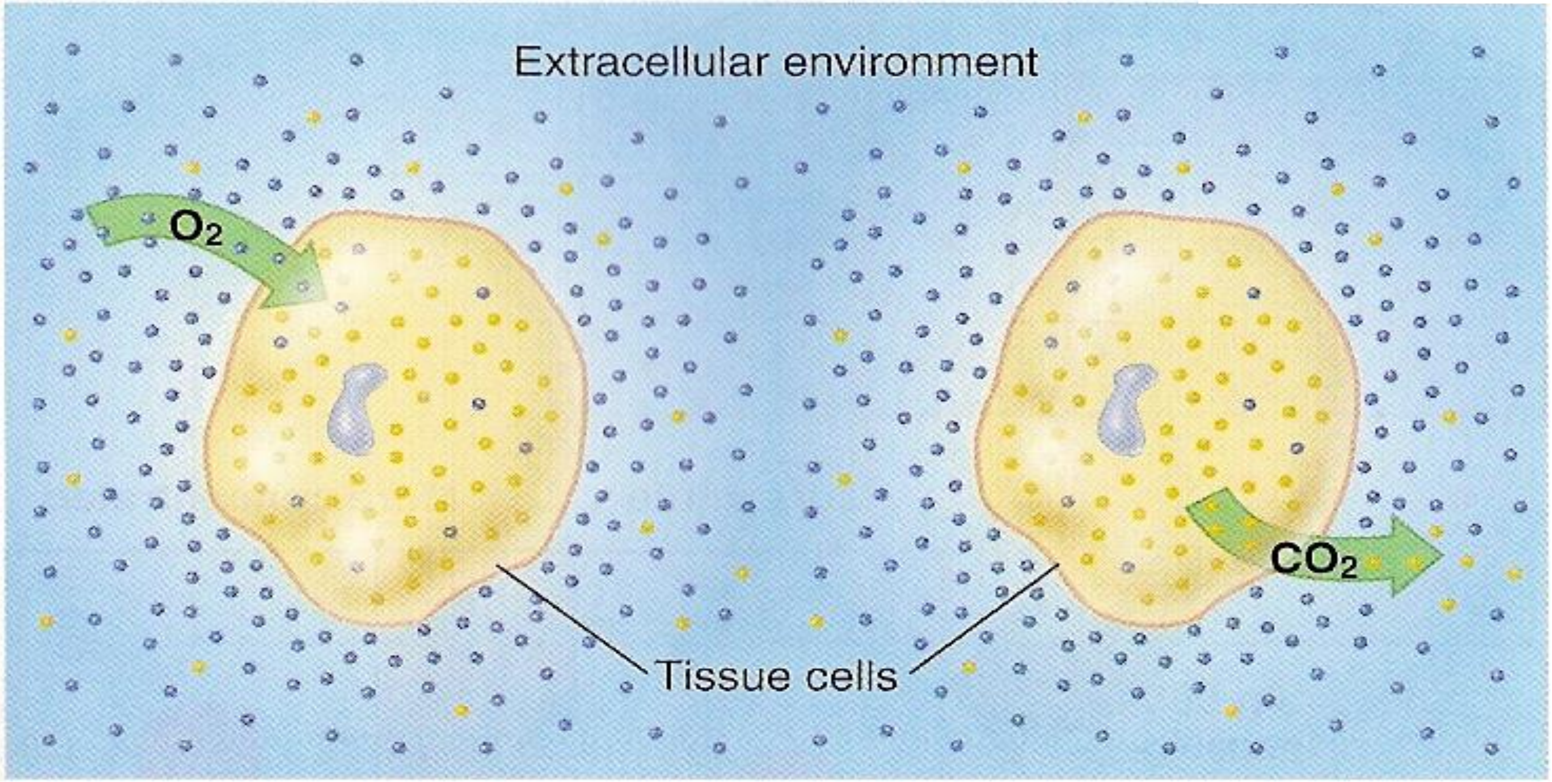
- *Cell membrane is selectively permeable to some molecules & ions.*
  - *Not permeable to proteins, nucleic acids, & other molecules.*

- *Lipid or fat-soluble substances, e.g. O_2, CO_2, OH; enter directly into cell membrane through the lipid bilayer.*

- *Water-soluble substances, e.g. ions, glucose, water; enter through proteins of the cell membrane.*

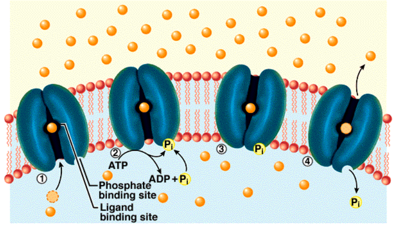
TRANSPORT THROUGH THE CELL MEMBRANE

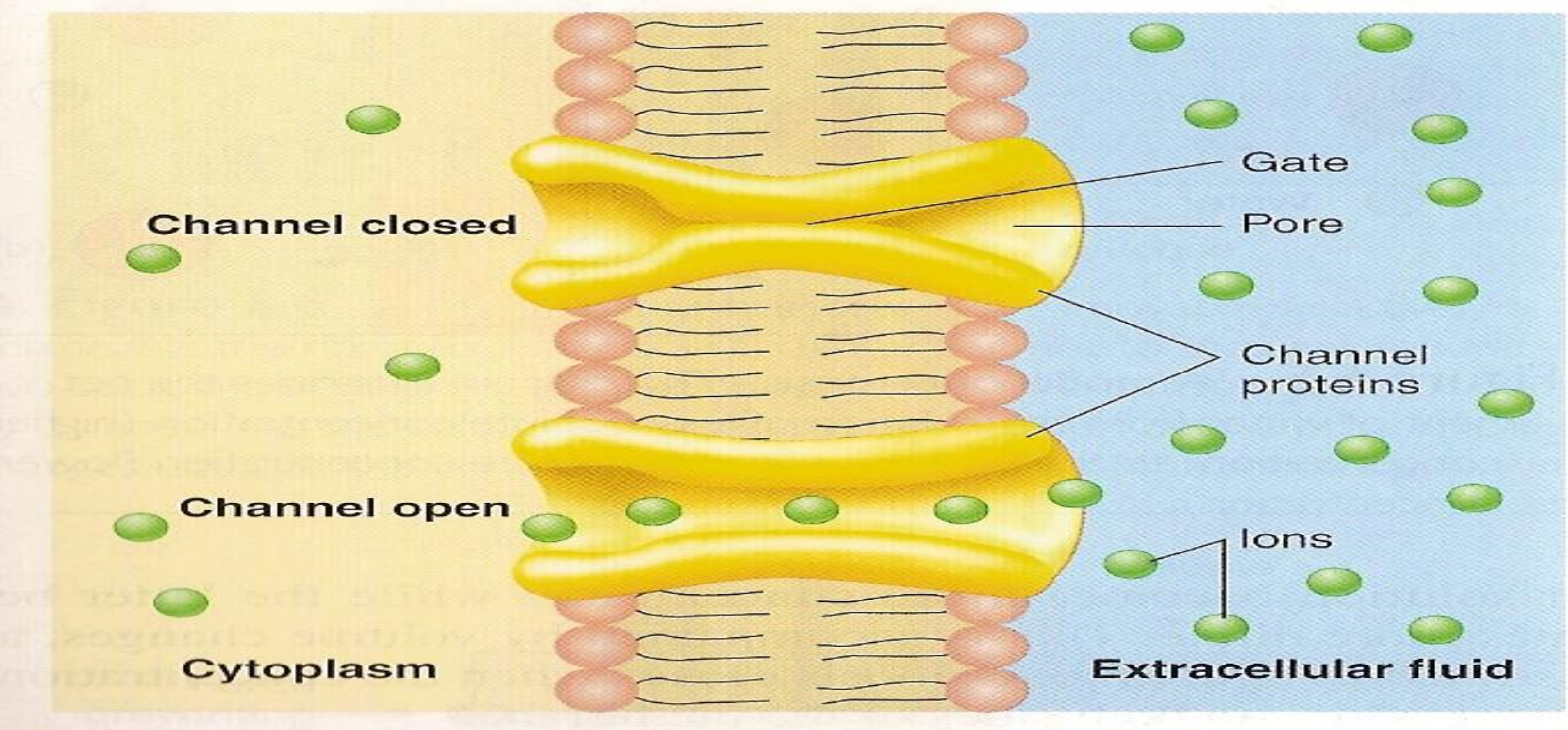




Gas exchange occurs by diffusion. The color dots, which represent oxygen & carbon dioxide molecules, indicate relative concentrations inside the cell & in the extracellular environment. Gas exchange between the intracellular & extracellular compartments thus occur by diffusion.

