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Body Fluids & Electrolytes

objectives

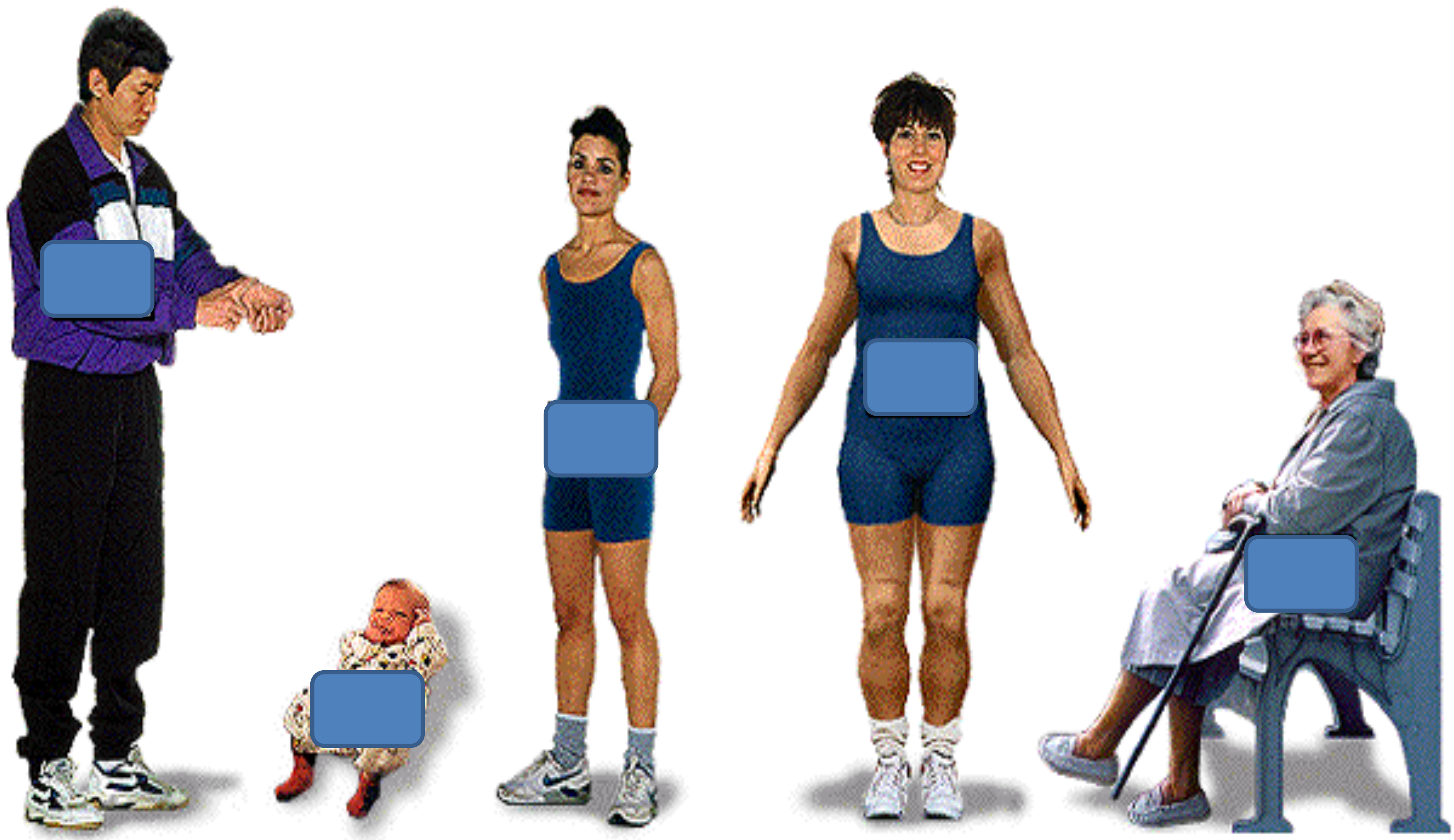
At the end of this session, the students should be able to:

- **Identify and describe daily intake and output of water and maintenance of water balance.**
- **List and describe of body fluid compartments as intra-cellular fluid (ICF) Extra-cellular fluid (ECF), interstitial fluid, trans-cellular fluid and total body water (TBW).**
- **Describe the composition of each fluid compartment, in terms of volume and ions and represent them in graphic forms.**
- **Physiology factor influencing body fluid: age, sex, adipose tissue, etc. Pathological factors: Dehydration, fluid infusion.**

- **Human body contain 50-70% water.**
  ≅ 60%

- **E.g.**
  - **70 kg man has 42 L of water.**
  - **(Kg of water = L of water)**

Percentage of Water in the Body



FACTORS AFFECTING

Infant: 73%

Male adult: 60%

Female adult: 40-50%

Obesity

Old age 45%

Body Water Content

- **Infants** have low body fat, low bone mass, and are 73% or more water.

- Total water content declines throughout life.

- Healthy **males** are about **60% water**; healthy **females** are around **50%**
  - This difference reflects females':
    - Higher body fat
    - Smaller amount of skeletal muscle

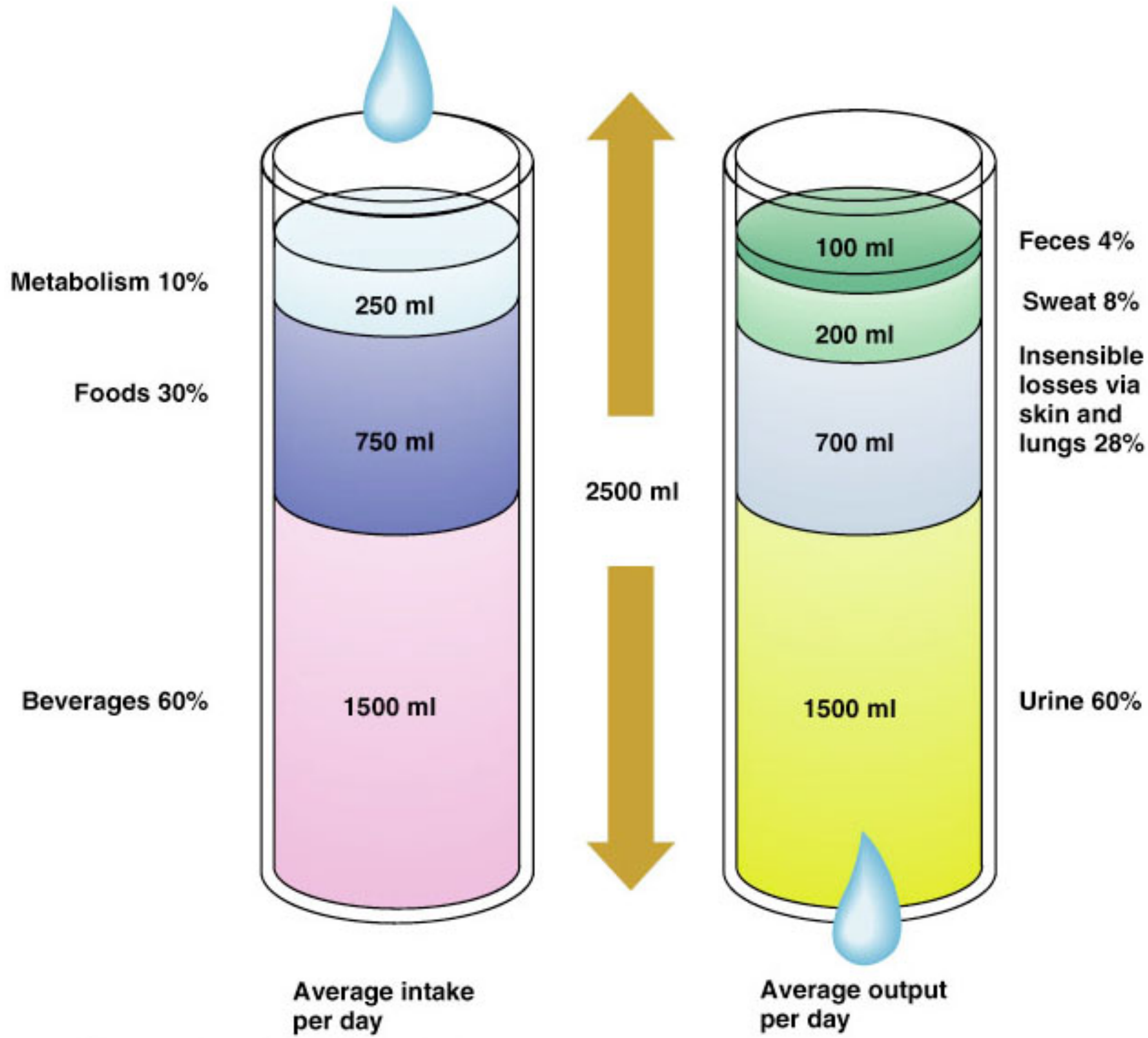
- In **old age**, only about 45% of body weight is water.

Daily intake of water

TABLE 20–1 DAILY INTAKE AND OUTPUT OF WATER (in ml/day)

	Normal	Prolonged, Heavy Exercise
Intake		
Fluids ingested	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

Water Intake and Output



Water Tank Analogy

Maintaining water homeostasis is a balancing act. The amount of water taken in must equal the amount of water lost.

Regulation of Water Intake

Climate

Habits

Level of physical activity.

Regulation of Water Intake

- The hypothalamic **thirst center** is stimulated:
  - By a decline in plasma **volume** of 10%–15%
  - By increases in plasma **osmolality** of 1–2%

In steady state water intake = water loss

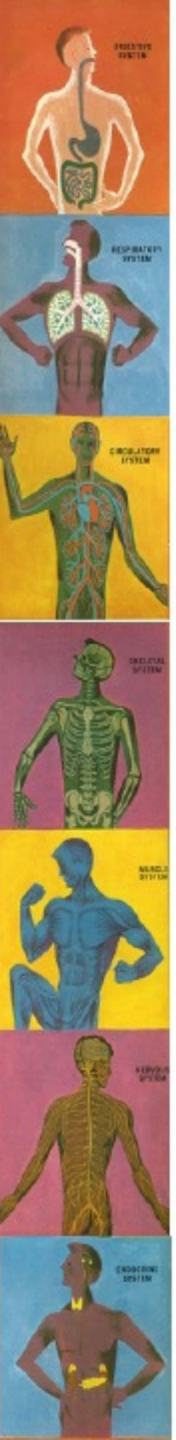
Factors that affect the TBW

Physiological factors:

- Age
- Sex
- Body fat
- Climate
- Physical activity

Pathological factors:

- Vomiting
- Diarrhea
- Diseases with excessive loss of water (DM, excessive sweating,….
- Blood loss



Regulation of Fluid Balance

Water deficit

- Leads to:
  - Hypovolemia
  - Dehydration

- **Physiologic regulation:**

1. ***Activates hypothalamic thirst centre → ↑fluid intake***
2. ***↑ ADH secretion by posterior pituitary → ↑ water reabsorption by the kidney.***

Water excess

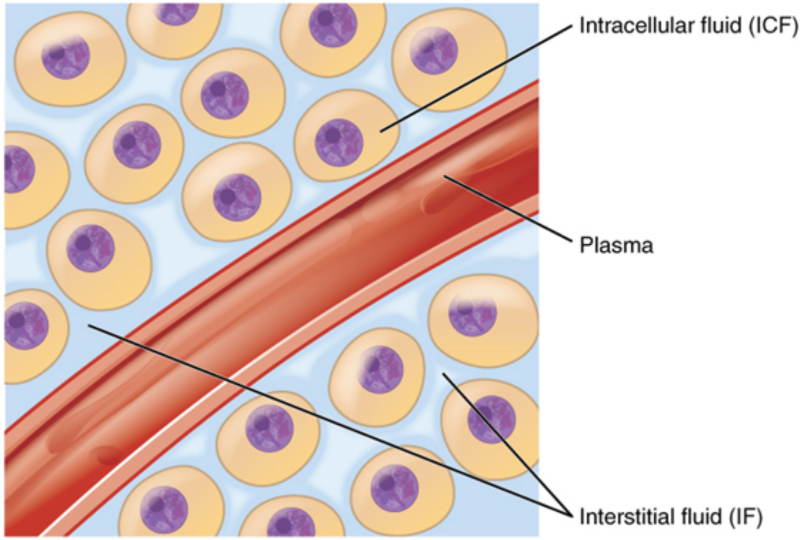
- Leads to:
  - Hypervolemia.
  - Edema.

- **Physiologic regulation:**

1. ***↓ ADH secretion → ↓ water reabsorption → ↑ water excretion by kidney.***
2. ***Decrease thirst***

Fluid Compartments

- Water occupies two main fluid compartments:
  - Intracellular fluid (ICF)
  - Extracellular fluid (ECF)
    - Plasma
    - Interstitial fluid (IF)



Fluid Compartments

B ody Fluid Compartments

Total body water = 60% TBW

***2/3 (40% of TBW)**
Intracellular

1/3 (20% of TBW)
Extracellular

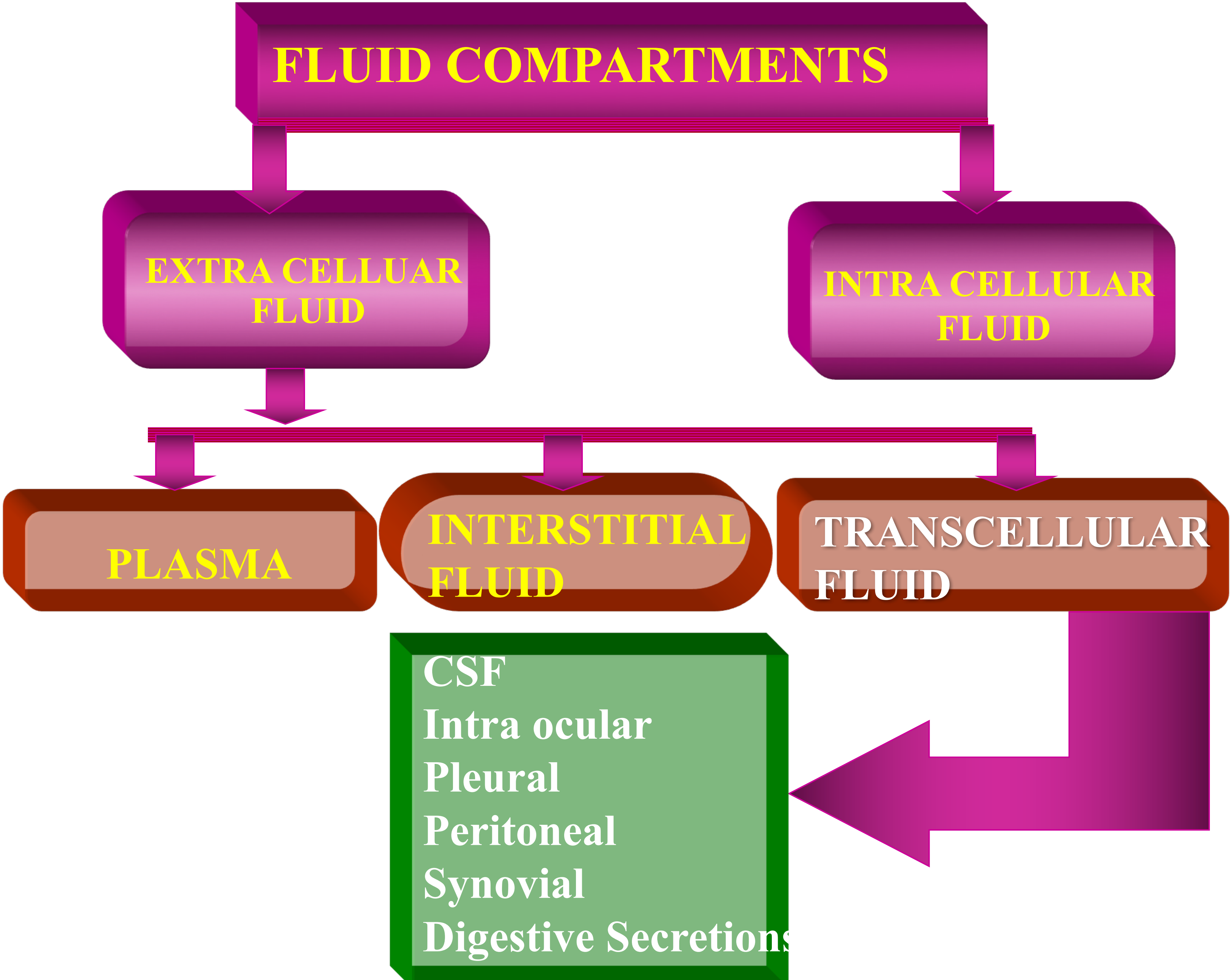
¾ (15%)
Interstitial Fluid

¼ (5%)
Plasma

Transcellular fluid (specialised type of ECF = 1-2L)

N. B. the fractions refer to its relation with the preceding compartment. While the percentage refers to its relation to Total Body Weight)

(Guyton and Hall Textbook of Medical Physiology. 13th ed. Ch-25)


FLUID COMPARTMENTS
EXTRA CELLULAR FLUID
INTRA CELLULAR FLUID
PLASMA
INTERSTITIAL FLUID
TRANSCELLULAR FLUID
CSF
Intra ocular
Pleural
Peritoneal
Synovial
Digestive Secretions

Intracellular fluid (ICF)

- Inside the cell.
- 2/3 of TBW.
- High concentration of protein.

Extracellular fluid (ECF)

- **Out side the cell.**
  1/3 of TBW.

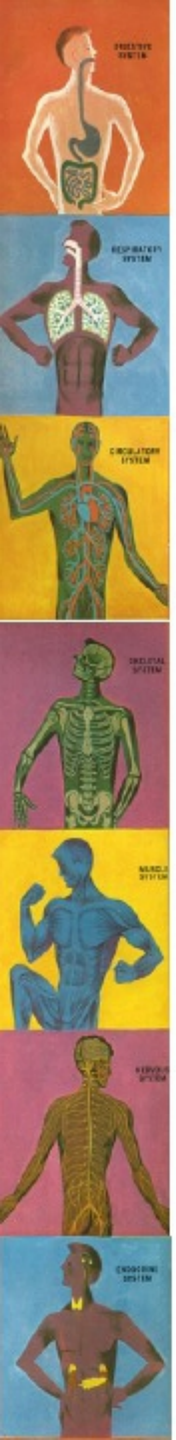
1- Plasma:

Fluid circulating in the blood vessels.
1/4 of ECF

2- Interstitial fluid:

Fluid bathing the cell.
Ultra filtration of plasma.
3/4 of ECF

- ***Plasma*** **and** ***interstitial fluid*** **are almost having the same composition except for high protein concentration in plasma.**



Calculate the total body water content of a 40-year-old 70kg man?

- TBW = 42 litres
- ***How many litres lie intracellularly?***
  - 42 X $\frac{2}{3}$ = 28L ***OR*** 70 X 40/100 = 28L.
- ***How many litres lie extracellularly?***
  - 42 X $\frac{1}{3}$ = 14L ***OR*** 70 X 20/100 = 14L.
- ***How many litres constitute the interstitial fluid?***
- ***How many litres are plasma?***

Composition of Body Fluids

- **Water is the universal solvent.**

- **Solutes are broadly classified into:**
  - ***Electrolytes*** **– inorganic salts, all acids and bases, and some proteins**
  - ***Nonelectrolytes*** **– examples include glucose, lipids, creatinine, and urea**

  - **Amount = in moles, osmoles.**

concentration

1- **Molarity** = moles/liter

(M/L)

2- **Osmolarity** = osmoles/liter

(osm/L)

3- **Osmolality** = osmoles/kg

(osm/kg)

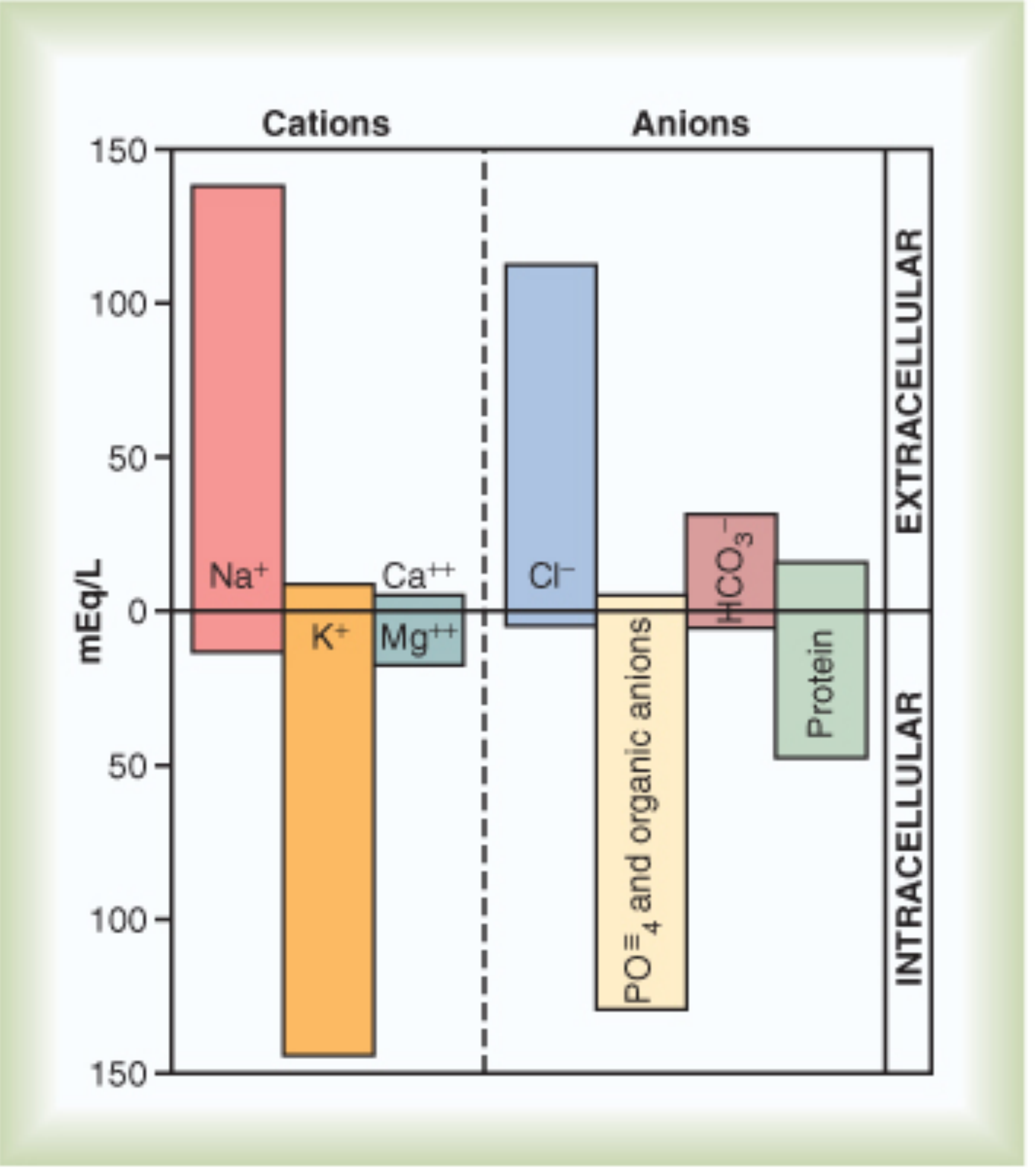
In biological solutions:

- **Millimoles per liter (mM/L)**
- **Milliosmoles per (mOsm/L)**
- **1mM=1/1000 M**
- **1mOsm=1/1000 Osm**

TABLE 20–2 OSMOLAR SUBSTANCES IN EXTRACELLULAR AND INTRACELLULAR FLUIDS

	Plasma (mOsm/liter of H_2O)	Interstitial	Intracellular
Na^+	142	139	14
K^+	4.2	4.0	140
Ca^{++}	1.3	1.2	0
Mg^+	0.8	0.7	20
Cl^-	108	108	4
HCO_3^-	24	28.3	10
HPO_4^{--}, $H_2PO_4^-$	2	2	11
SO_4^{--}	0.5	0.5	1
Phosphocreatine			45
Carnosine			14
Amino acids	2	2	8
Creatine	0.2	0.2	9
Lactate	1.2	1.2	1.5
Adenosine triphosphate			5
Hexose monophosphate			3.7
Glucose	5.6	5.6	
Protein	1.2	0.2	4
Urea	4	4	4
Others	4.8	3.9	10
Total mOsm/liter	301.8	300.8	301.2
Corrected osmolar activity (mOsm/liter)	282.0	281.0	281.0
Total osmotic pressure at 37° C (mm Hg)	5443	5423	5423

Constituents of ECF and ICF



Extracellular and Intracellular Fluids

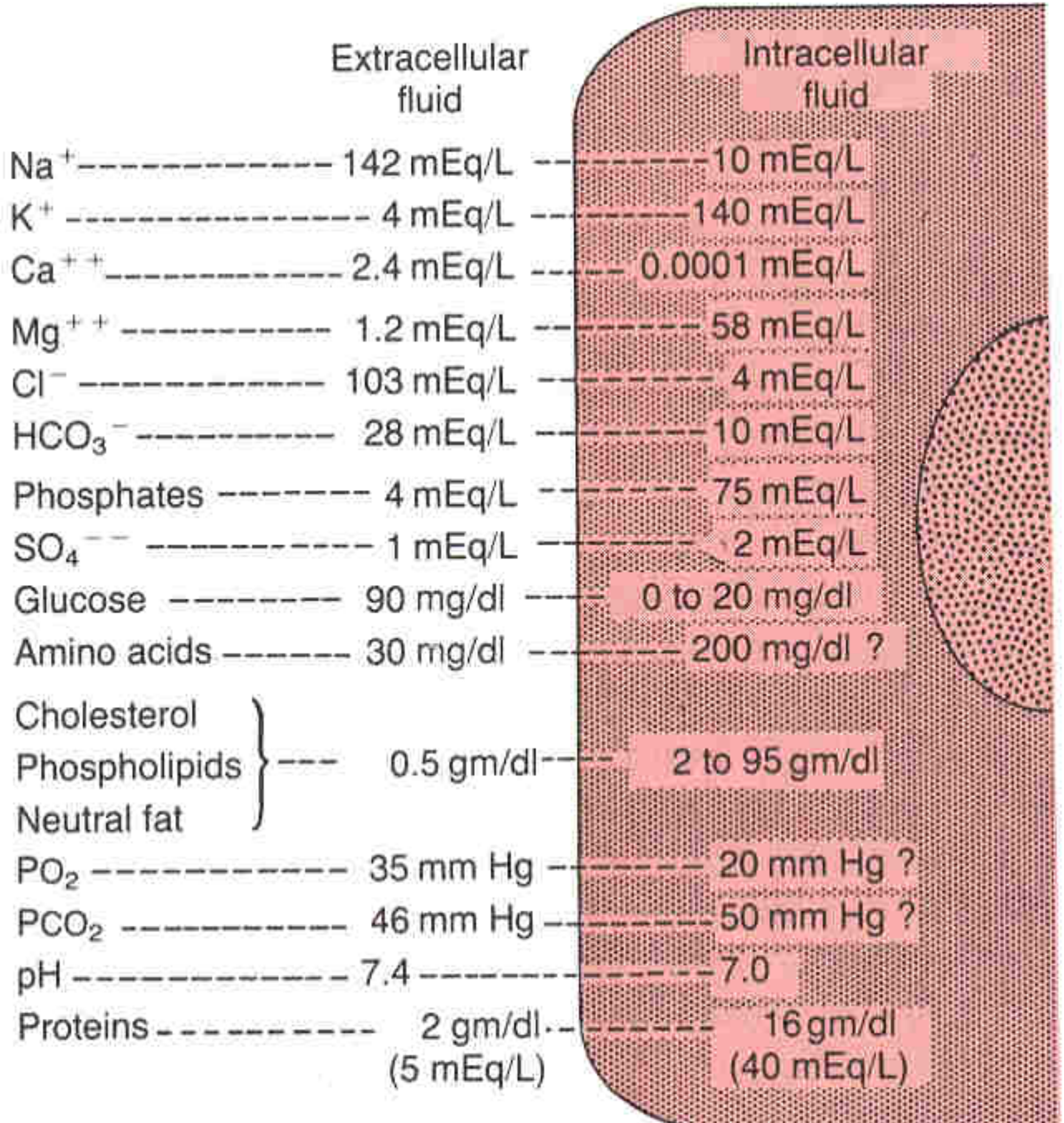
- Each fluid compartment of the body has a distinctive pattern of electrolytes.

- Extracellular fluids are similar (except for the high protein content of plasma)
  - Sodium is the chief cation
  - Chloride is the major anion

- **Intracellular fluid** has low sodium and chloride
  - **Potassium** is the chief **cation**
  - **Phosphate** is the chief **anion**

- **Each compartment must have almost the same concentration of positive charge (cations) as of negative charge (anion).**

(Electroneutrality)



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
HCO3− 28 mEq/L 10 mEq/L
Phosphates 4 mEq/L 75 mEq/L
SO4−− 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 0.5 gm/dl 2 to 95 gm/dl
Neutral fat
PO2 35 mm Hg 20 mm Hg ?
PCO2 46 mm Hg 50 mm Hg ?
pH 7.4 7.0
Proteins 2 gm/dl (5 mEq/L) 16 gm/dl (40 mEq/L)

- **Hypokalemia:** decrease in K concentration in the ECF.

1-2 mEq/L

- **Hyperkalemia:** increase in K 60-100% above normal.

Hypernatremia:

increase **in Na concentration in ECF.**

Hyponatremia:

decrease **in Na concentration in the ECF.**

osmosis

- **Net diffusion of water from a region of high water concentration to region of low water concentration.**

Osmotic equilibrium is maintained between intracellular and extracellular fluids:

- **Small changes in concentration of solutes in the extracellular fluid can cause tremendous change in cell volume.**

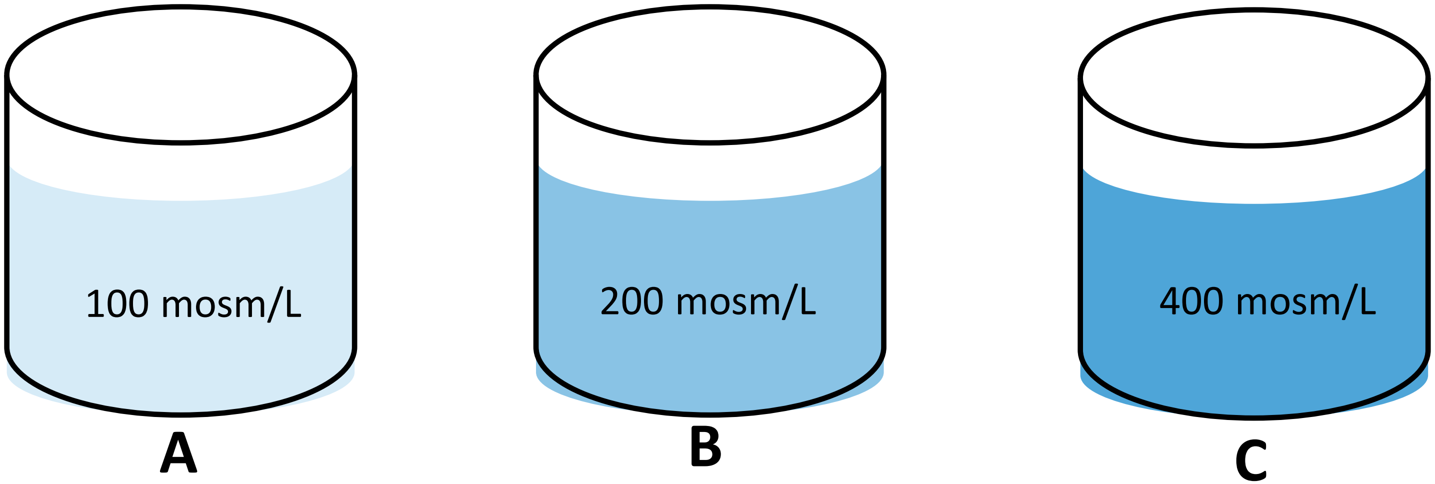
- **Intracellular osmolarity = extracellular osmolarity .**
- **≈ 300 mosm/L**

What is Tonicity?

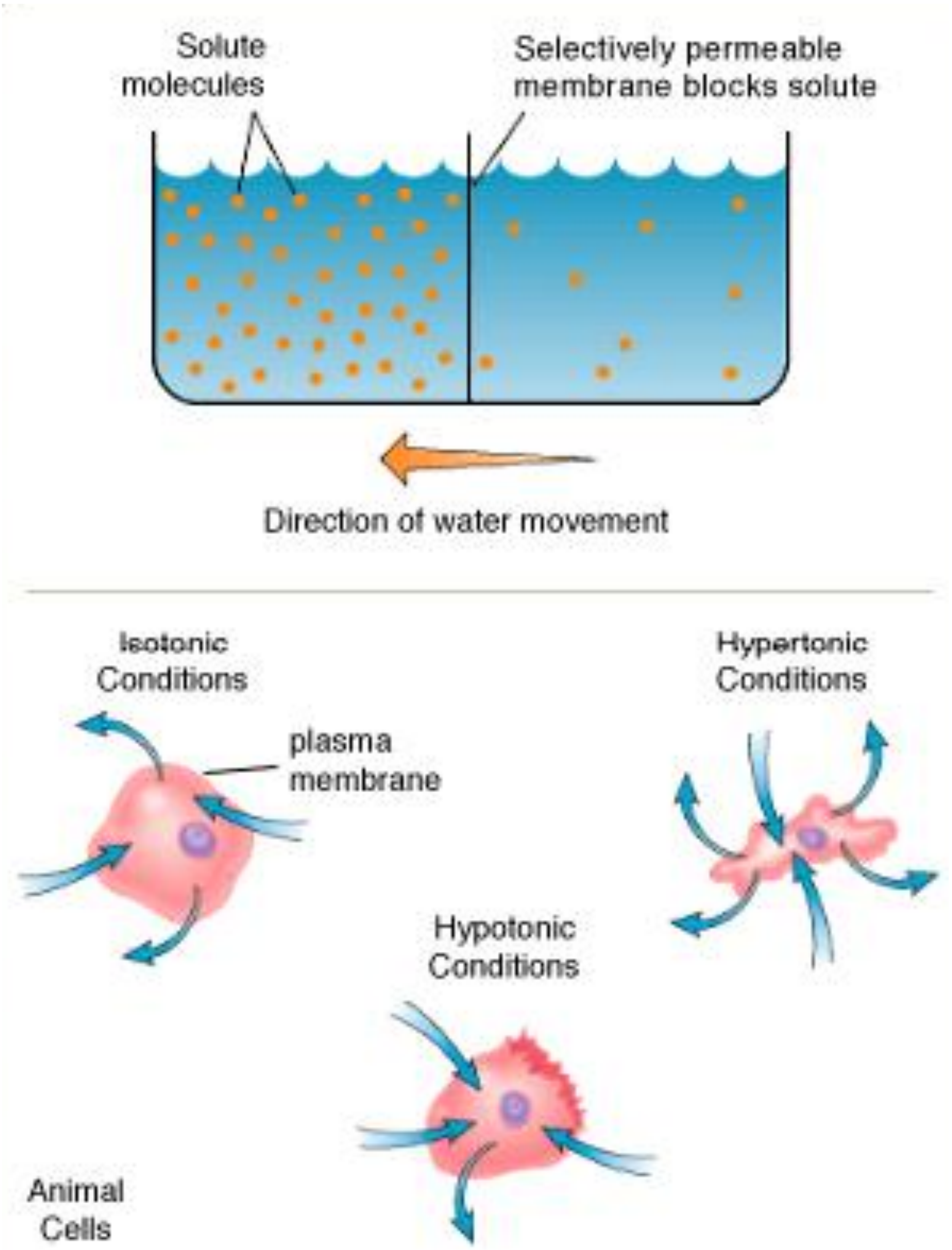
- ***Osmolarity*** describes the concentration of **one** solution.

- ***Tonicity*** is used to compare between the osmolarities of **two or more** solutions separated by a semi-permeable membrane.

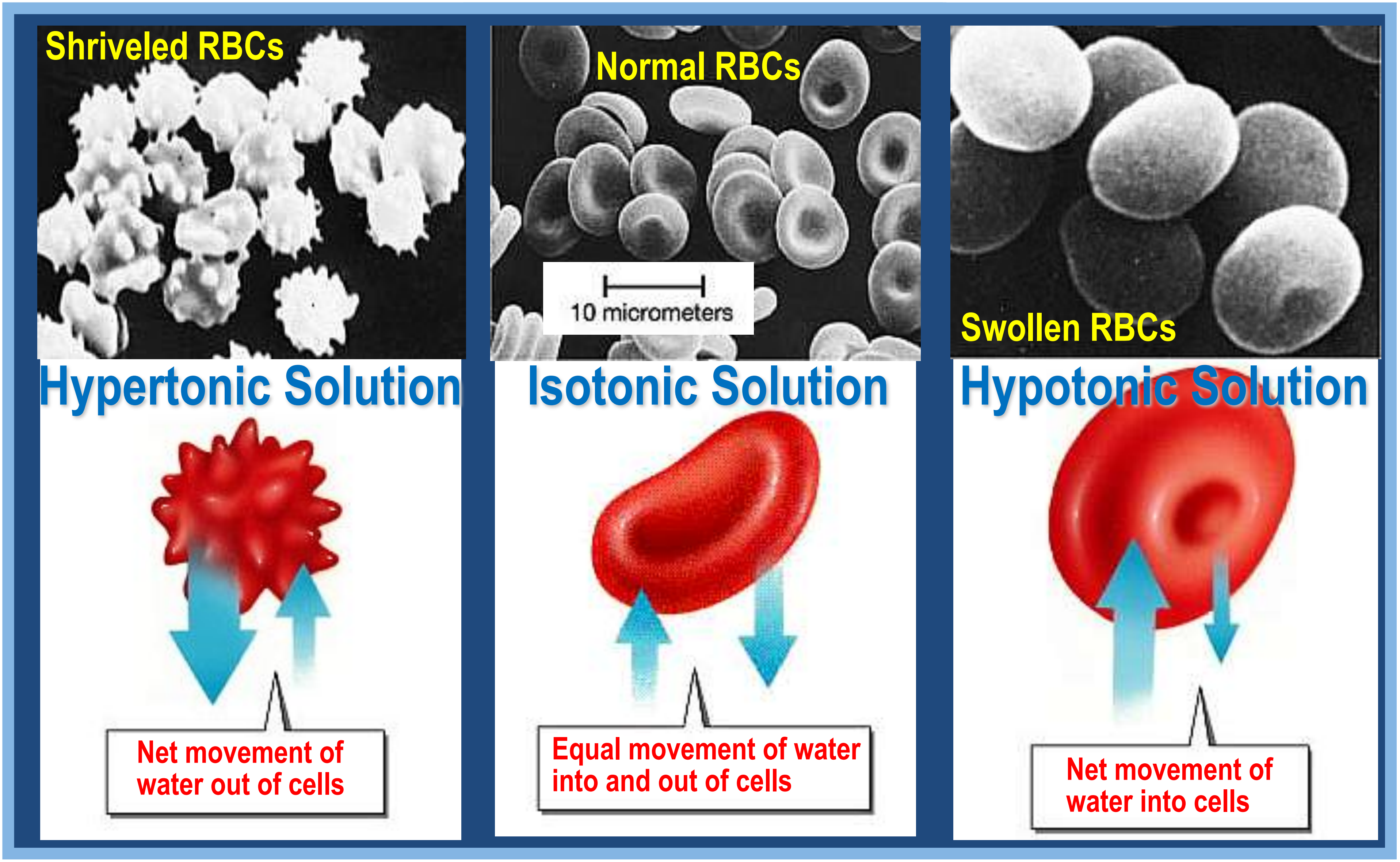
Which solution is hypertonic to B?



Osmosis


Solute
molecules
Selectively permeable
membrane blocks solute
Direction of water movement
Isotonic
Conditions
plasma
membrane
Hypertonic
Conditions
Hypotonic
Conditions
Animal
Cells

Osmosis



Shriveled RBCs
Normal RBCs
10 micrometers
Swollen RBCs
Hypertonic Solution
Isotonic Solution
Hypotonic Solution
Net movement of water out of cells
Equal movement of water into and out of cells
Net movement of water into cells

Osmosis

- **If environment is:**
  - **Hypertonic:**
    - **MORE SOLUTES outside cell**
    - **MORE WATER IN CELL**
    - **over time, cell loses water**
  - **Isotonic:**
    - **same**
    - **No change in cell volume**
  - **Hypotonic:**
    - **LESS SOLUTES outside cell**
    - **LESS WATER IN CELL, more solutes in cell.**
    - **over time, cell gains water**

❖ Isotonic solution :

- (not swell or shrink)
- 0.9% solution of sodium chloride or 5% glucose .
- same in and out .

❖ Hypotonic solution :

- (swelling) ↓ 0.9%
- in is higher than out .