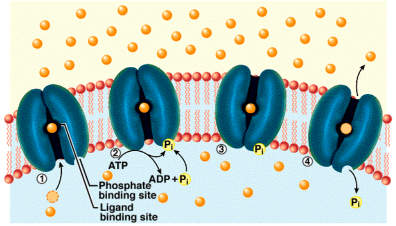
TRANSPORT THROUGH THE CELL MEMBRANE





Ions pass through membrane channels. These channels are composed of integral proteins that span the thickness of the membrane. Although some channels are always open, many others have structures known as 'gates' that can open or close the channel. This figure depicts a generalized ion channel; most, however, are relatively selective – they allow only particular ions to pass.

TRANSPORT THROUGH THE CELL MEMBRANE



1. Diffusion

(passive transport)

- *net movement of molecules & ions across a membrane from higher to lower conc.*

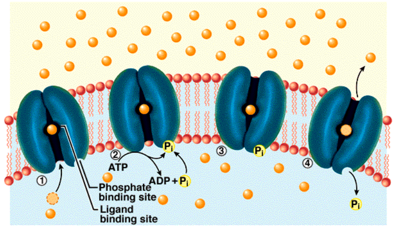
  (down conc gradient)
- *doesn't require metabolic energy.*

2. Active transport

- *net movement across a membrane that occurs against conc gradient.*

  (to region of higher conc)
- *Requires metabolic energy (ATP), & involves specific carrier proteins.*

TRANSPORT THROUGH THE CELL MEMBRANE



1. Diffusion

(passive transport)

a. Simple diffusion.

b. Osmosis

c. Facilitated diffusion. (Carrier-mediated)

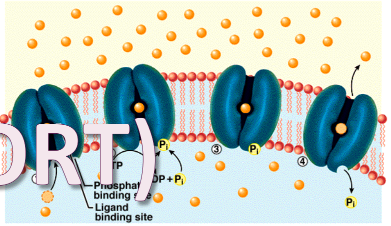
2. Active transport

a. Primary active transport.

b. Secondary active transport.

.

DIFFUSION (PASSIVE TRANSPORT)



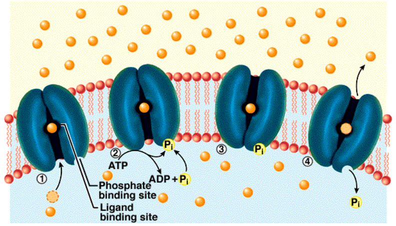
- *Random movement of substance through the membrane, either directly or in combination w carrier protein <u>down</u> an electrochemical gradient.*

  a. simple diffusion

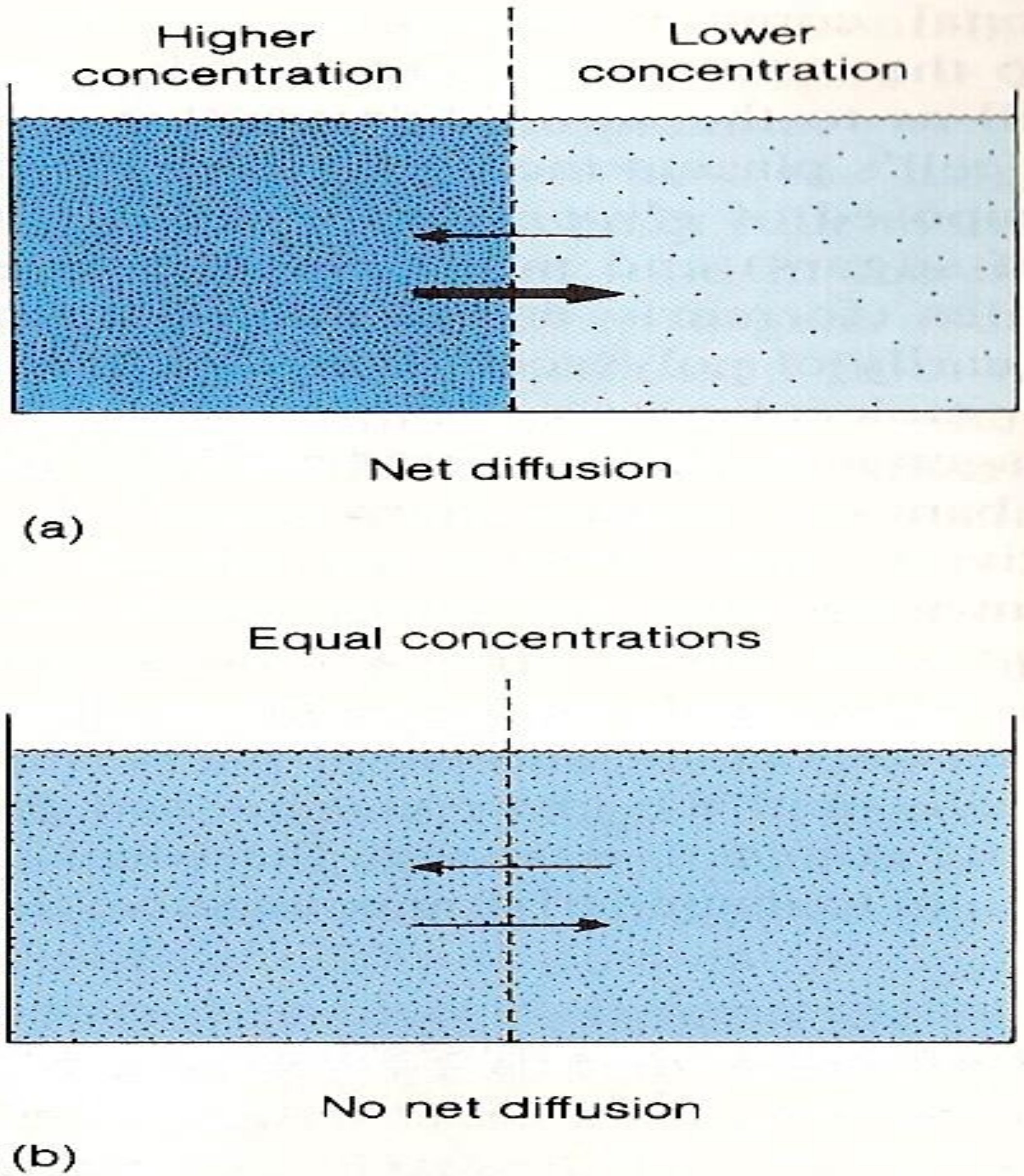
  b. osmosis

  c. facilitated diffusion

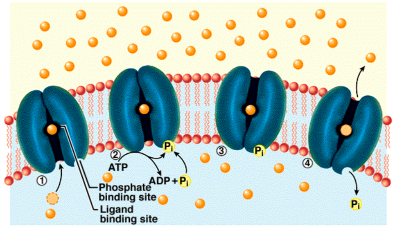
A. SIMPLE DIFFUSION



- *Non-Carrier mediated transport.*
- *Involves net transport <u>down</u> an electrochemical gradient (from higher to lower conc).*
- *Does not need cellular metabolism energy. However, it's powered by thermal energy of the diffusing molecules.*
- *Net diffusion stops when the conc is equal on both sides of the membrane.*