❖ Hypertonic solution :

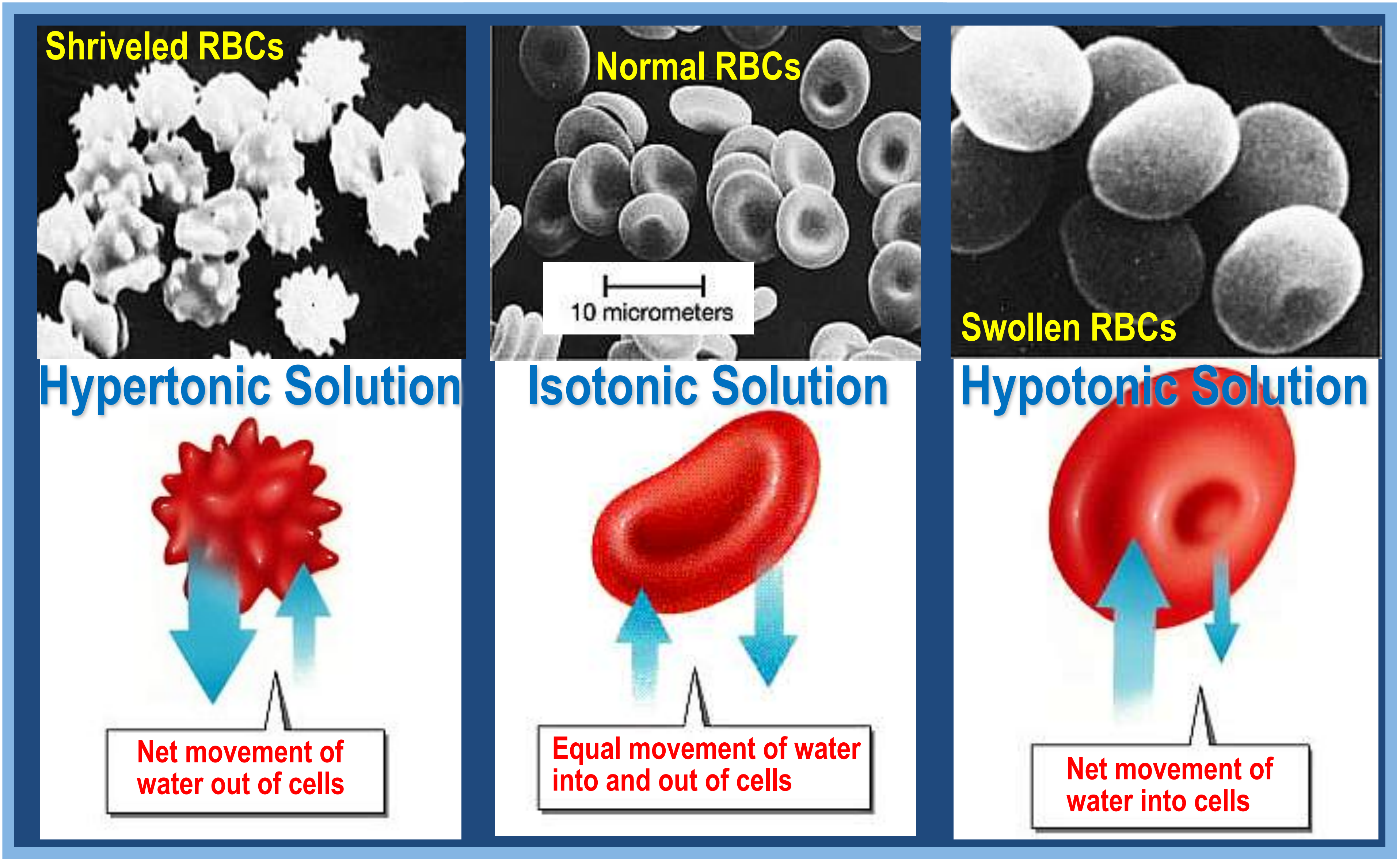
- (shrink) ↑ 0.9%
- out is higher than in

Glucose and other solutions administered for nutritive purposes

- People who can not take adequate amount of food.
- Slowly.
- Prepared in isotonic solution.

Changes in The Body Fluid Compartments (ECF & ICF) and Edema

Osmosis


Shriveled RBCs
Normal RBCs
10 micrometers
Swollen RBCs
Hypertonic Solution
Isotonic Solution
Hypotonic Solution
Net movement of water out of cells
Equal movement of water into and out of cells
Net movement of water into cells

Volumes And Osmolarities of ECF and ICF In Abnormal States.

- **Some factors can cause the change:**
  - dehydration
  - intravenous infusion (IV)
  - abnormal sweating.
  - etc..

- **Changes in volume :**

1. **Volume contraction.**

2. **Volume expansion.**

Changes in volume

Volume contraction

removing

1- ***isotonic*** solution.

2- ***hypertonic*** solution.

3- ***hypotonic*** solution.

Volume expansion

Adding

1- ***isotonic*** solution.

2- ***hypertonic*** solution.

3- ***hypotonic*** solution.

What is Tonicity?

- ***Osmolarity*** describes the concentration of **one** solution.

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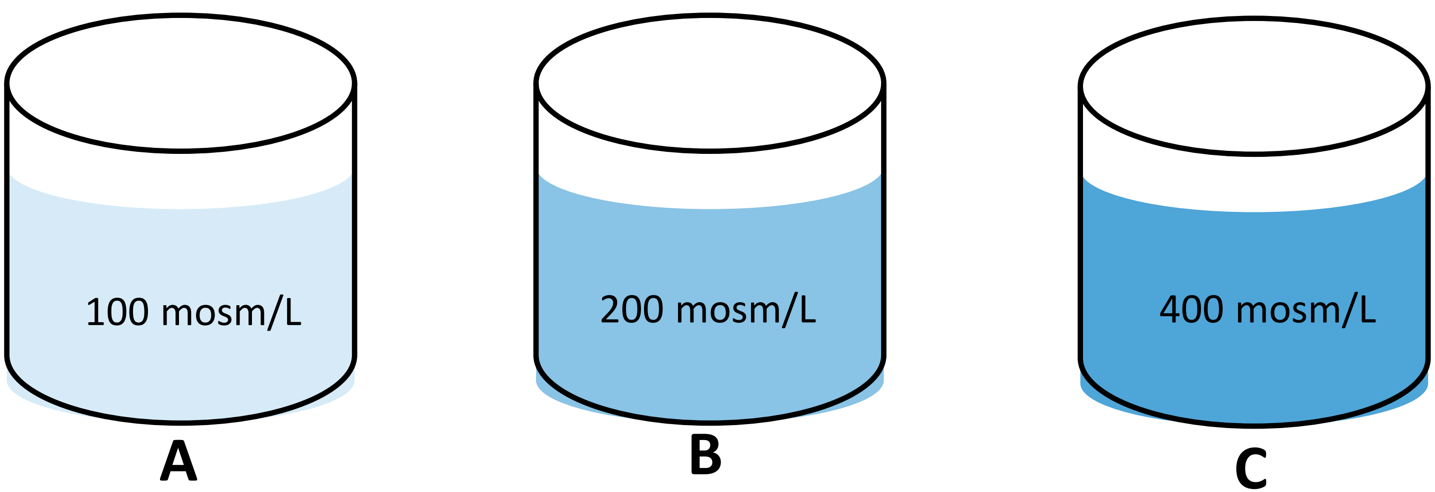
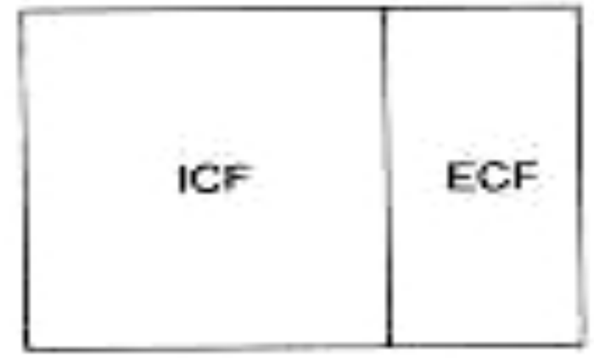


1- Loss of iso-osmotic fluid e.g. Diarrhea

NORMAL STATE



Volume contraction:

1. Diarrhea.

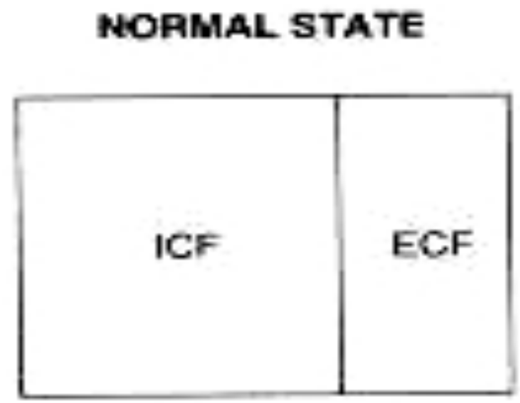
- osmolarity of fluid lost ≈ osmolarity of ECF

(loss of isosmotic fluid).

- ↓ volume in ECF.

- ↓ arterial pressure.

2. Loss of hypotonic solution
e.g. Water deprivation



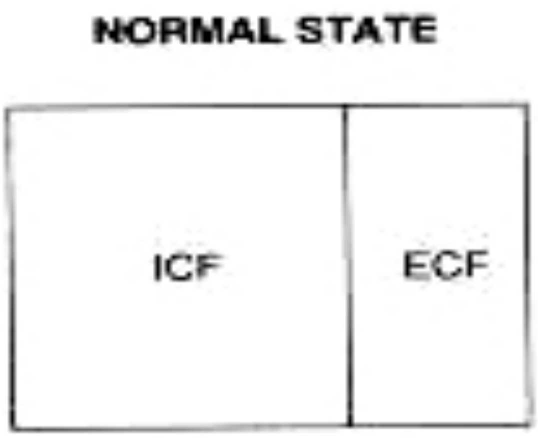
2. Water deprivation :

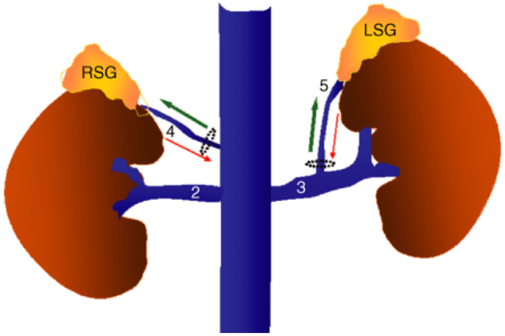
- Osmolarity and volume will change .

- ↑ Osmolarity in both ECF and ICF.

- ↓ Volume in both ECF and ICF.

3- Loss of hypertonic sol. e.g. Adrenal insufficiency





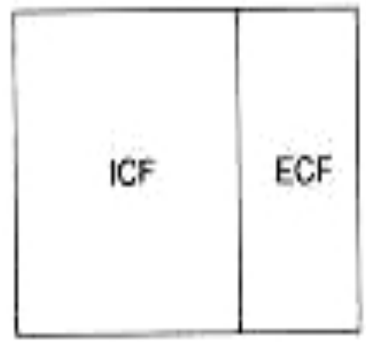
3. Loss of hypertonic solution

e.g. Adrenal insufficiency:

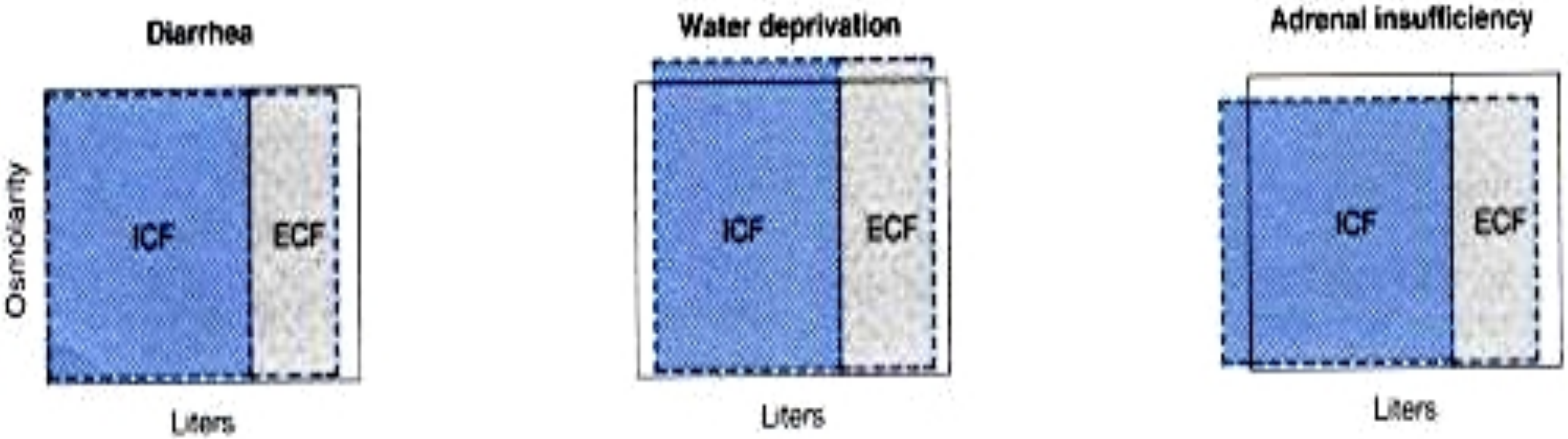
i.e. Aldosterone deficiency.

- **↓- Na^+ in the ECF.**
- **↓- osmolarity in both .**
- **↓- in ECF volume.**
- **↑- in ICF volume.**

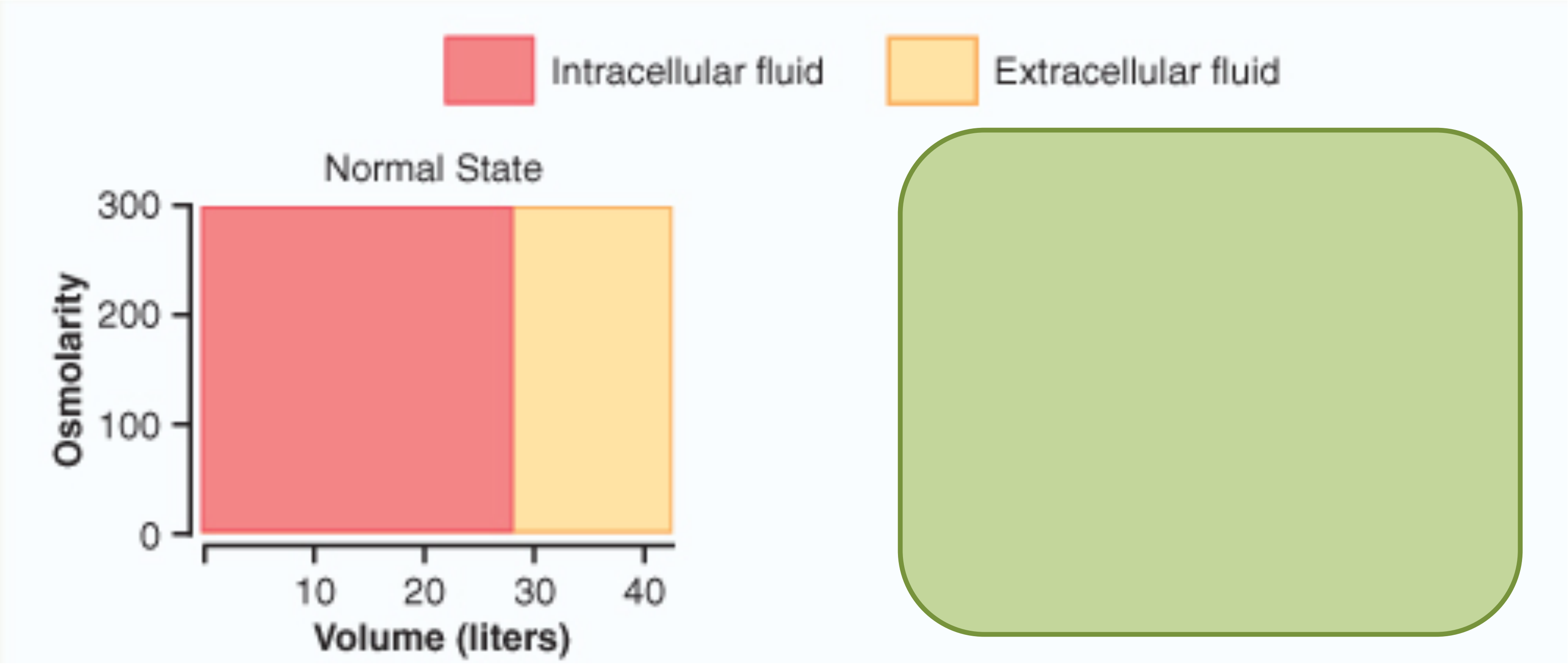
NORMAL STATE



VOLUME CONTRACTION



Volume Expansion



1. **Adding of isotonic NaCl.**

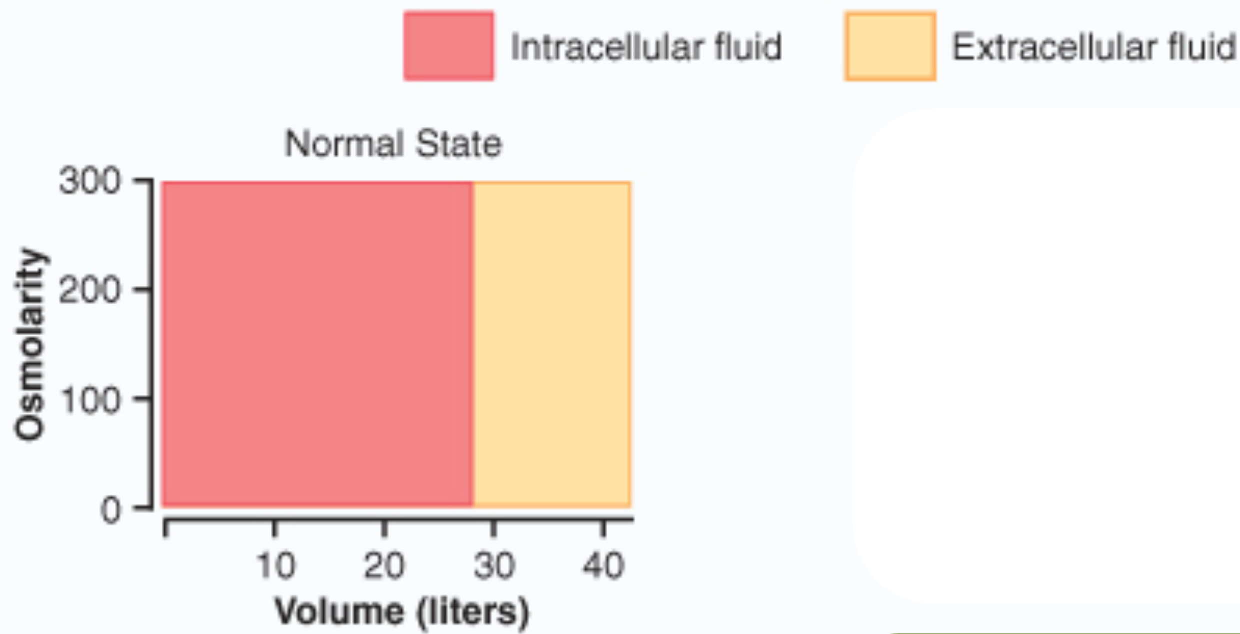
Volume Expansion

1. **Infusion of isotonic NaCl.**

↑ - in ECF volume.

- No change in osmolarity.

- ***Isomotic expansion*** .



2- High NaCl intake

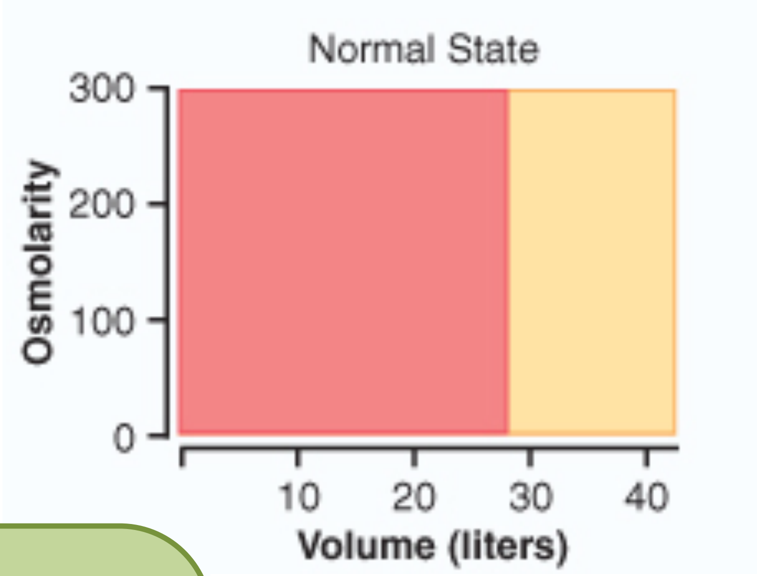
2. High NaCl intake.

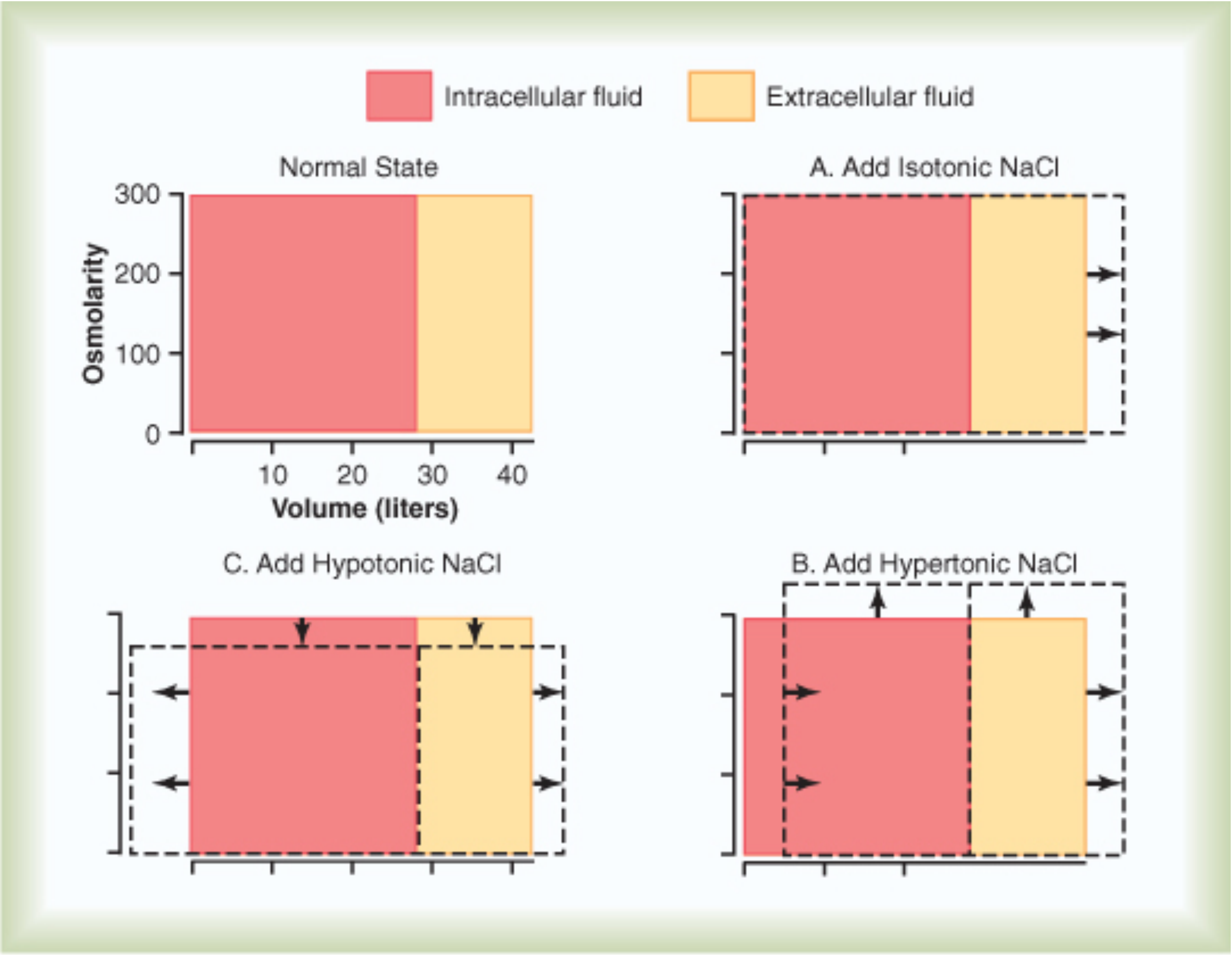
- ↑ eating salt.
- ↑ osmolarity in both.
- ↓ volume of ICF .
- ↑ volume of ECF .
- ***hyperosmotic volume expansion***.

3- **Adding hypotonic solution e.g. Syndrome of inappropriate antidiurtic hormone (SIADH)**

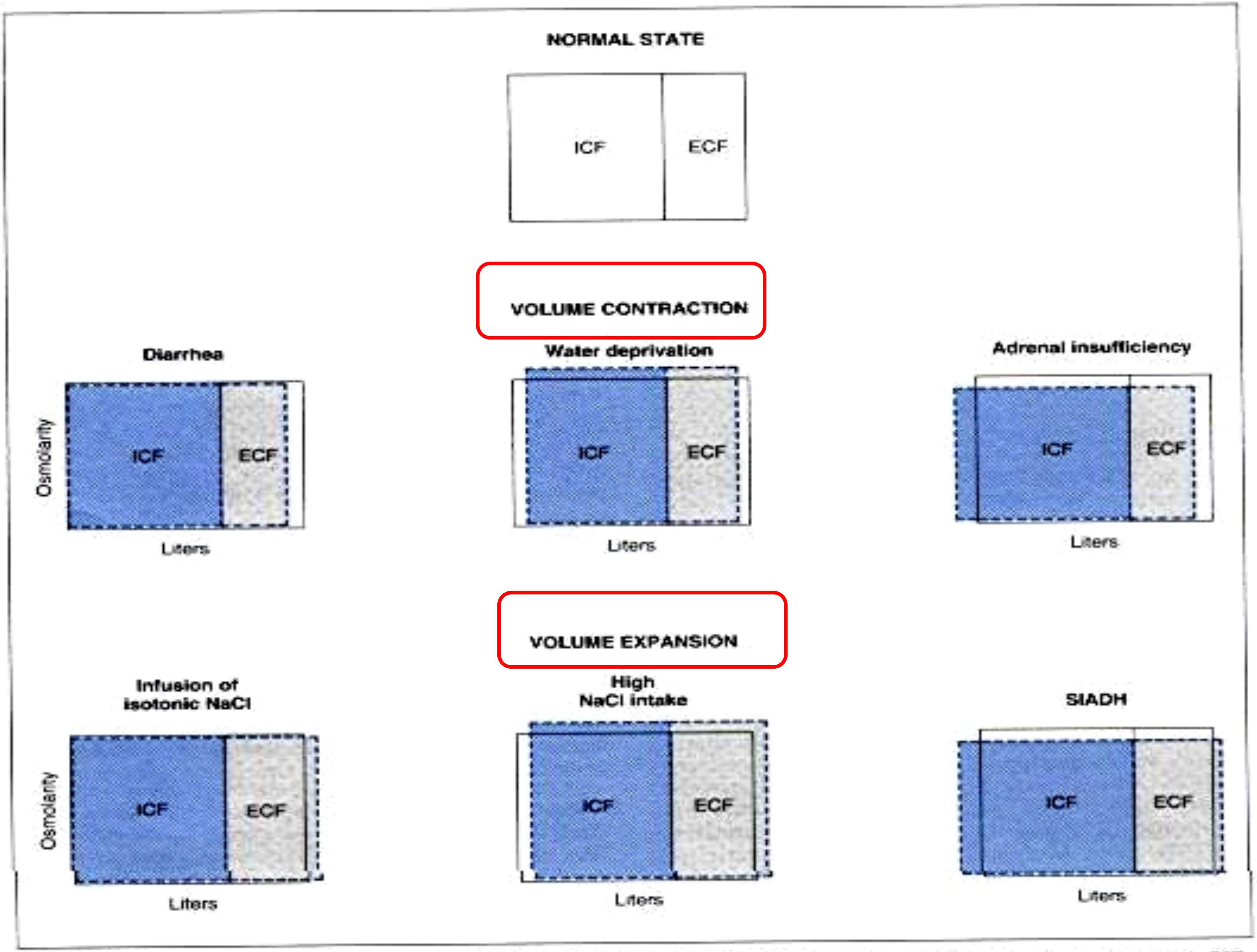
- ↑ volume

- ↓ osmolarity

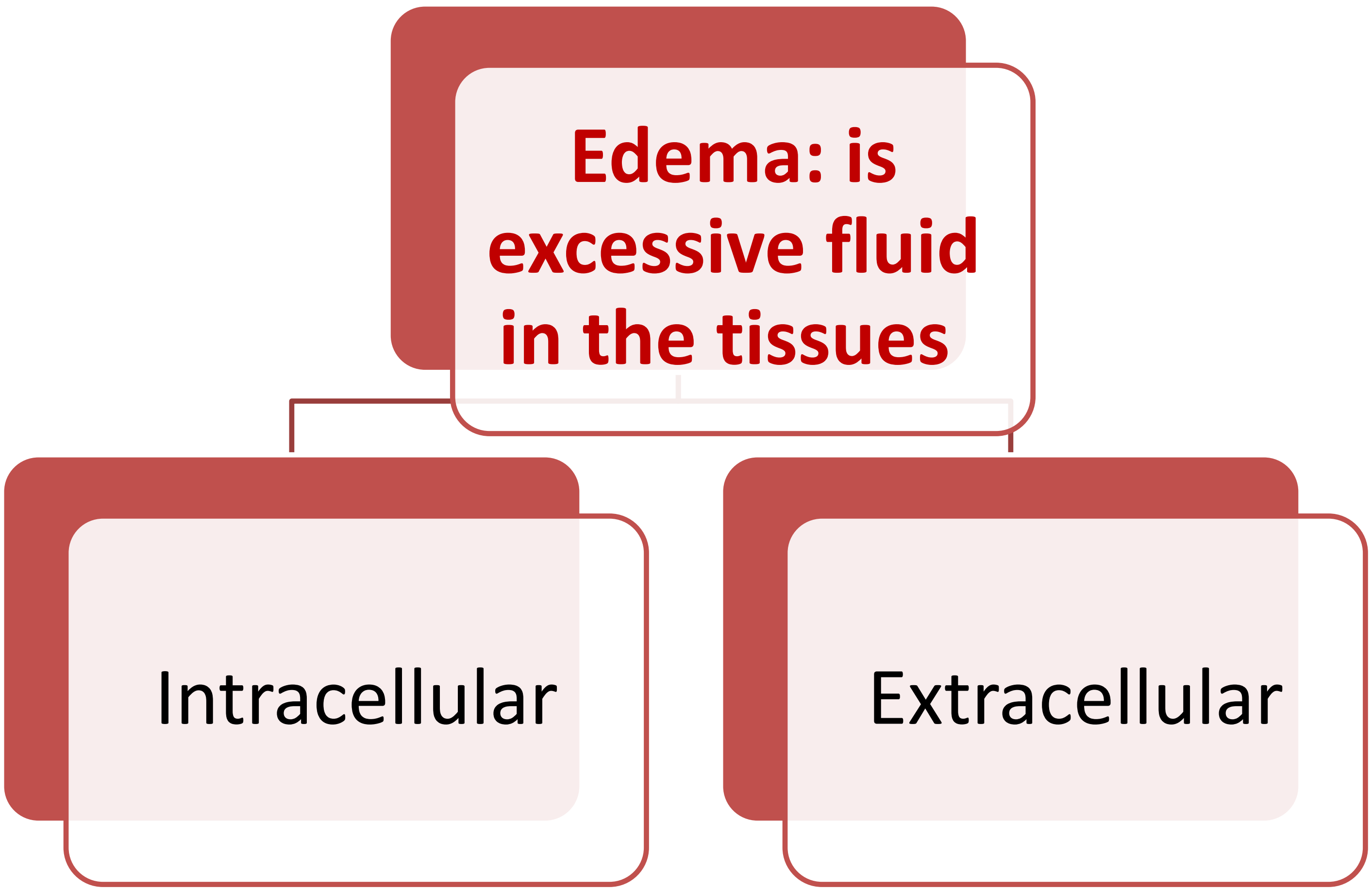




Intracellular fluid
Extracellular fluid
Normal State
300
200
100
0
Osmolarity
10
20
30
40
Volume (liters)
A. Add Isotonic NaCl
C. Add Hypotonic NaCl
B. Add Hypertonic NaCl


NORMAL STATE
ICF
ECF
VOLUME CONTRACTION
Diarrhea
Osmolarity
ICF
ECF
Liters
Water deprivation
ICF
ECF
Liters
Adrenal insufficiency
ICF
ECF
Liters
VOLUME EXPANSION
Infusion of
isotonic NaCl
Osmolarity
ICF
ECF
Liters
High
NaCl intake
ICF
ECF
Liters
SIADH
ICF
ECF
Liters

Edema



- **Edema occurs mainly in the ECF compartment**

Objectives

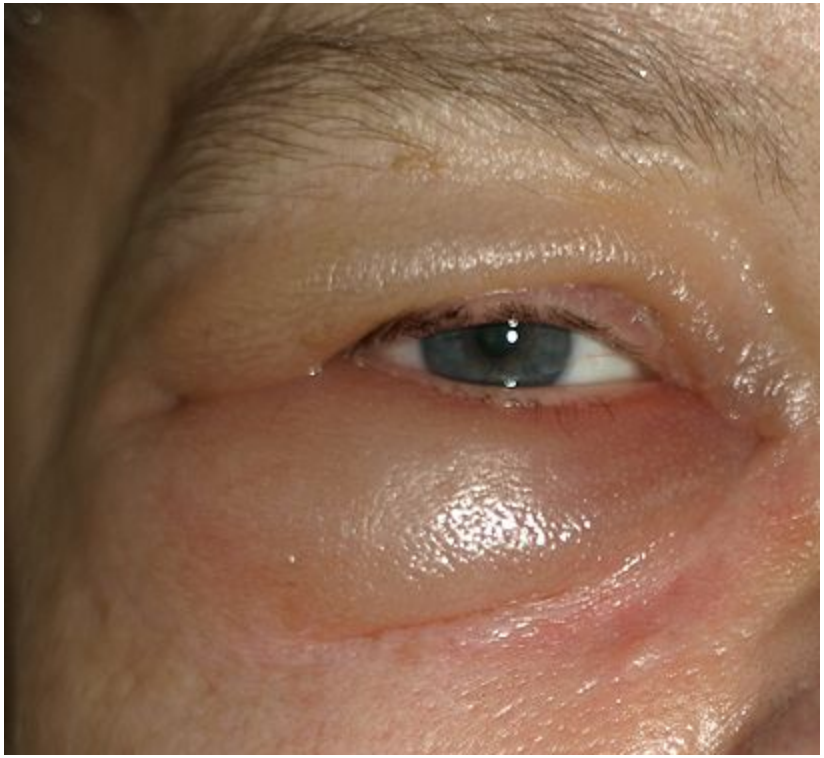
- Define edema and describe its different types.
- Discuss and describe the Starling forces governing fluid exchange across capillary walls.
- Link changes in hydrostatic and osmotic pressures to the pathogenesis of edema.

Study source for this lecture:
(Guyton & Hall Textbook of Medical Physiology, 13th ed, pages: 316-320 & 191-201)

Edema

- **What is "*edema*"?**
  - Edema = swelling
  - The presence of abnormally large amounts of fluid in the intercellular tissue spaces of the body.

(Dorland's illustrated medical dictionary, 28th ed)



Types of Edema

Edema occurs mainly in the ECF compartment, but it can involve the ICF compartment as well.

Edema

Intracellular

- Due to intracellular swelling.
- ***Caused by:***
  - Hyponatremia.
  - Depressed metabolism
  - Lack of nutrition to the cells.
  - Inflammation.

Extracellular

- More common clinically
- Due to accumulation of fluid in the extracellular space.
- Can be caused by many conditions.

(Guyton & Hall Textbook of Medical Physiology; 13th ed, Chapter 25)

Intracellular Edema:

inflammation of tissues.

↓

↑ membrane permeability.

↓

Na inside cells.

↓

water

↓

edema

Extracellular Edema

- Extracellular edema = the abnormal accumulation of fluid in intercellular tissue space (i.e. interstitial space).

- Normally, fluid is constantly moving in & out of the interstitial space to allow ECF to distribute between plasma and IF.

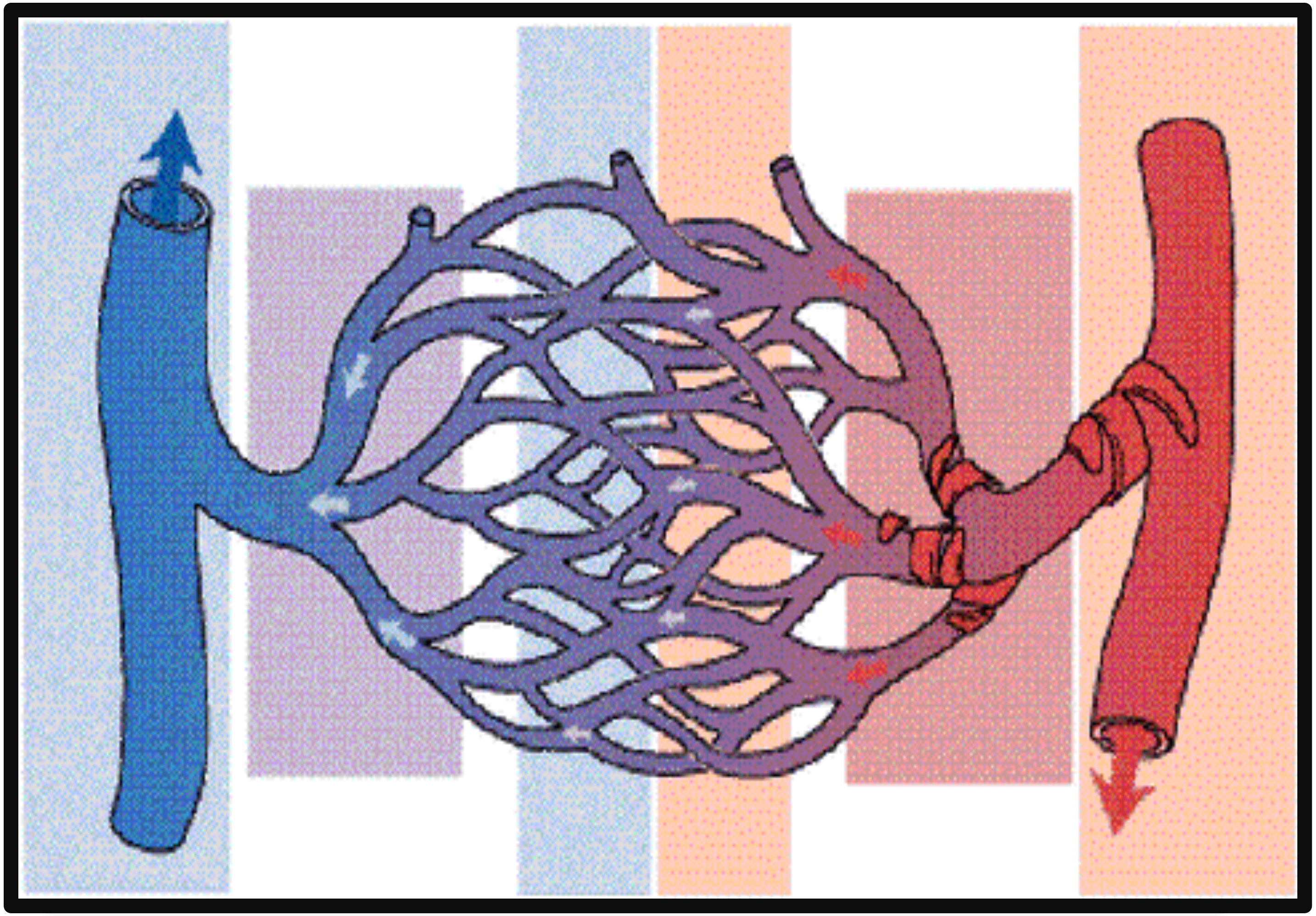
- This process happens without fluid accumulating between the cells.

- What happens to cause fluid to accumulate between the cells leading to edema?

- To understand EC edema one must first understand how fluid exchange occurs between capillaries and tissue cells.