Higher concentration
Lower concentration
Net diffusion
(a)
Equal concentrations
No net diffusion
(b)

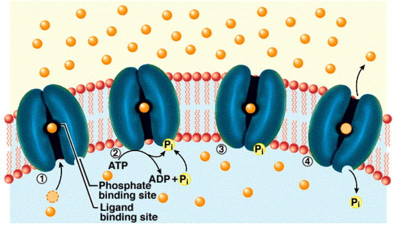
A. SIMPLE DIFFUSION



- *Cell membrane is permeable to:*
  - *Non-polar molecules (0_2).*
  - *Lipid soluble molecules (steroids).*
  - *Small polar covalent bonds ($C0_2$).*
  - *H_20 (small size, lack charge).*

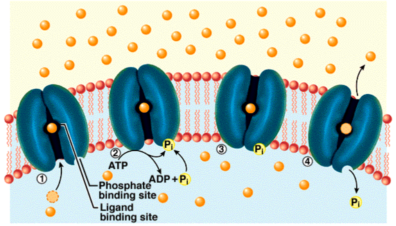
- *Cell membrane impermeable to:*
  - *Large polar molecules (glucose).*
  - *Charged inorganic ions (Na^+).*

RATE OF DIFFUSION

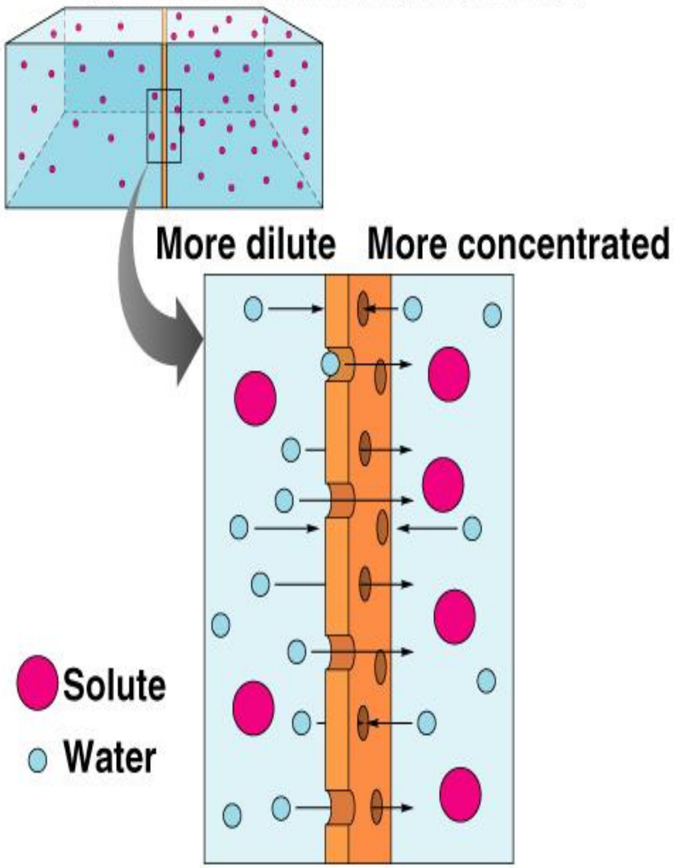


- *Speed at which diffusion occurs depends on:*
  - *Magnitude of conc gradient across the 2 sides of the membrane.*
    - *Higher gradient drives the force of diffusion.*
  - *Permeability of the membrane to the diffusing substances.*
    - *Depending on size & shape of the molecules.*
  - *Temperature of the solution.*
    - *Higher temperature, faster diffusion rate.*
  - *Surface area of the membrane.*
    - *Microvilli increase surface area.*

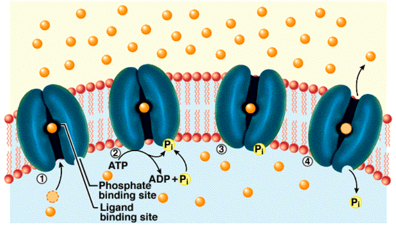
B. OSMOSIS

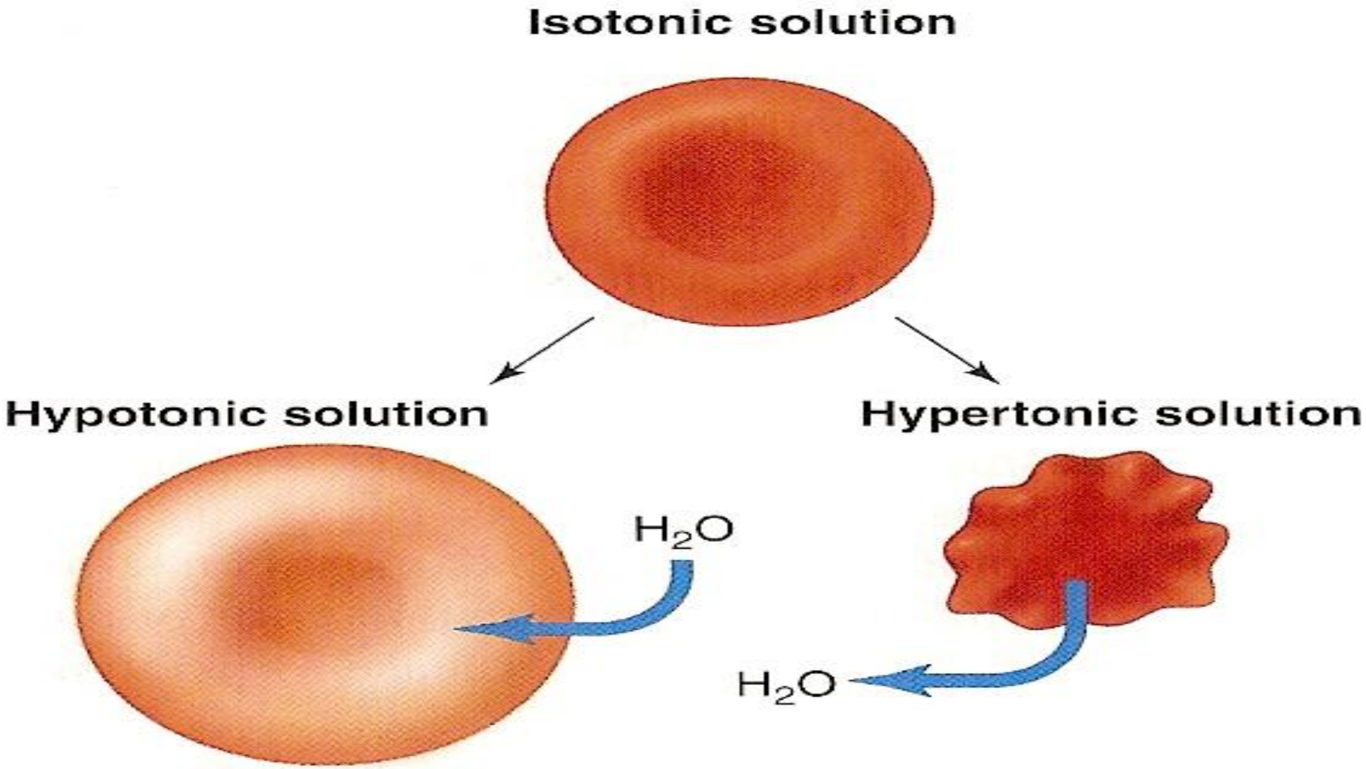


- *Net diffusion of H_20 across a selectively permeable membrane.*
- *Movement of H_20 from a high $[H_20]$ to lower $[H_20]$ until equilibrium is reached.*
- *2 requirements for osmosis:*
  - *Must be difference in [solute] on the 2 sides of the membrane.*
  - *Membrane must be impermeable to the solute.*
- *Osmotically active solutes:*
  - *When solutes cannot pass freely through the membrane.*



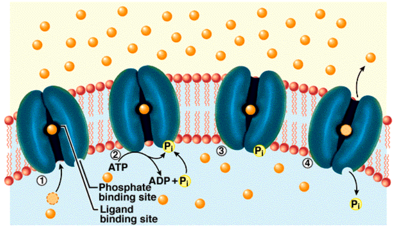
B. OSMOSIS





Red blood cells in isotonic, hypotonic, & hypertonic solutions. In each case, the external solution has an equal, lower, or higher osmotic pressure, respectively, than the intracellular fluid, As a result, water moves by osmosis into the red blood cells placed in hypotonic solutins, causing them to swell and even to burst. Similarly, water moves out of red blood cells placed in a hypertonic solution, causing them to shrink & become crenated.

C. FACILITATED DIFFUSION



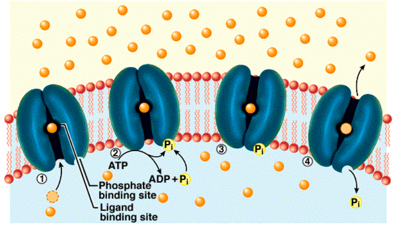
- *<u>Protein-Carrier mediated</u> transport, within the membrane.*

- *Involves net transport <u>down</u> an electrochemical gradient*
  (from higher to lower conc).

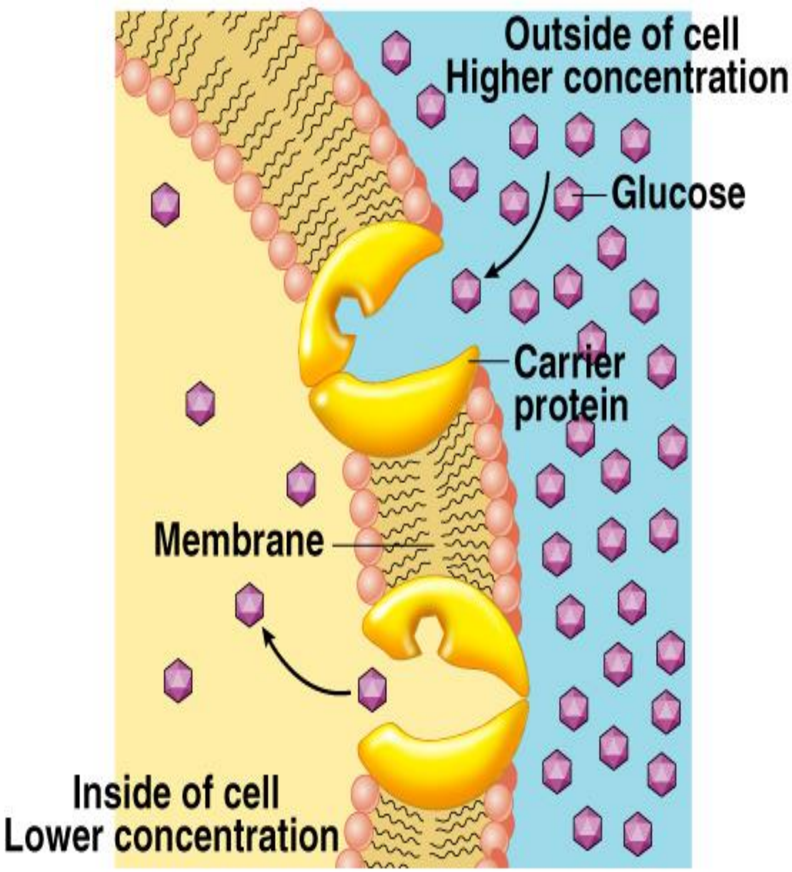
- *Does not need cellular metabolic energy. However, it's powered by thermal energy of diffusing molecules.*

- *Molecules that are too large & polar to diffuse are transported across plasma membrane by protein carriers.*
  e.g. Glucose, most of amino acids, & other organic molecules.

C. FACILITATED DIFFUSION

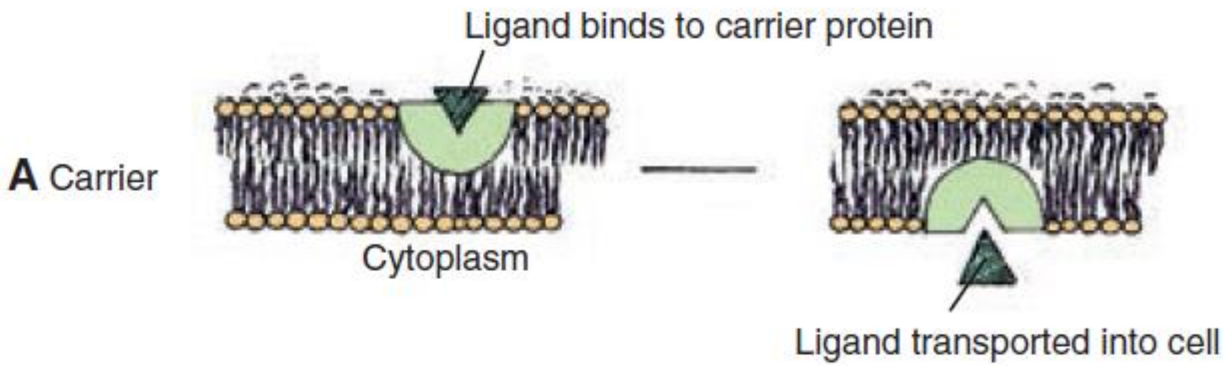


- *Passive transport:*
  - *ATP not needed.*
    - *Powered by thermal energy of diffusing molecules.*
  - *Involves transport of substance through cell membrane down conc gradient by carrier proteins.*
    - *Transport carriers for glucose in intestines & in kidney's basal membrane.*



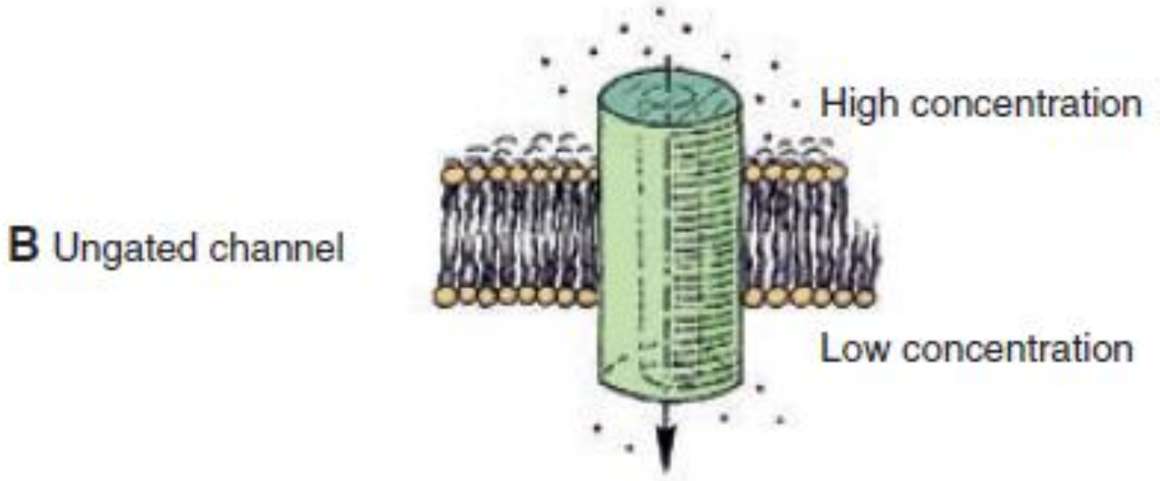
C. FACILITATED DIFFUSION

- Types of transport proteins mediating facilitated diffusion.