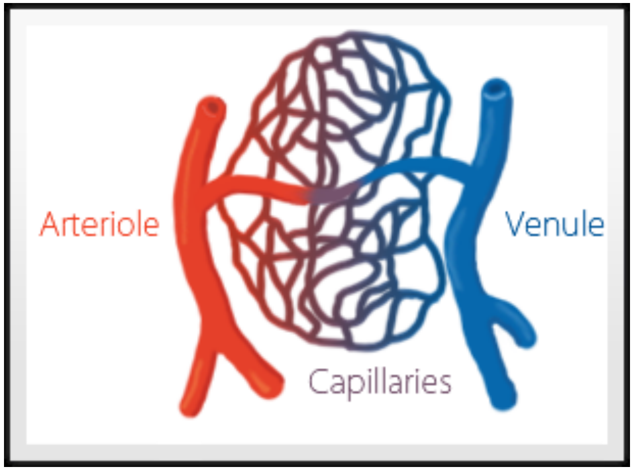
Extracellular Edema

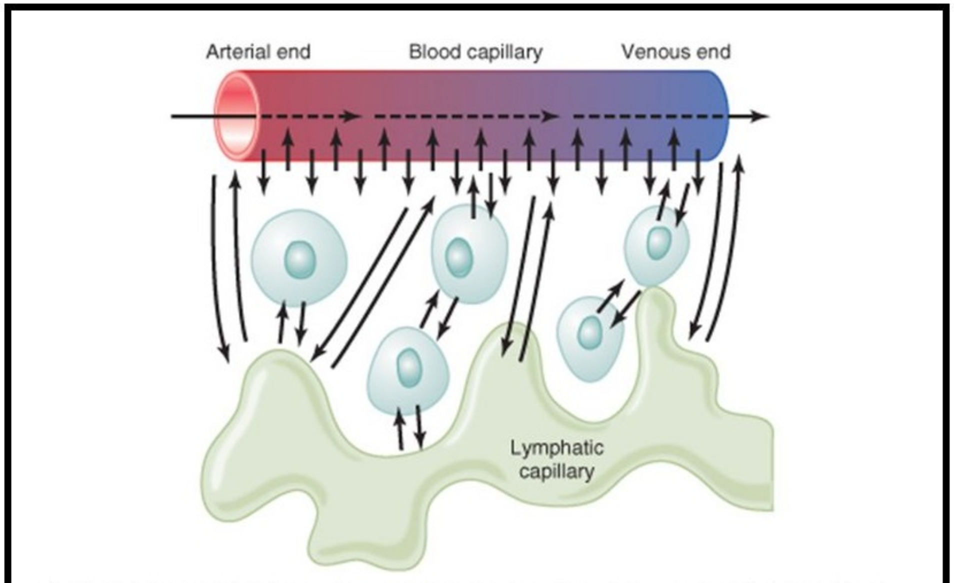
common clinical cause is excessive capillary fluid filtration.



Fluid Exchange Between Blood & Interstitial Fluid

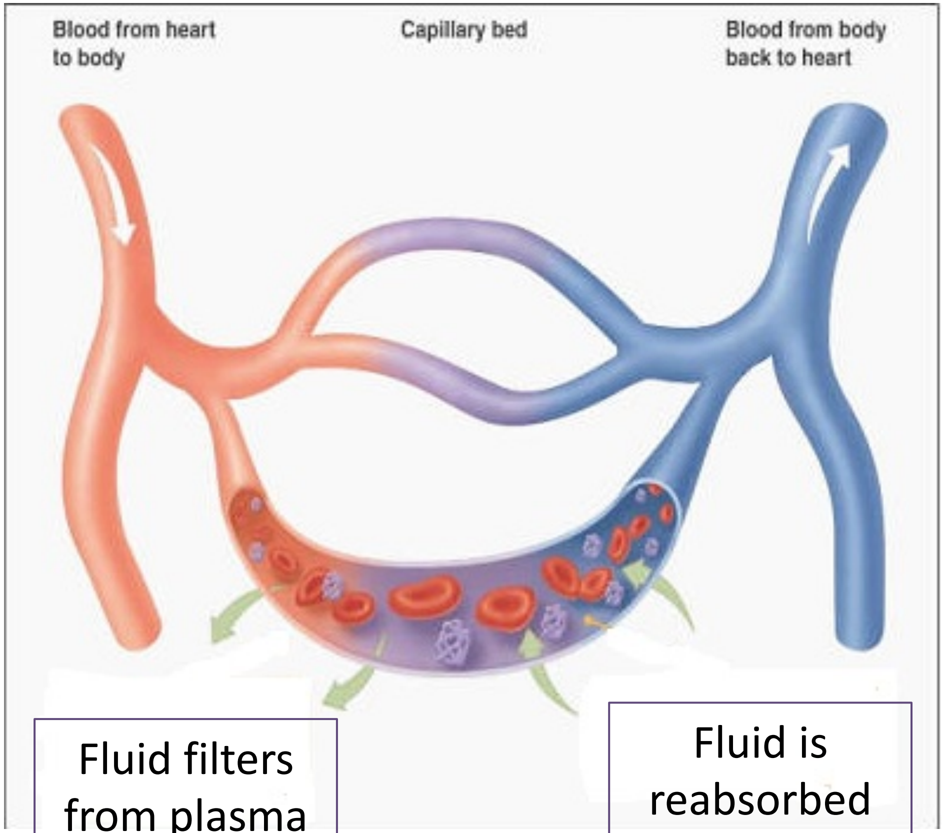
- Fluid exchange between blood and tissue cells occurs at the level of the capillaries.
- Capillaries are the **smallest** blood vessels in our vascular tree.
- They are very small and have a very thin wall allowing easy exchange of fluid across the walls.





Fluid Filtration Across Capillaries

As blood passes through capillaries



Fluid filters from plasma to interstitium

Fluid is reabsorbed from interstitium into plasma

Factors Controlling Fluid Filtration Across Capillary Walls

Movement of fluids across capillary walls depends on the balance of ***starling forces*** acting across the capillary wall.

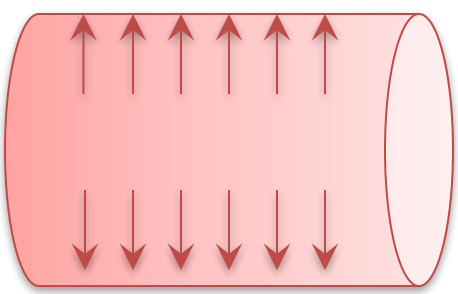
Starling Forces

Starling Forces

Forces that control movement of fluid in/out of a capillary

Hydrostatic pressure (P)

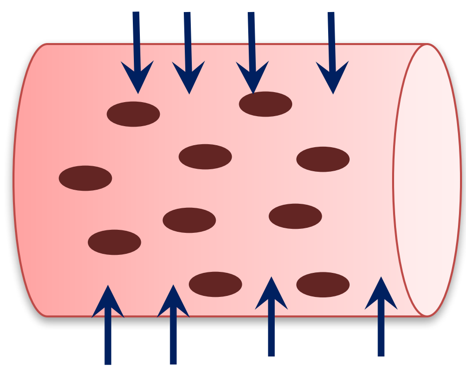
The pressure exerted by blood (water) on the walls of the blood vessel



Pushes fluid ***OUTSIDE***

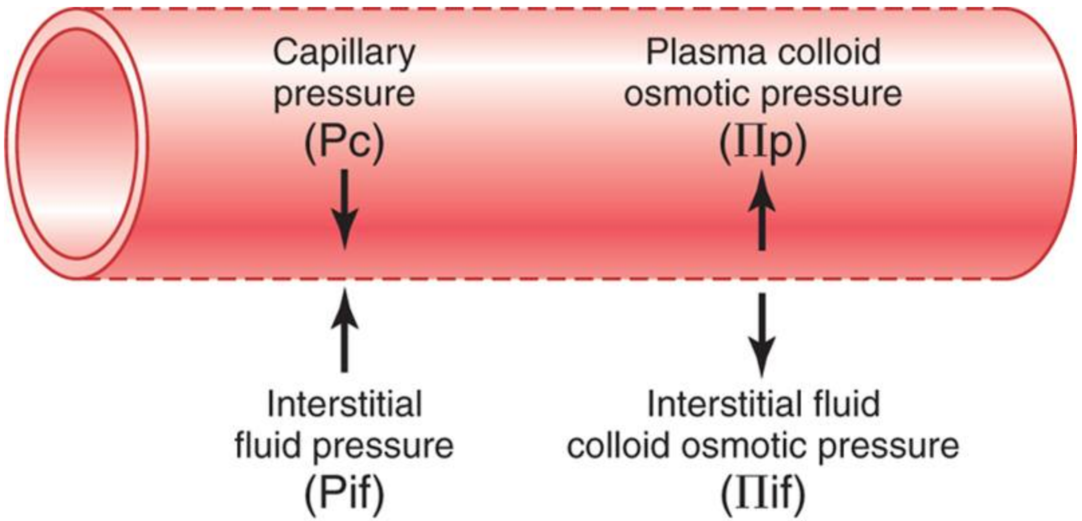
Colloid osmotic (oncotic) pressure (π)

The osmotic pressure created by the non-diffusible plasma proteins inside the blood vessel



Pulls fluid ***INSIDE***

Starling Forces Acting Across Capillary Membrane



Hall: Guyton and Hall Textbook of Medical Physiology, 12th Edition

- **4 primary forces determine whether fluid moves in or out of blood** "***Starling forces***":
  - Capillary "***hydrostatic***" pressure → out of blood.
  - IF "***hydrostatic***" pressure → into blood if +ve and out of blood if -ve.
  - Plasma ***colloid osmotic*** pressure → into blood.
  - IF ***colloid osmotic*** pressure → out of blood.

Starling Forces Acting Across Capillary Membrane

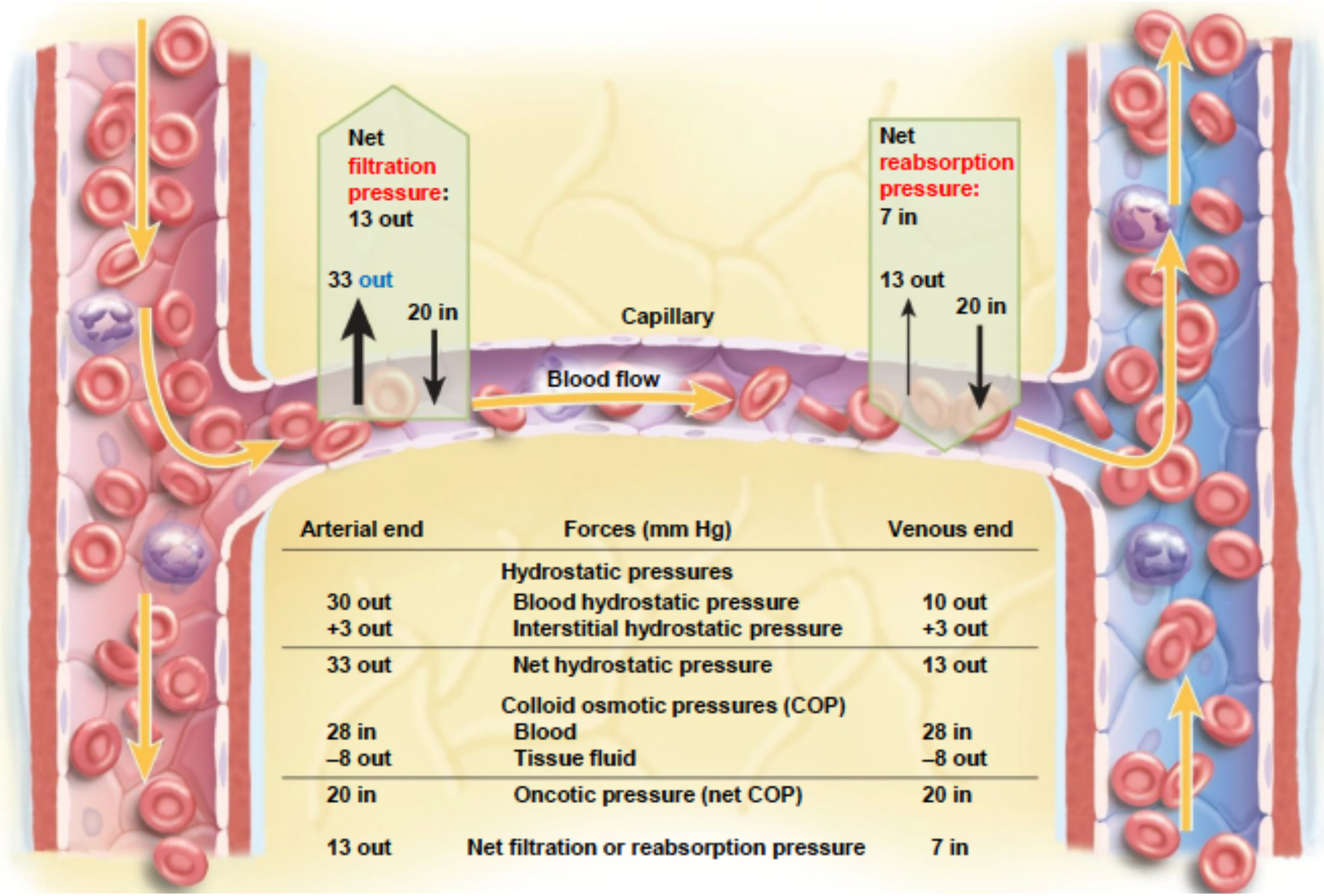
- Capillary ***hydrostatic pressure (P_c)***:
  - Arterial end = 30 mmHg
  - Venous end = 10 mmHg (usually 15-25 mmHg less than arterial end).

- IF ***hydrostatic pressure (P_{if})*** is usually subatmospheric in loose connective tissue (≈ -3 mmHg). Because P_{if} is negative it will actually favour filtration rather than oppose it.

- Plasma ***colloid osmotic pressure (π_p)*** = 28 mmHg.

- IF ***colloid osmotic pressure (π_{if})*** = 8 mmHg.

Forces that Determine Fluid Movement through Capillary Membrane

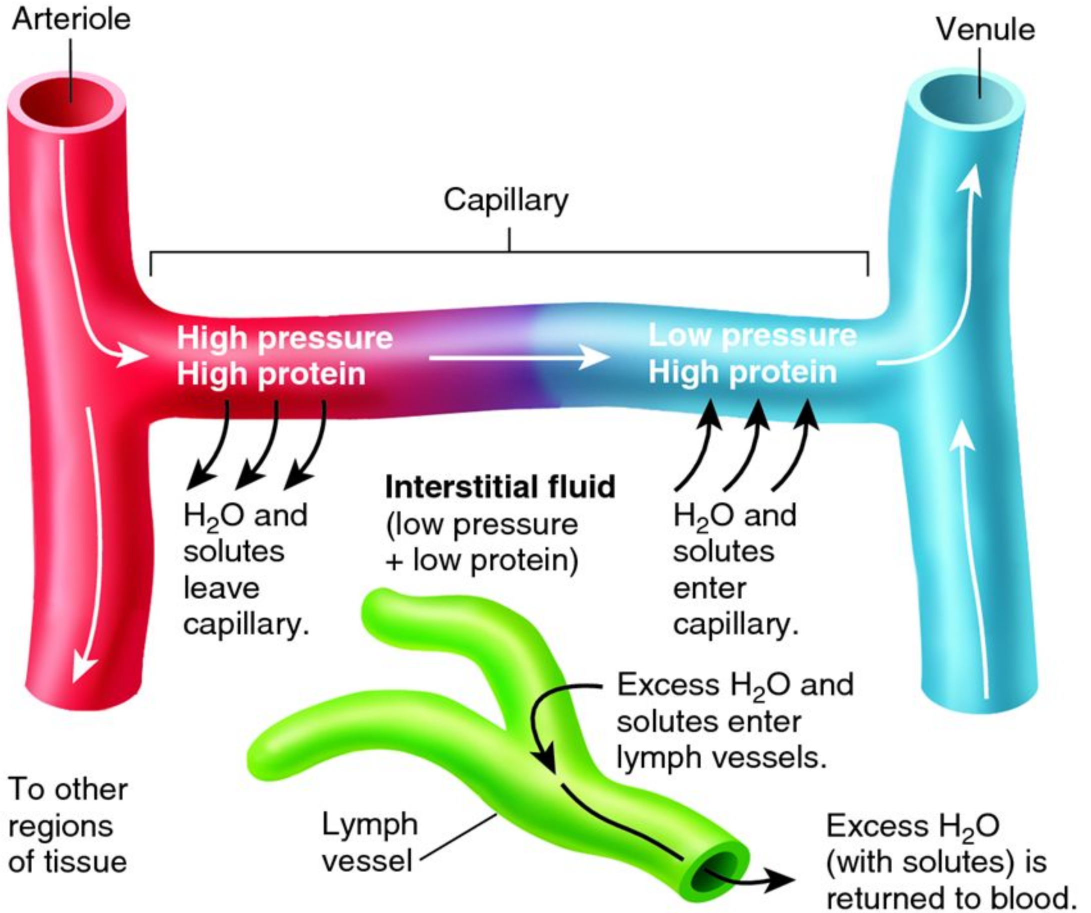


Arterial end	Forces (mm Hg)	Venous end
	Hydrostatic pressures	
30 out	Blood hydrostatic pressure	10 out
+3 out	Interstitial hydrostatic pressure	+3 out
33 out	Net hydrostatic pressure	13 out
	Colloid osmotic pressures (COP)	
28 in	Blood	28 in
–8 out	Tissue fluid	–8 out
20 in	Oncotic pressure (net COP)	20 in
13 out	Net filtration or reabsorption pressure	7 in

The Lymphatic System

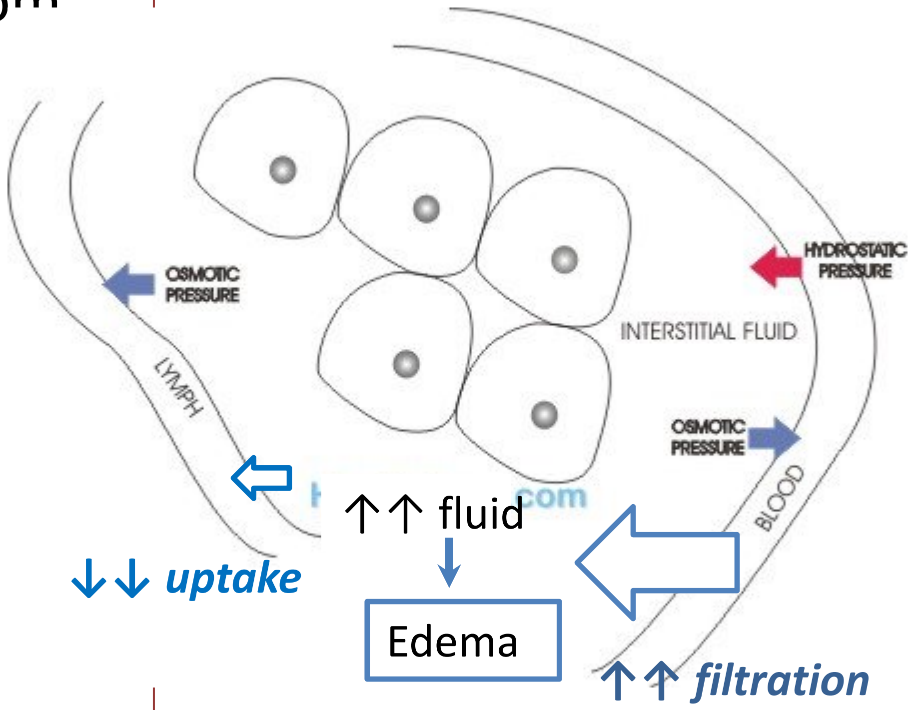
The reabsorption pressure causes 9/10 of the filtered fluid to be reabsorbed while 1/10th remains in the IF.. ***What happens to this 1/10th?***

The total quantity of lymph ≈ 2-3L/day.



Edema

- ***Two main reasons***:
  1. Abnormal **leakage** of fluid from plasma to interstitial space.
  2. Failure of **lymphatic uptake**.



Edema

Increase capillary filtration

1. ***Increased capillary pressure***
   - Kidney failure
   - Heart failure.
   - Venous obstruction

2. ***Decreased plasma oncotic pressure***
   - Loss of proteins (nephrotic syndrome, burns).
   - Inability to synthesize proteins (liver failure, malnutrition).