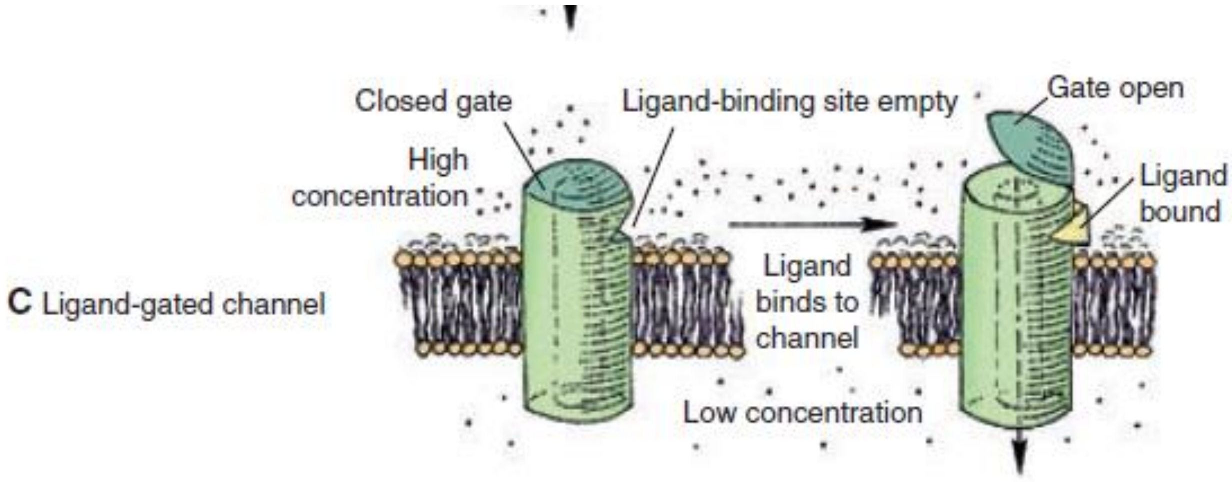
A. Carriers. In a few cases, material is carried by a transport protein that binds tightly to the material, and the complex moves through the lipid bilayer.

C. FACILITATED DIFFUSION



- **B,** Leak channels. These channels are thought not to open and close as do gated channels, and thus they support a small but persistent leak of a particular ion through the pore.

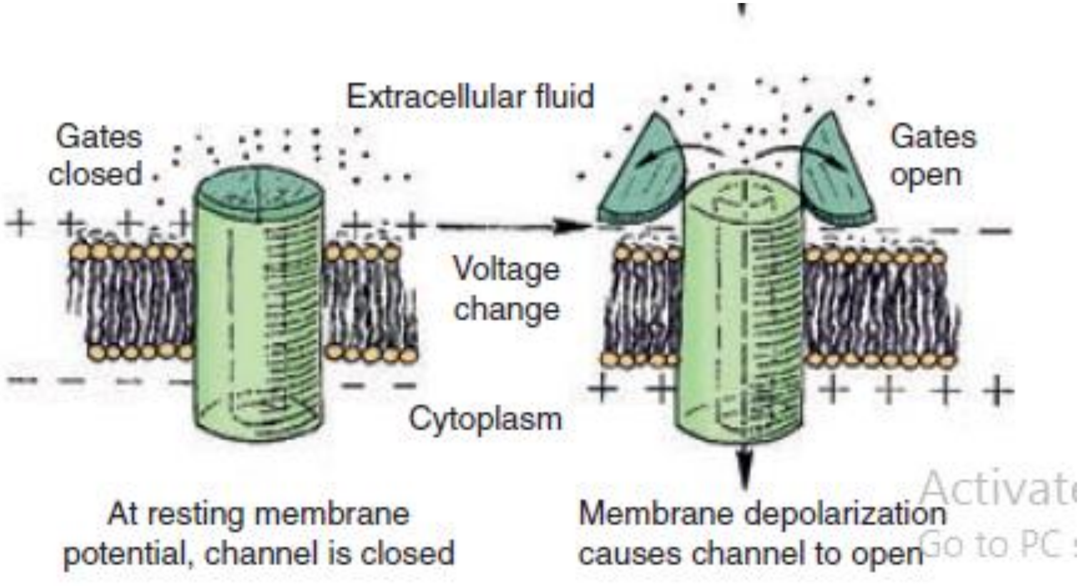
C. FACILITATED DIFFUSION



C, Ligand-gated channels. The transport protein again forms a pore through the membrane. In the case of gated channels, access of the ion to the pore is controlled by a gate, a substructure of the transport protein that can open and close the pore. In ligand-gated channels the opening and closing of the gate are controlled by the binding of a ligand to the channel.

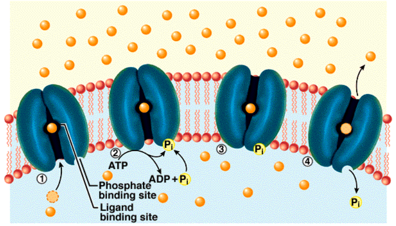
C. FACILITATED DIFFUSION

D Voltage-gated channel



D, Voltage-gated channels are similar to ligand-gated channels, except the opening and closing of the gate are controlled by the electrical field around the channel.

2. ACTIVE TRANSPORT:

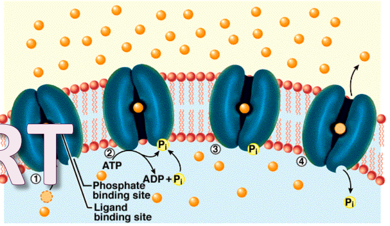


- *<u>Protein-Carrier mediated</u> transport.*

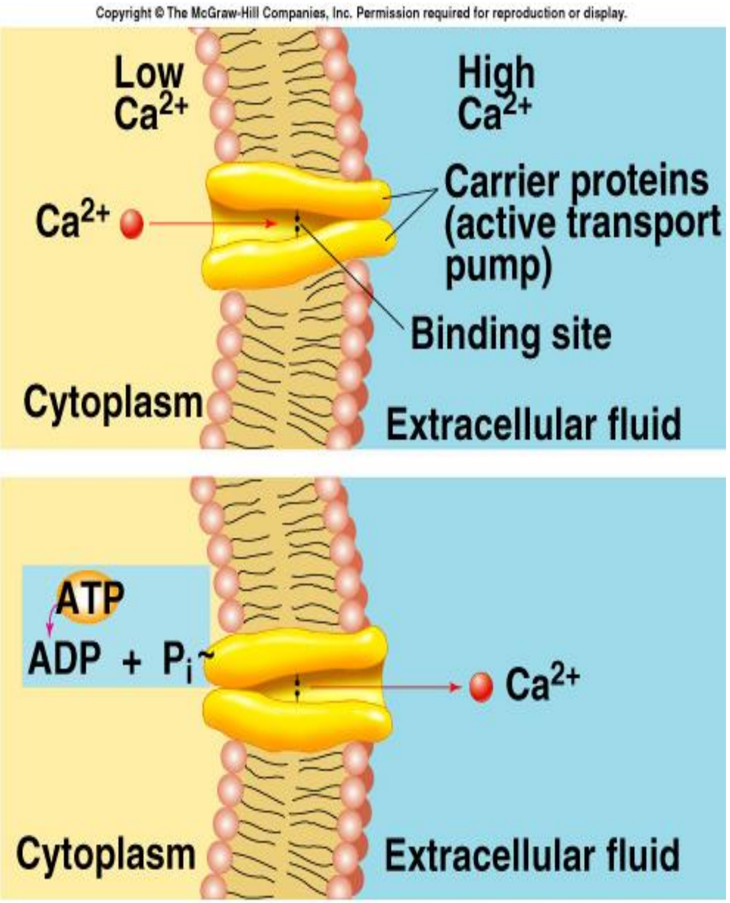
- *Involves net transport (<u>uphill</u>), i.e. against electrochemical gradient (from lower to higher conc).*
- *Requires metabolic energy (ATP).*
- *Two types:*