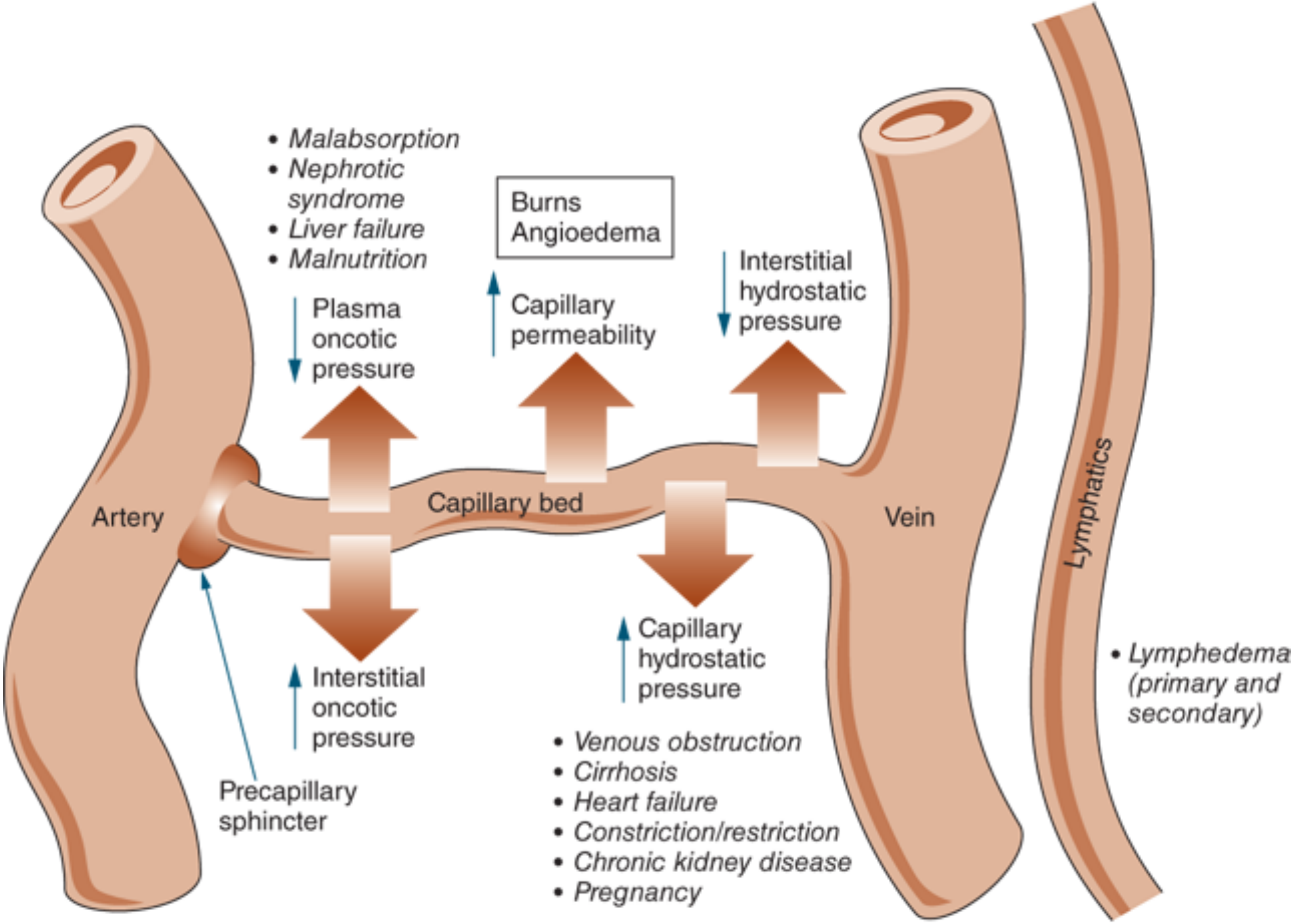
3. ***Increased capillary permeability***
   - Inflammation
   - Infection.
   - Immune reactions.

Decrease lymph uptake

Lymphatic obstruction

- Infection (filaria).
- Surgery.
- Congenital absence.
- Cancer.

Edema


• Malabsorption
• Nephrotic syndrome
• Liver failure
• Malnutrition
Plasma oncotic pressure
Burns
Angioedema
Capillary permeability
Interstitial hydrostatic pressure
Artery
Capillary bed
Vein
Lymphatics
Interstitial oncotic pressure
Capillary hydrostatic pressure
Precapillary sphincter
• Venous obstruction
• Cirrhosis
• Heart failure
• Constriction/restriction
• Chronic kidney disease
• Pregnancy
• Lymphedema (primary and secondary)

الله يوفقن

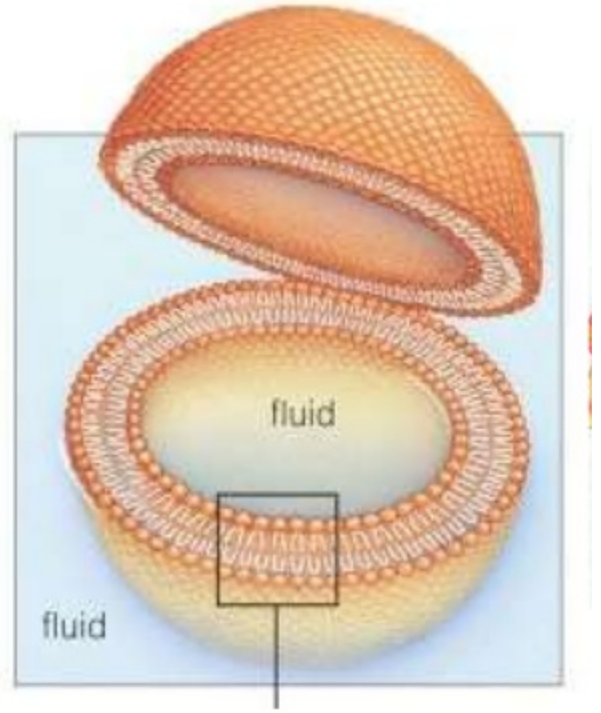
Cell membrane structure & transport across cell membrane

objectives

- **Describe the fluid mosaic model of membrane structure and function.**
- **Define permeability and list factors influencing permeability.**
- **Identify and describe carried-mediated transport processes: Primary active transport, secondary active transport, facilitates diffusion.**
- **Differentiate between passive and active transport mechanisms and give examples on each.**

#Study source for this lecture: (Guyton & Hall Textbook of Medical Physiology, 13th edition) #

Cell Membran



- Envelops the cell.
- Thin, pliable and elastic.
- 7 - 10 nanometer thick.
- Also, referred to as the plasma membrane .

Composition

Lipoprotein

protein 55%

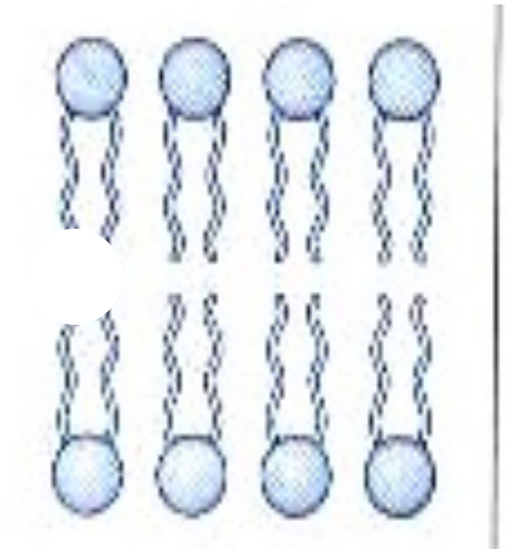
phospholipids 25%
cholesterol 13% } **lipid**
glycolipid 4%

carbohydrates 3%

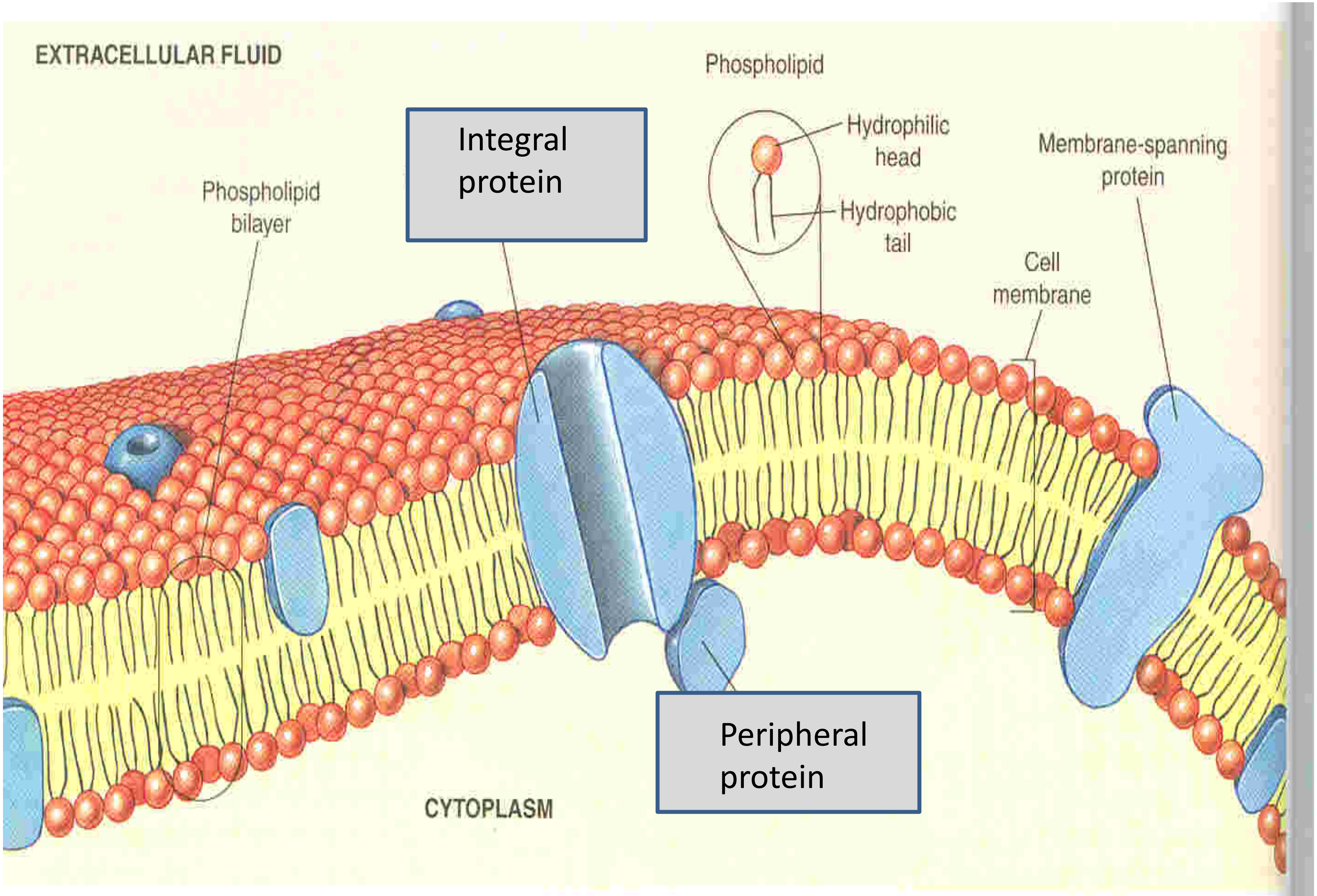
The Cell Membrane Phospholipids Consist Of :

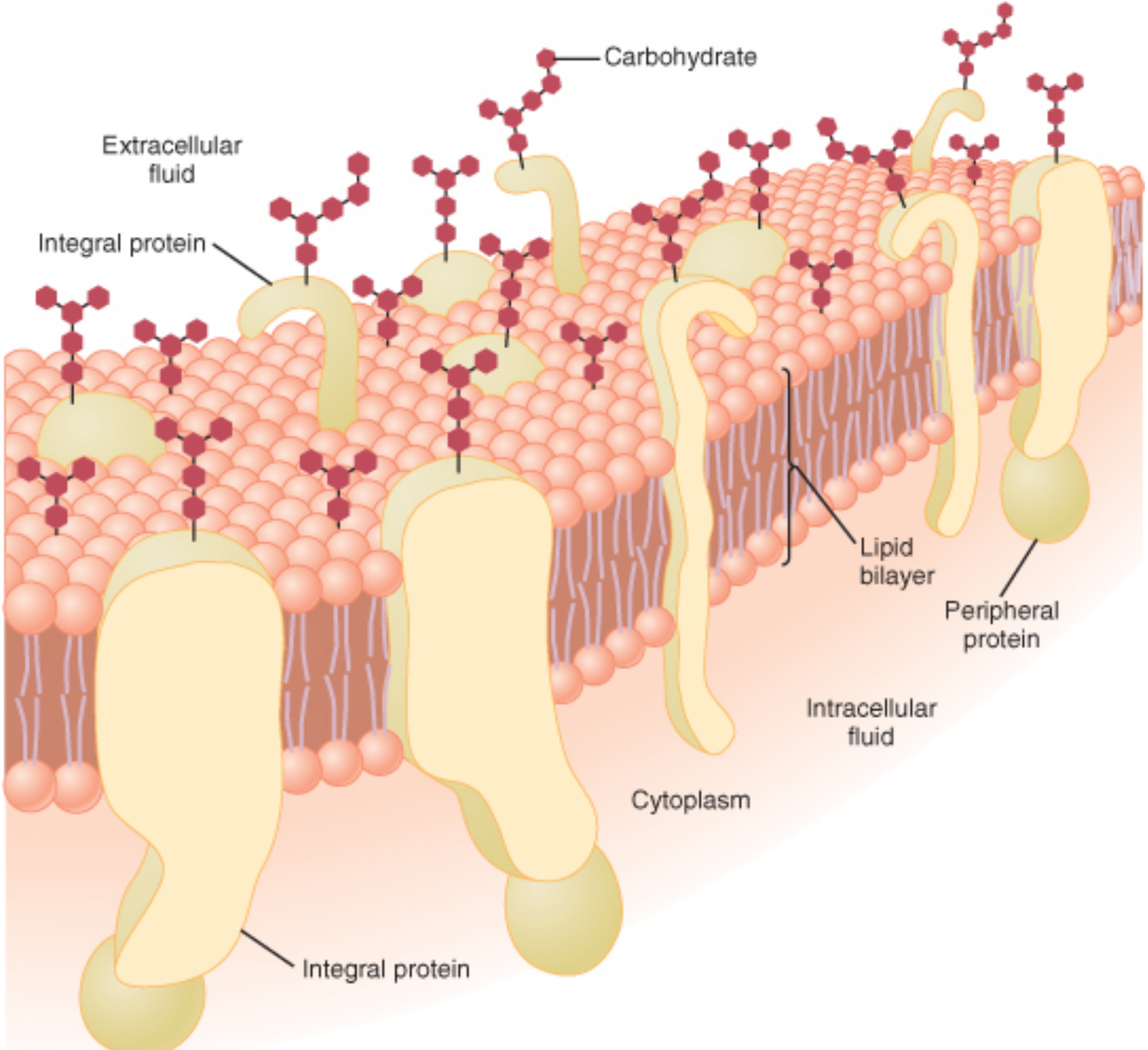
1. Glycerol head (hydrophilic).

2. Two fatty acid ''tails'' (hydrophobic).



The Cell Membrane Proteins





Carbohydrate
Extracellular fluid
Integral protein
Lipid bilayer
Peripheral protein
Intracellular fluid
Cytoplasm
Integral protein

The Cell Membrane Proteins.

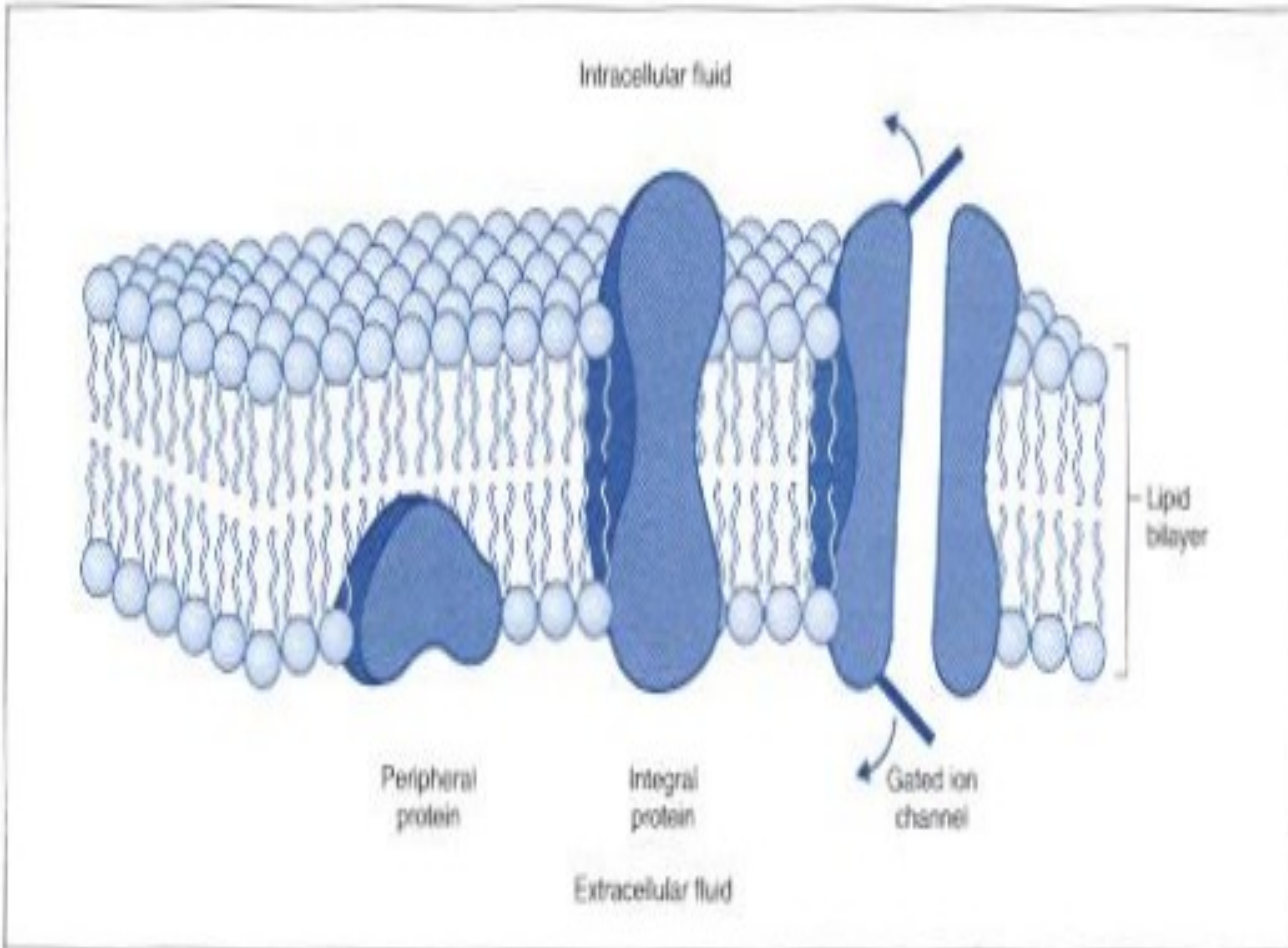
1. **Integral proteins** span the membrane .

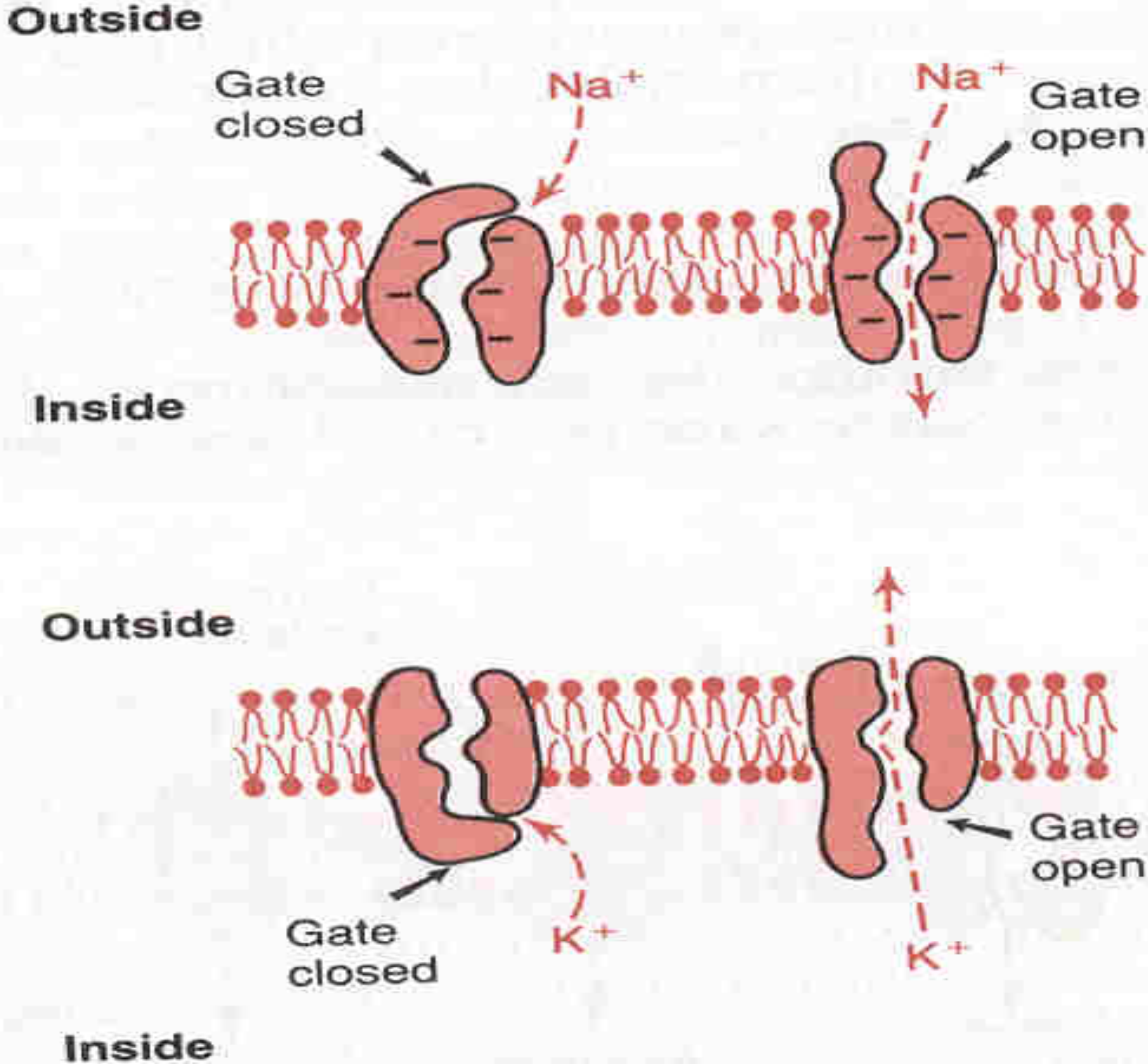
- Proteins provide structural **channels** or **pores**.
- **Carrier** proteins.

2. **Peripheral proteins**

-Present in one side.

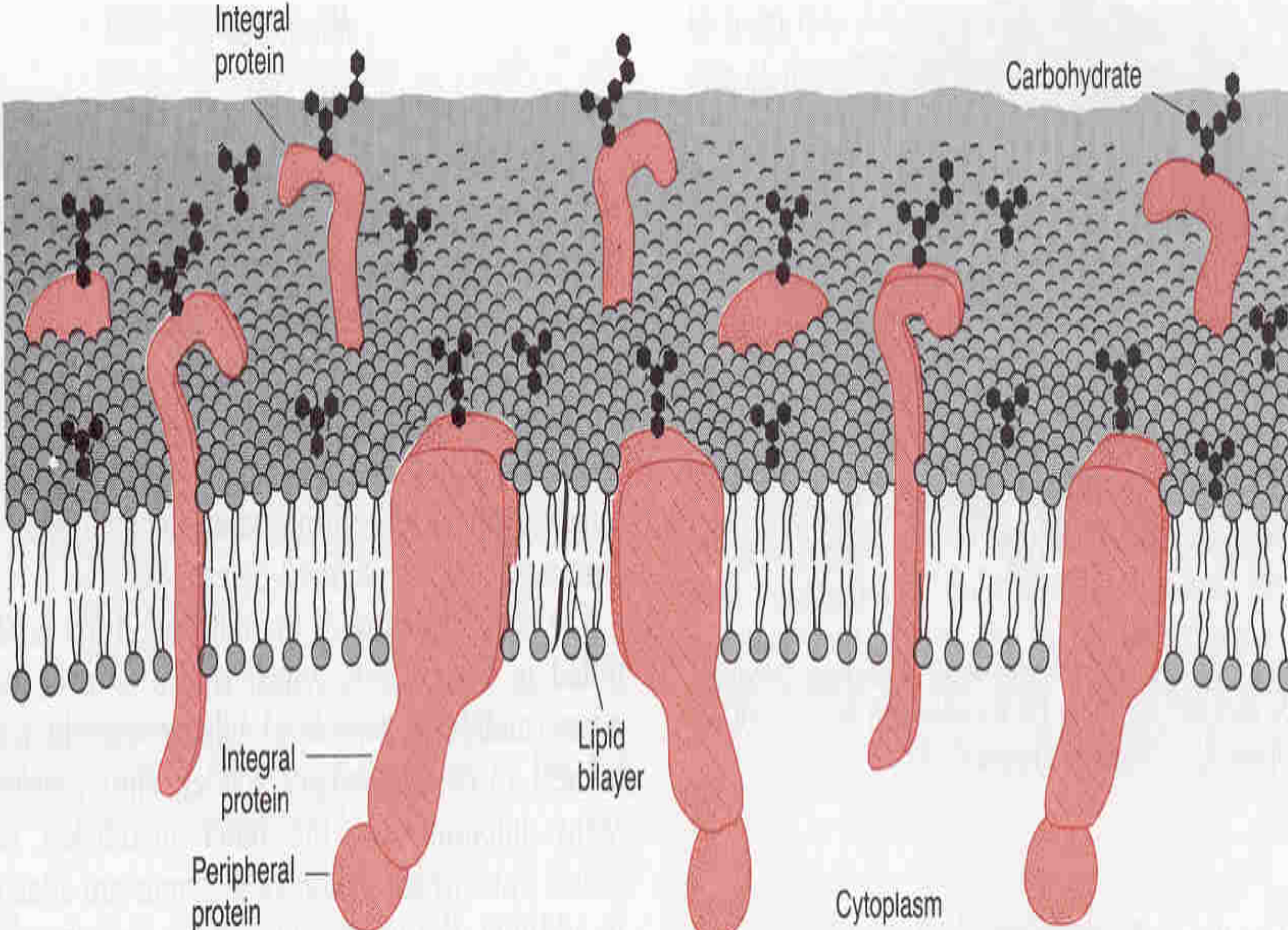
- Hormone receptors .
- Cell surface antigens .


Intracellular fluid
Lipid bilayer
Peripheral protein
Integral protein
Gated ion channel
Extracellular fluid


Outside
Gate
closed
Na+
Na+
Gate
open
Inside
Outside
Gate
open
Gate
closed
K+
K+
Inside

The Cell Membrane Carbohydrates:

- **Glycoproteins** (most of it).
- **Glycolipids** (1/10)
- Proteoglycans (mainly carbohydrate substance bound together by protein)
- ''glyco'' part is in the surface forming.
- Glycocalyx (Carbohydrate molecules protrude to the outside of the cell forming a loose carbohydrate coat "glycocalyx"



Integral protein
Carbohydrate
Integral protein
Lipid bilayer
Peripheral protein
Cytoplasm

Function Of Carbohydrates:

- **Attaches** cell to each others.
- Act as **receptors** substances (help ligend to recognize its receptor).
- Some enter in to **immune reactions**.
- Give most of cells overall **–ve surface**.

Transport Through The Cell Membrane

- Cell membrane is ***selectively permeable***.

- Through the **proteins**.
  - Water-soluble substances e.g. ions, glucose ..

- Directly through the **bilayer**.
  - Fat-soluble substance (O_2, CO_2, N_2, alcohol..

	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 gm/dl	2 to 95 gm/dl
PO_2	35 mm Hg	20 mm Hg ?
PCO_2	46 mm Hg	50 mm Hg ?
pH	7.4	7.0
Proteins	2 gm/dl (5 mEq/L)	16 gm/dl (40 mEq/L)

Types Of Membrane Transport

1- Diffusion

a) simple diffusion.

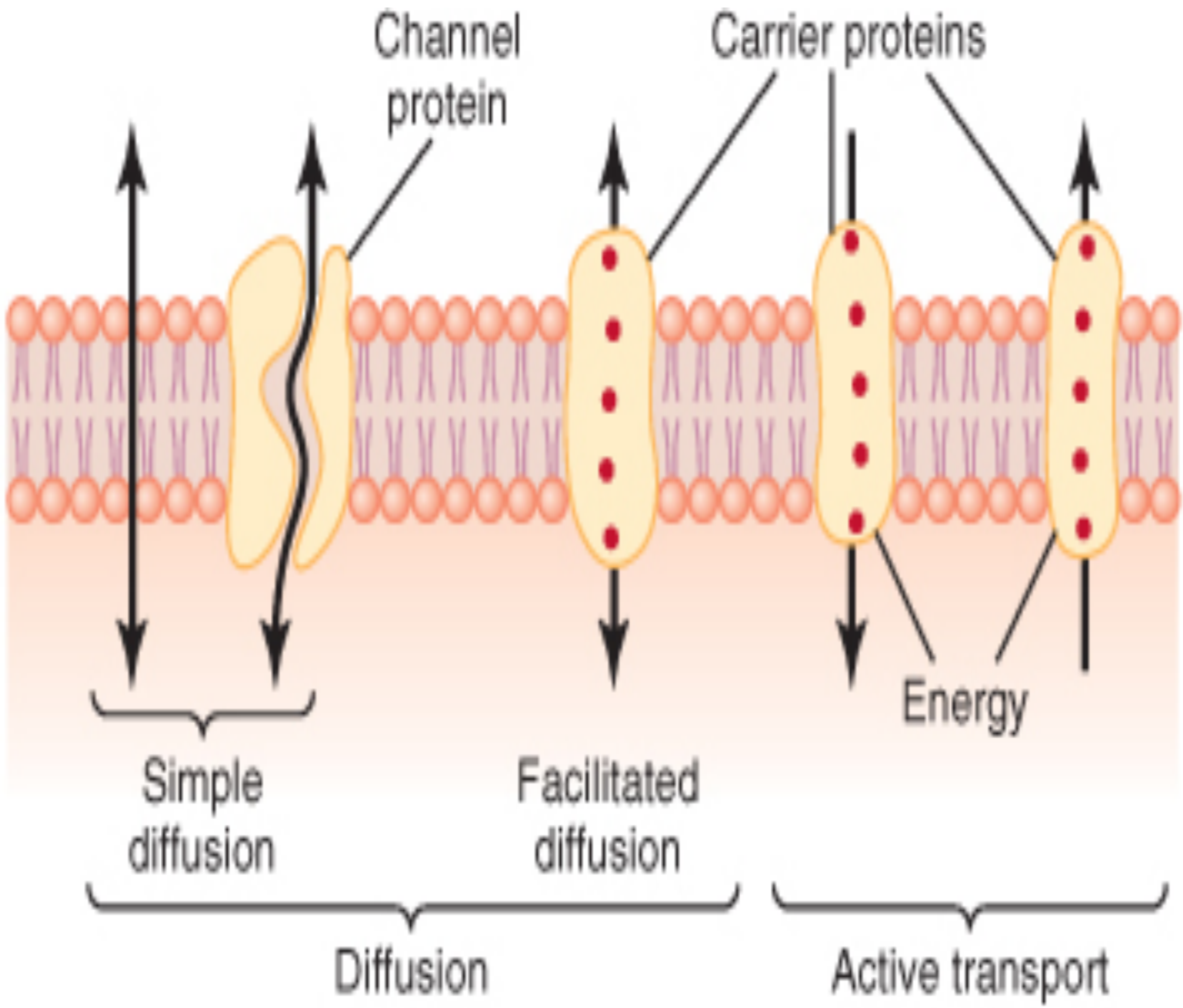
b) facilitated diffusion.

2- Active transport.

a) primary active transport.

b) secondary active transport.

3- Osmosis.


Channel
protein
Carrier proteins
Energy
Simple
diffusion
Facilitated
diffusion
Diffusion
Active transport

Diffusion

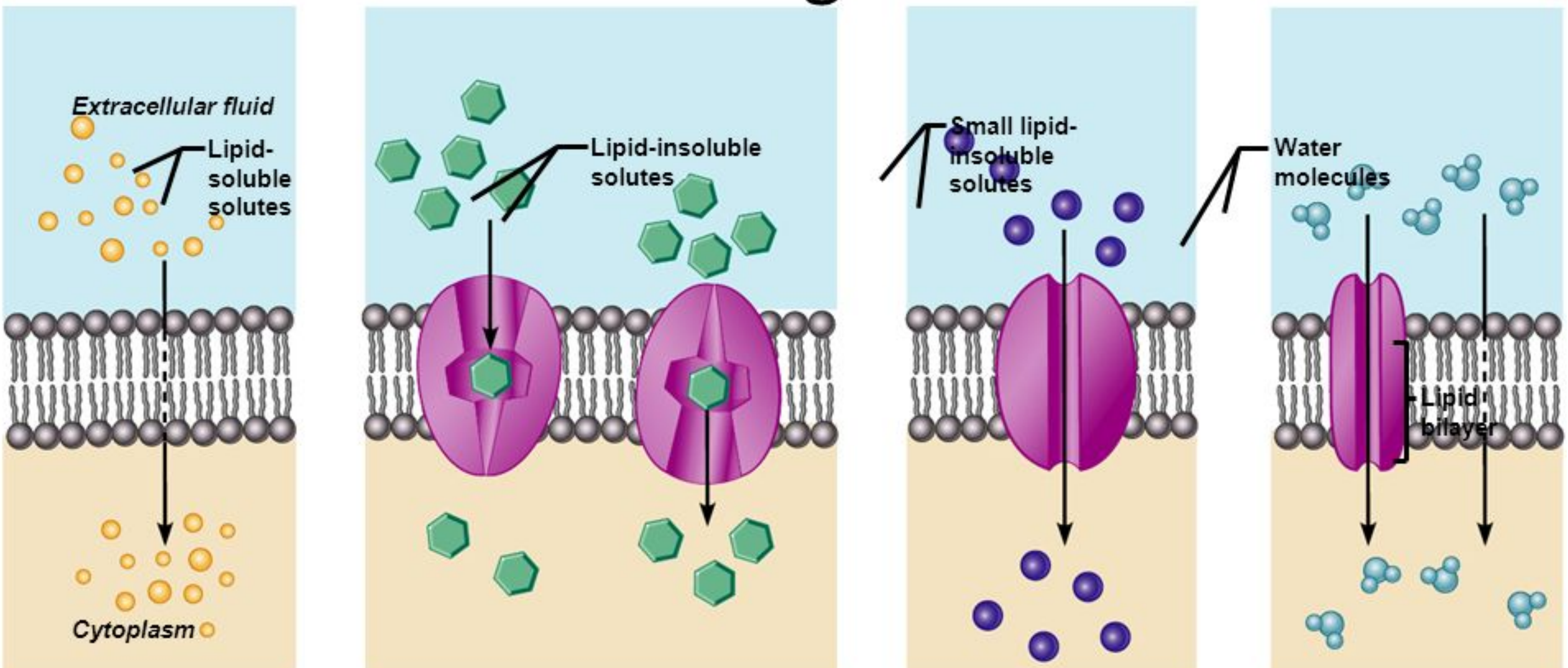
Random movement of substance either through the membrane directly or in combination with carrier protein down an electrochemical gradient.

1- Simple diffusion.

2- facilitated diffusion.

- Simple and facilitated diffusion Do NOT require input of energy = powered by concentration gradient or electrical gradient.
- Active transport = uses ATP.

Diffusion Through the Plasma



(a) Simple diffusion directly through the phospholipid bilayer

(b) Carrier-mediated facilitated diffusion via protein carrier specific for one chemical; binding of substrate causes shape change in transport protein

(c) Channel-mediated facilitated diffusion through a channel protein; mostly ions selected on basis of size and charge

(d) Osmosis, diffusion through a specific channel protein (aquaporin) or through the lipid bilayer

Simple Diffusion

- Non-carrier mediated transport down an electrochemical gradient.
- Diffusion of non-electrolytes (uncharged) from high concentration to low concentration.
- Diffusion of electrolytes (charged) depend on both chemical, as will as, electrical potential difference.

Rate Of Simple Diffusion Depend On:

1- Amount of substance available.

2- The number of opening in the cell membrane for the substance (pores).

selective gating system

3- Chemical concentration difference.

4- Electrical potential difference.

5- Molecular size of the substance.

6- Lipid solubility.

Factors Affecting Rate of Diffusion *cont…*

$$Rate\ of\ diffusion = P\ X\ A\ (C1 - C2)$$

1. P = Permeability coefficient.

a.Temperature. b. Size of molecule. c. Solubility in lipids. d. Thickness of membrane.

2. A = surface area.

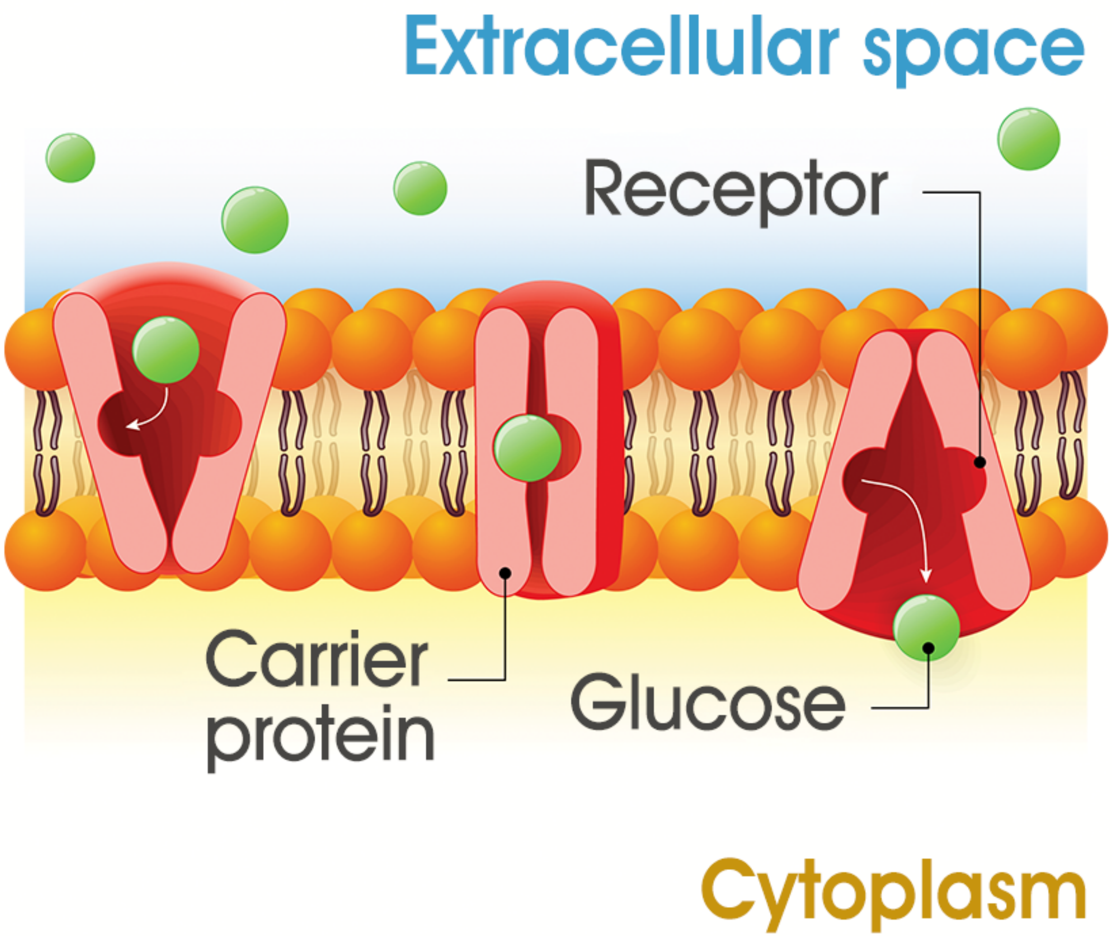
3. C1-C2 = gradient difference:

a. **Concentration difference**
b. **b. Electrical difference.**
c. **Pressure difference.**

Facilitated Diffusion

- Carrier mediated transport down an electrochemical gradient.
- E.g. glucose & amino acids.

Facilitated diffusion—the process that allows selective movement in and out of the **cell membrane**.