1. *Primary active transport*
2. *Secondary active transport*

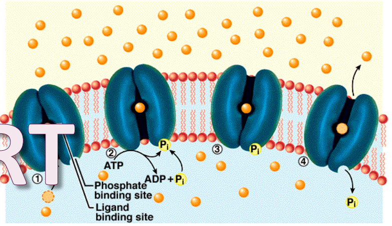
I. PRIMARY ACTIVE TRANSPORT



- *Energy is supplied directly from hydrolysis of ATP for the fx of the protein carriers.*
- *Molecule or ion binds to "recognition site" on one side of carrier protein.*
- *Binding stimulates phosphorylation (breakdown of ATP) of carrier protein.*
- *Carrier protein undergoes conformational change.*
  - *Hinge-like motion releases transported molecules to opposite side of membrane.*
- *Some of these carriers transport only one molecule or ion for another.*



I. PRIMARY ACTIVE TRANSPORT



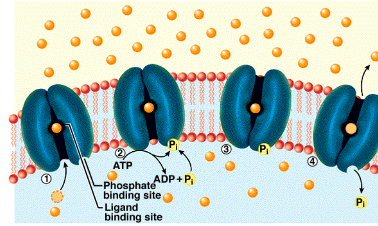
- *Examples:*

a. Sodium-Potassium pump (Na^+/K^+ pump).

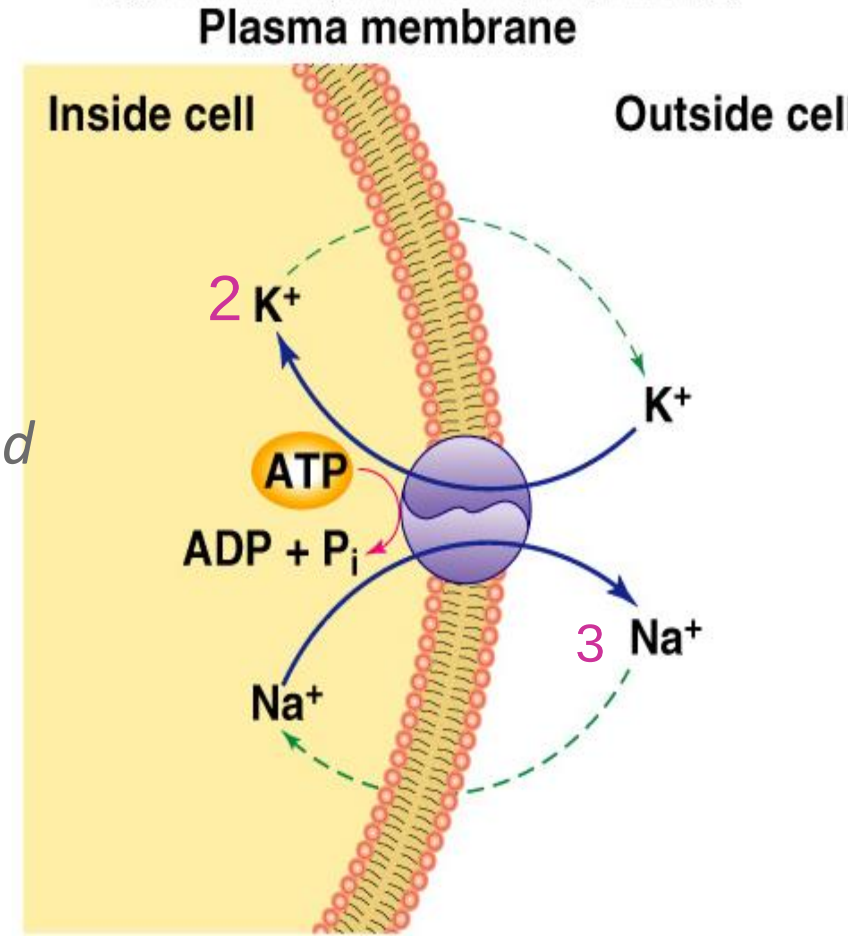
b. Primary active transport of calcium (Ca^{2+} ATPase).

c. Primary active transport of hydrogen ions (H^+/K^+ ATPase)

NA^+/K^+ PUMP

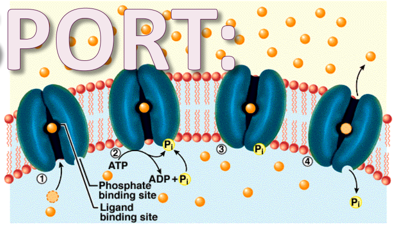


- *Is also an ATP enzyme that converts ATP to ADP and Pi.*
  - *Actively extrudes 3 Na^+ & transports 2 K^+ inward against conc gradient.*
- *Steep gradient serves 4 fxs:*
  - *Provides energy for "coupled transport" of other molecules.*
  - *Regulates resting calorie expenditure & BMR.*
  - *Involvement in electrochemical impulses.*
  - *Promotes osmotic flow.*



II. SECONDARY ACTIVE TRANSPORT:

(COUPLED TRANSPORT)



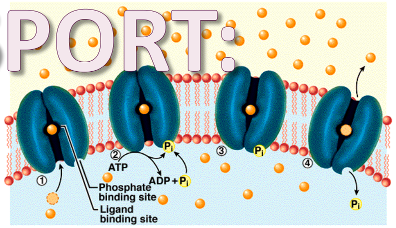
- *Transport of one or more solutes against an electrochemical gradient, coupled to the transport of another solute down an electrochemical gradient.*

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

- *Hydrolysis of ATP by Na^+/K^+ pump required indirectly to maintain $[Na^+]$ gradient.*

II. SECONDARY ACTIVE TRANSPORT:

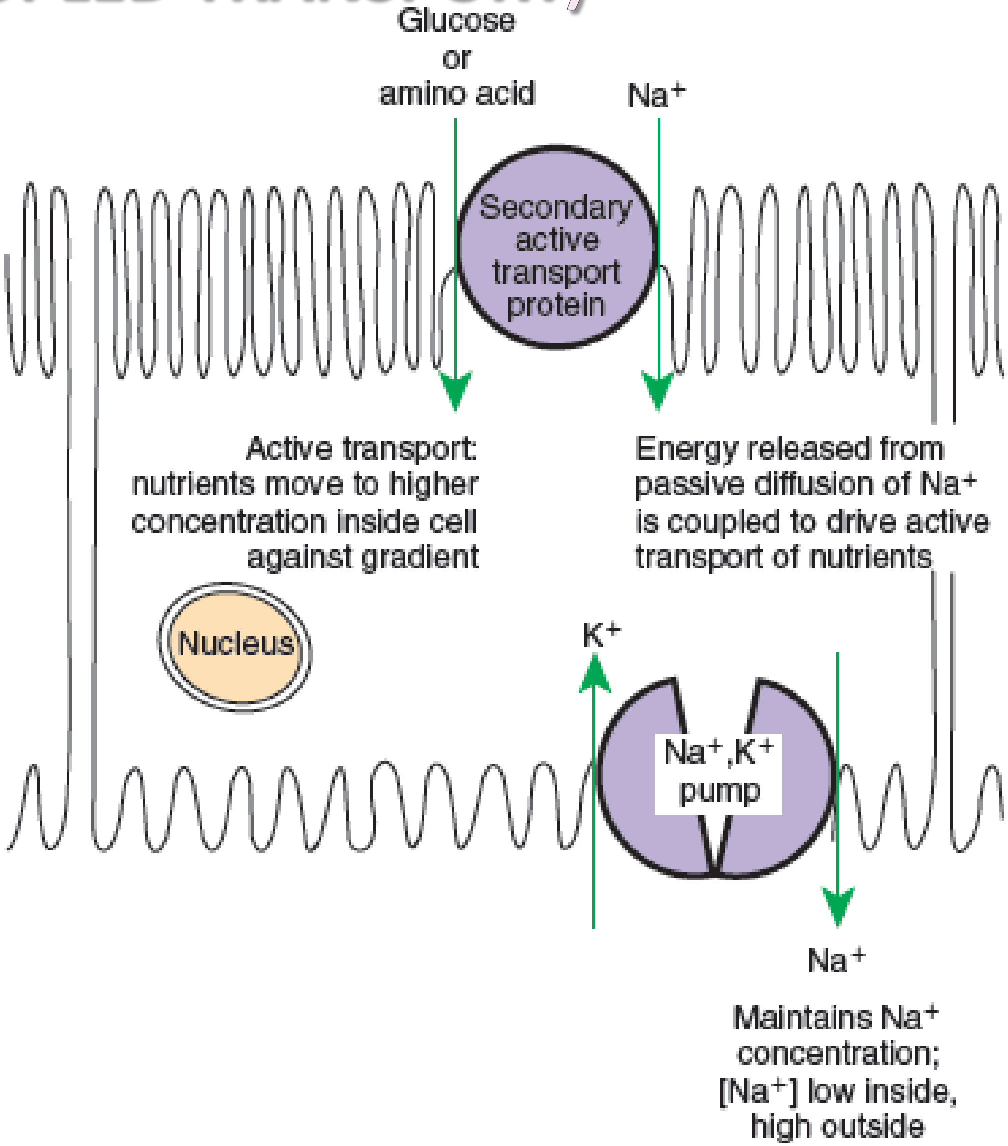
(COUPLED TRANSPORT)



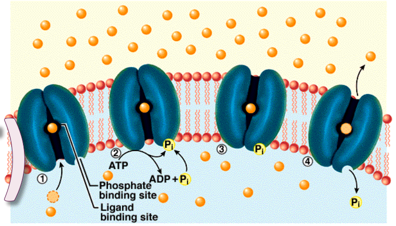
- *If the other molecule or ion is moved in the <u>same direction</u> as Na^+ (into the cell), the coupled transport is called either: '**cotransport**' or '**symport**'.*

- *If the other molecule or ion is moved in the <u>opposite direction</u> as Na^+ (out of the cell), the process is called either: '**countertransport**' or '**antiport**'.*

II. SECONDARY ACTIVE TRANSPORT:
(COUPLED TRANSPORT)



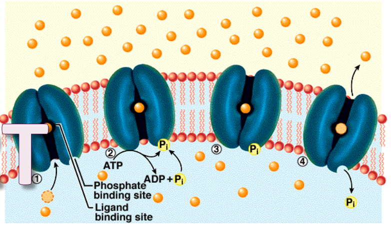
A. CO-TRANSPORT (SYMPORT)

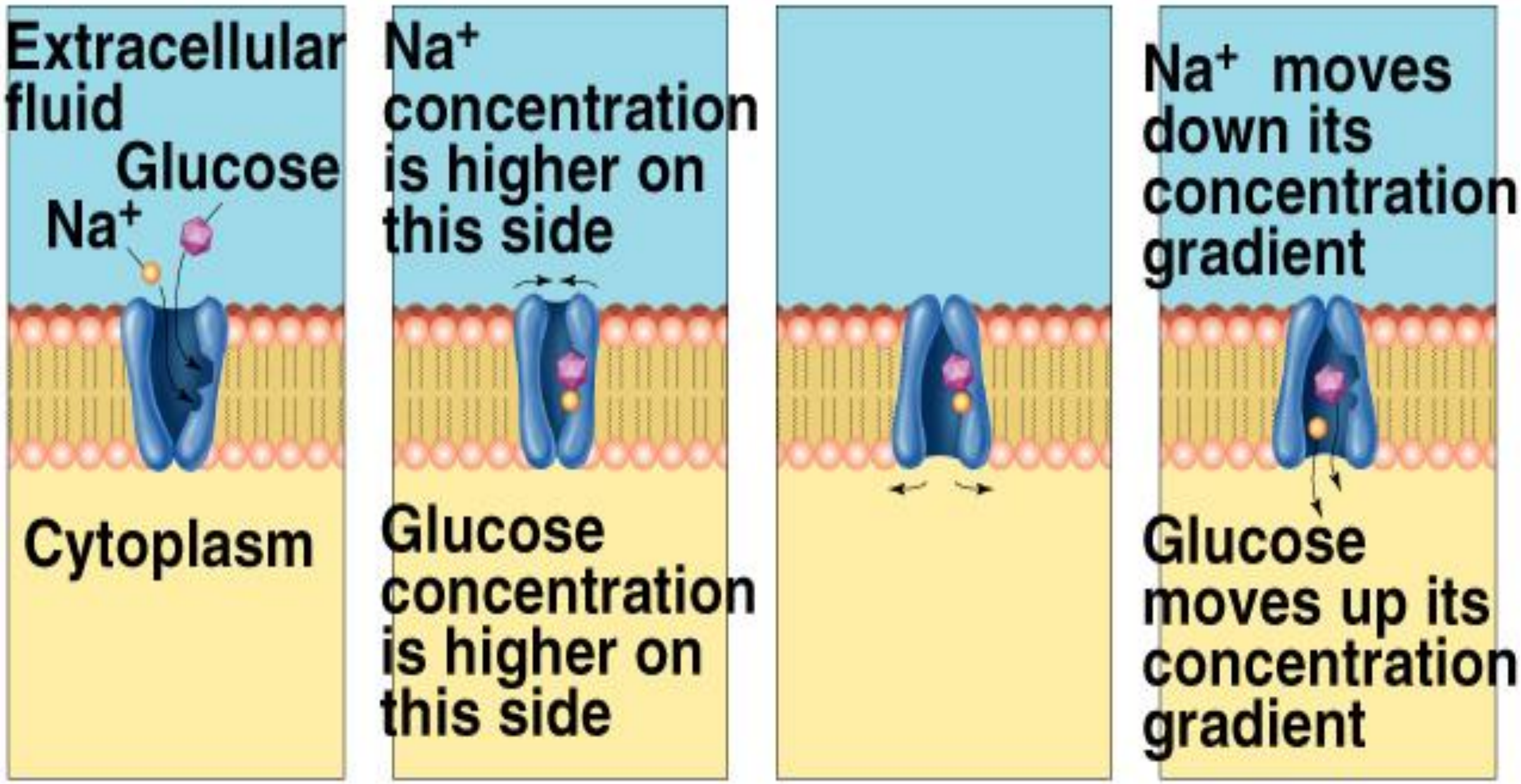


- *All solutes move in the same direction → "to the inside of the cell"*

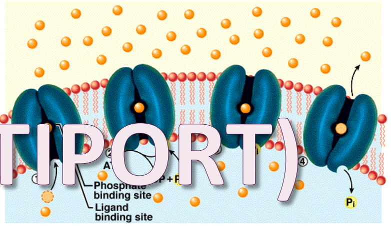
- *e.g.*
  - Na^+– glucose Co transport
  - Na^+– amino acid Co transport
- *In the intestinal tract, & kidney's brush borders.*