Features Of Carrier Mediated Transport (Facilitated diffusion)

1- saturation:

↑ concentration ⟶ ↑ binding of protein

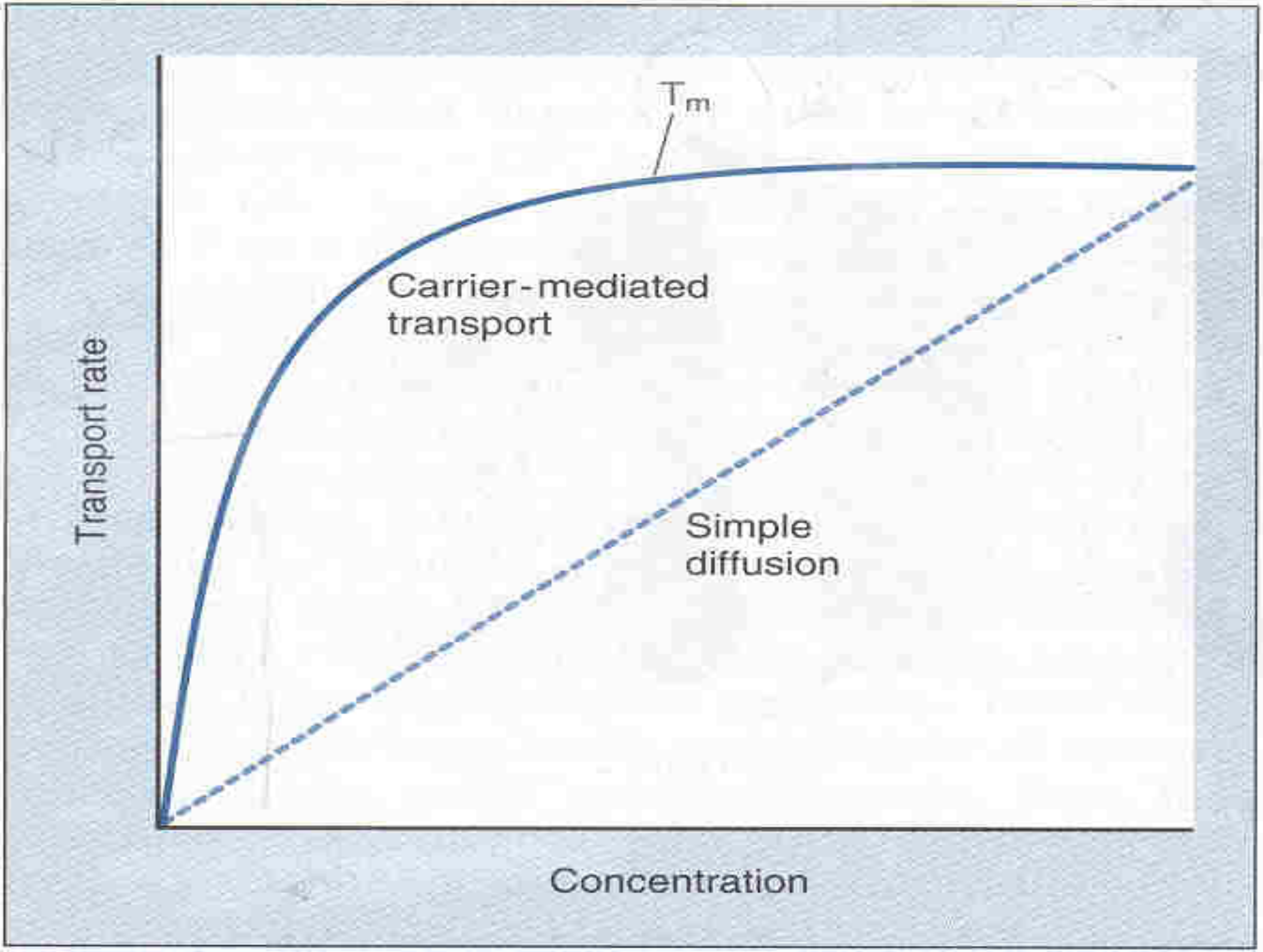
If all protein is occupied we achieve full saturation.

i.e. The rate of diffusion reaches a maximum (Vmax) when all the carriers are functioning as rapidly as possible.

2- stereopecificity:

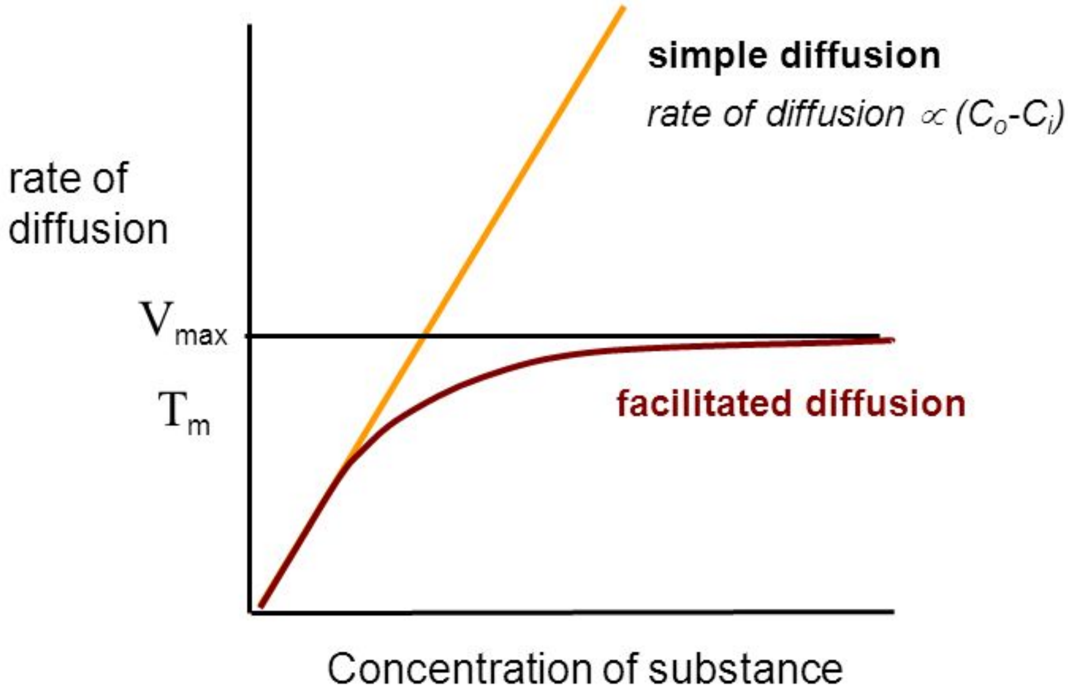
The binding site recognize a specific substance

D-glucose but not L-glucose.



T_m
Carrier-mediated transport
Simple diffusion
Transport rate
Concentration

Simple vs. Facilitated



What limits maximum rate (Vmax) of facilitated diffusion? Number of carriers

3- Competition:

Chemically similar substance can compete for the same binding site.

D- galactose / D-glucose.

Substance → binding site → substance protein complex → conformational changes → release of substance

Active Transport:

- Transport (uphill) → against electrochemical gradient.
- Required energy → direct.
  → indirect.
- Required carrier – protein.

1- Primary Active Transport:

-Energy is supplied directly from ATP.

ATP ⟶ ADP +P+ energy.

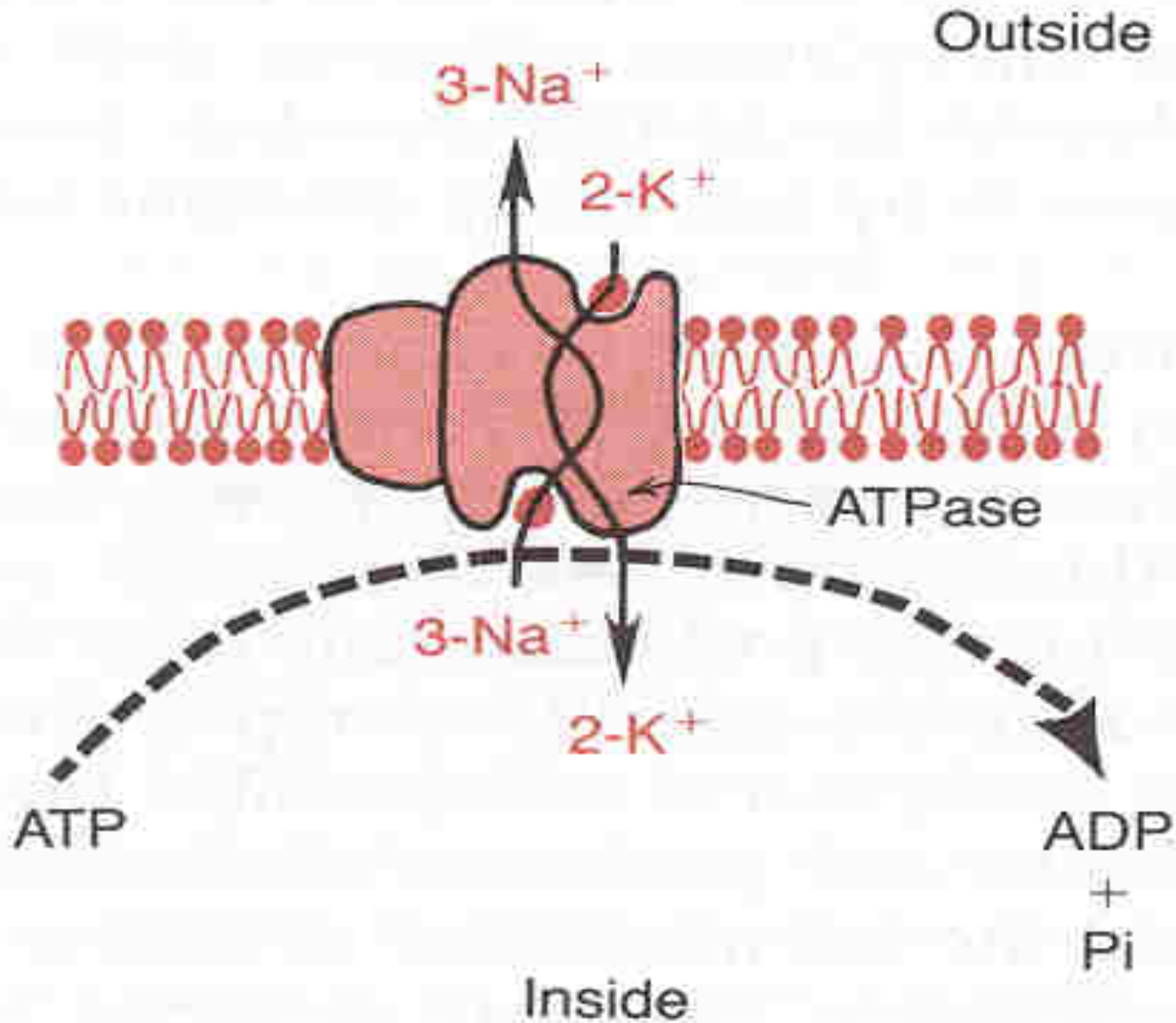
A. - **Sodium-Potassium pump (Na^+-K^+ pump).**

- its present in all cell membranes.
- 3 Na^+ in ⟶ out.
- 2 K^+ out ⟶ in.

Discovery

- Na^+/K^+-ATPase was discovered by Jens Christian Skou in 1957.

- In 1997, he received one-half of the Nobel Prize in Chemistry .


Outside
3-Na+
2-K+
ATPase
3-Na+
2-K+
ATP
ADP
+
Pi
Inside

Characteristic Of The Pump:

1. Carrier protein is formed from α and β subunits.
2. Binding site for Na inside the cell.
3. Binding site for K outside the cell.
4. It has ATPase activity.
5. 3 Na out.
6. 2 K in.

Function:

1. Maintaining Na^{+} and K^{+} concentration difference .

2. It's the basis of nerve signal transmtion .

3. Maintaining –ve potential inside the cell.

4. Maintains a normal cell volume.

B. **primary active transport of calcium (Ca^{2+} ATPase).**

- sarcoplasmic reticulum (SR).
- mitochondria.
- in some cell membranes.

Function:

Maintaining a low Ca^{2+} concentration inside the cell.

- **C. primary active transport of hydrogen ions H^+-K ATPase.**

  - stomach.
  - kidneys.
  - pump to the lumen.
  - H^+-K ATPase inhibitors (treat ulcer disease). (omeprazol)

2) Secondary Active Transport:

- **Co- transport and countertransport:**

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

- ''downhill'' solute is Na.

- Energy is supplied indirectly form primary transport.

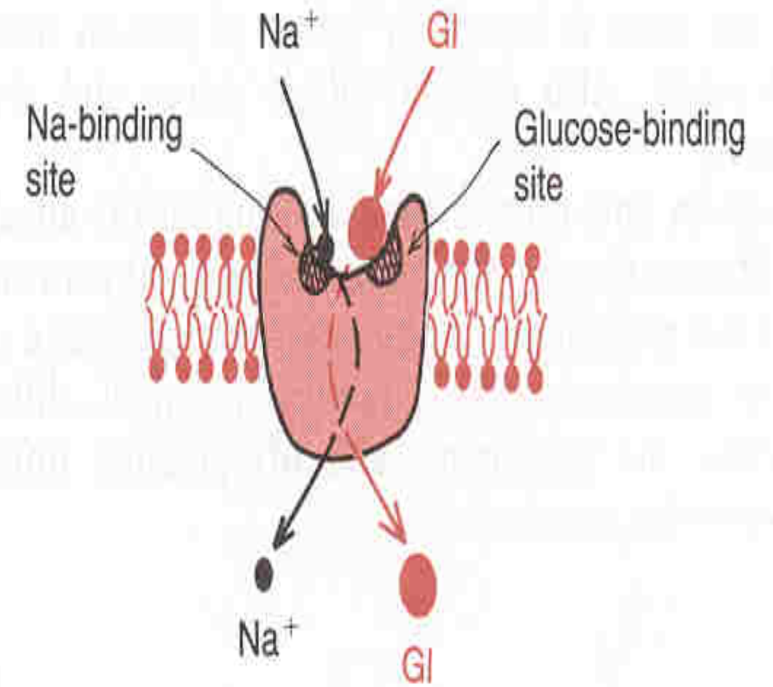
- **Co-transport:**

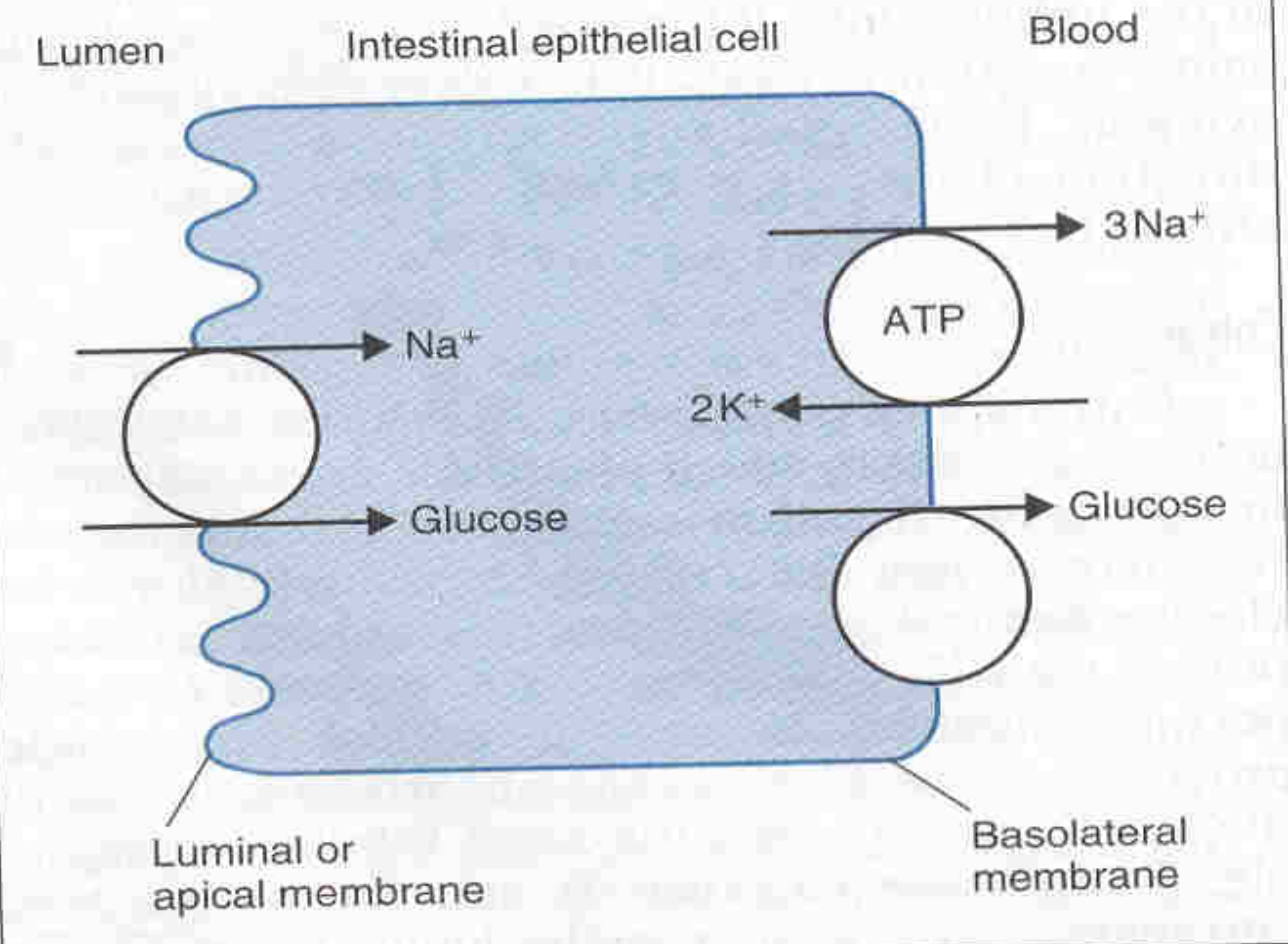
- All solutes move in the same direction " inside cell".

- e.g. – Na^+ - glucose Co-transport.

- Na^+ - amino acid Co-transport.

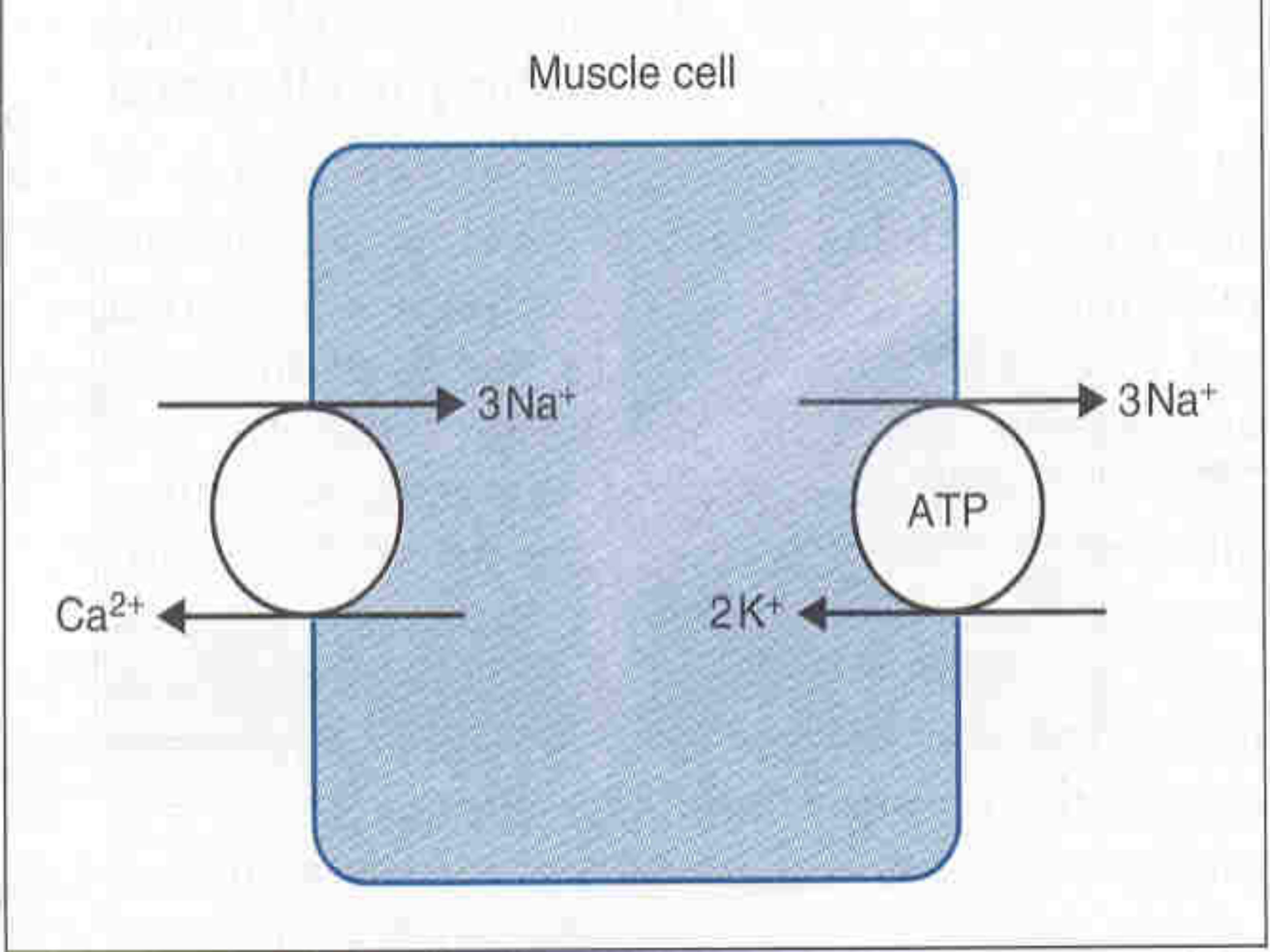
- in the intestinal tract kidney.





Lumen
Intestinal epithelial cell
Blood
3Na+
ATP
Na+
2K+
Glucose
Glucose
Luminal or
apical membrane
Basolateral
membrane

- **Countertransport:**
- Na^{+} is moving to the interior causing other substance to move out.
- Ca^{2+} - Na^{+} exchange.
  (present in many cell membranes)
- Na^{+} - H^{+} exchange in the kidney.


Muscle cell
3Na+
3Na+
ATP
Ca2+
2K+

Electrolyte Concentration

- Expressed in milliequivalents per liter (mEq/L), a measure of the number of electrical charges in one liter of solution.
- mEq/L = (concentration of ion in [mg/L]/the atomic weight of ion) × number of electrical charges on one ion.
- For single charged ions, 1 mEq = 1 mOsm
- For bivalent ions, 1 mEq = 1/2 mOsm