NA^{+}– GLUCOSE CO TRANSPORT





B. COUNTER TRANSPORT (ANTIPORT)



- *Na^+ is moving to the interior causing other substance to move out.*

- *e.g.*

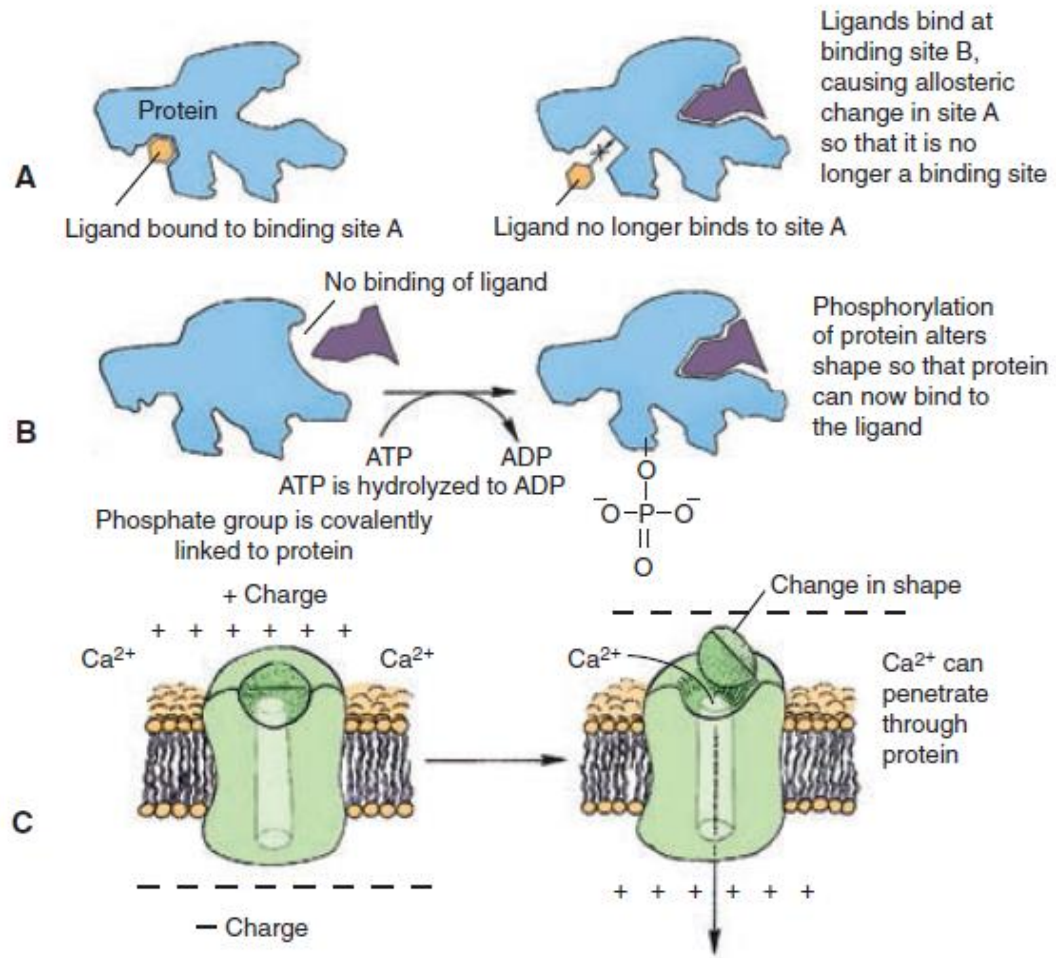
  - Ca^{2+}– Na^+ exchange

  … (present in many cell membranes)

  - Na^+– H^+ exchange in the kidney

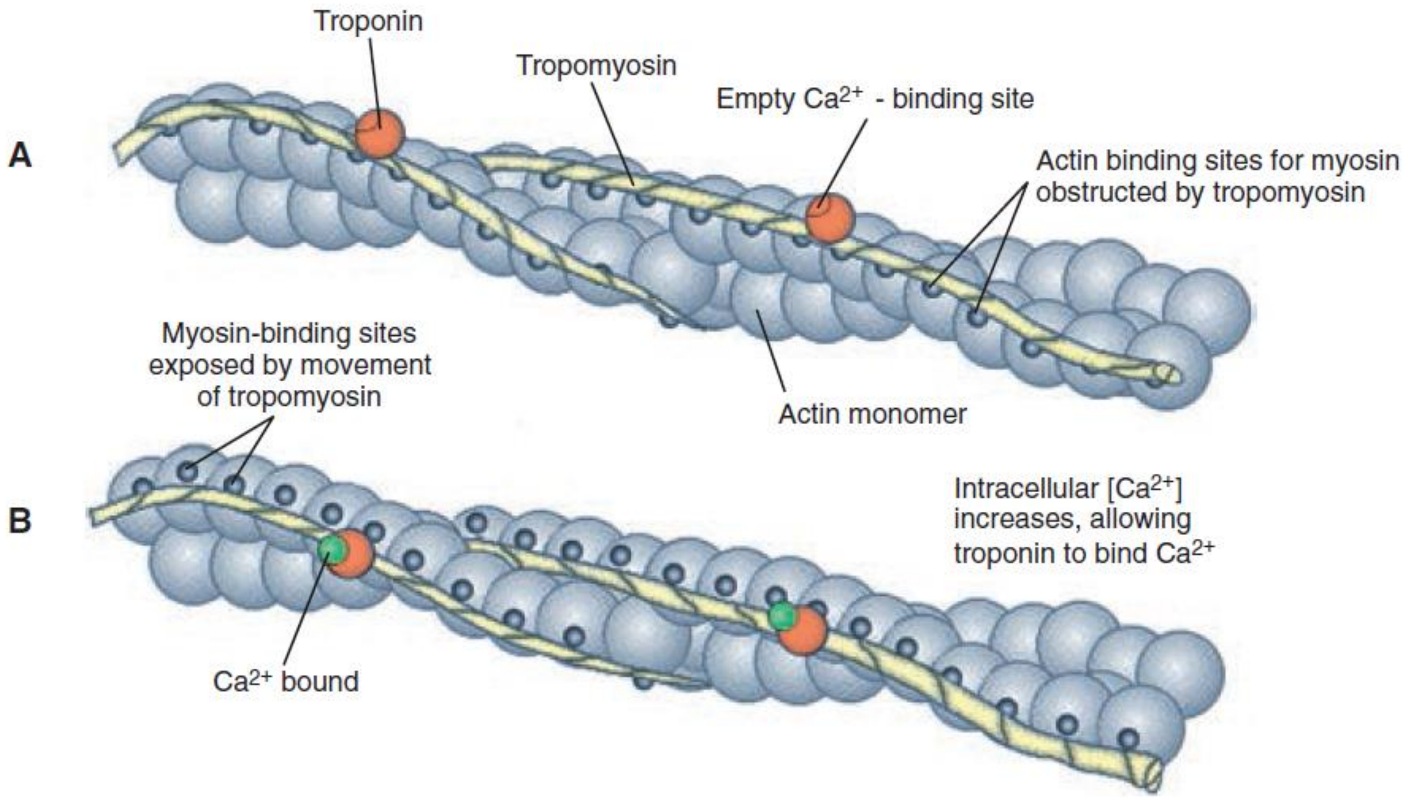
  - Cl^-– HCO_3^- exchange across RBCs.

SIGNALING METHODS OF PROTEINS



Three common mechanisms of allosteric shape change in proteins.

SIGNALING METHODS OF PROTEINS



Regulation of the actomyosin ATPase and striated muscle contraction by Ca^{2+}.
A, In the absence of high concentrations of Ca^{2+}, tropomyosin sits in the groove of the actin filament to obstruct the binding sites on actin for myosin.
B, In the presence of higher Ca^{2+} concentrations, the ion binds to troponin, causing an allosteric change in the interaction of troponin with tropomyosin. This allosteric change in turn changes the interaction of tropomyosin with the actin filament to expose the myosin-binding sites on actin.