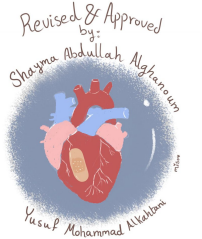
Body Fluids and Electrolytes & Edema



Red: Important
Black: In Male & Female slides
Blue: In male slides
Pink: In female slides
Green: Notes & extra information

Team Leaders:
Haya Alenazi
Abdulrahman Alswat

Objectives

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

Factors that affect the TBW

	Percentage of body water	clarification
Infants (fleshy)	70%* or more	Low body fat, low bone mass
Healthy males adult	60%	larger amount of skeletal muscle, lower body fat
Healthy females adult	50%**	Smaller amount of skeletal muscle , Higher body fat
obesity	45%***	Higher amount of fats
Older age	45%	TBW declines throughout life

- *73% or more **40-50% ***40%
- human body contain 50-70% ~ 60%
- Body water distribution: 50% muscles , 20% skin, 20% organs and 10% blood
- TBW: Total body water

Daily water intake and output

- maintaining water homeostasis **(steady state)** is a balancing act.the amount of water taken in must equal the amount of water lost.
- Regulation of water intake :

1. Climate
2. habits
3. level of physical

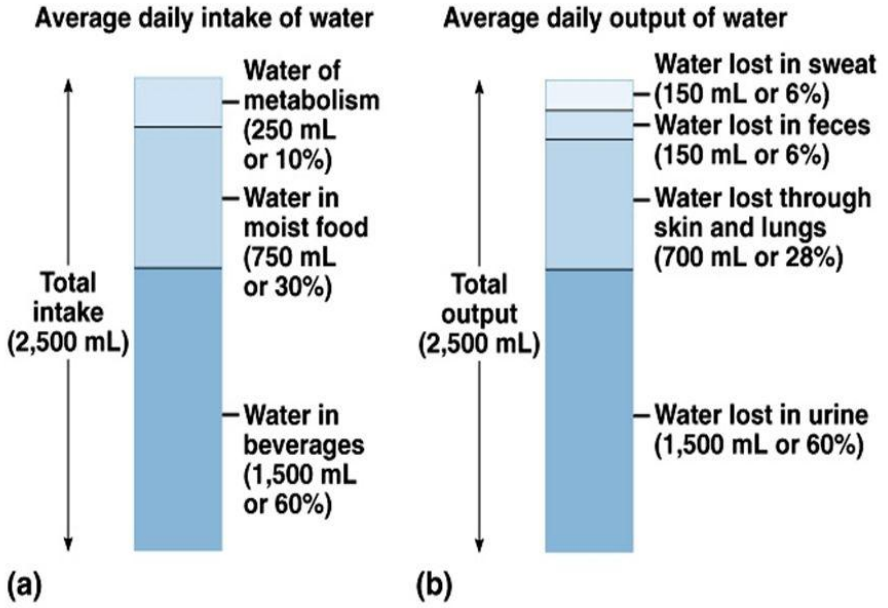
*sweat 8% -200 feces 4%-100

Table 25–1

Daily Intake and Output of Water (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

*the major output source changed when prolonged.



Factors that affect the TBW

Physiological factors	Pathological factors
Age	Vomiting
Sex	Diarrhea
Body fat	Diseases with excessive loss of water (DM, excessive sweating,…)
Climate	Blood loss
Physical activity	-

- DM : Diabetes Mellitus

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

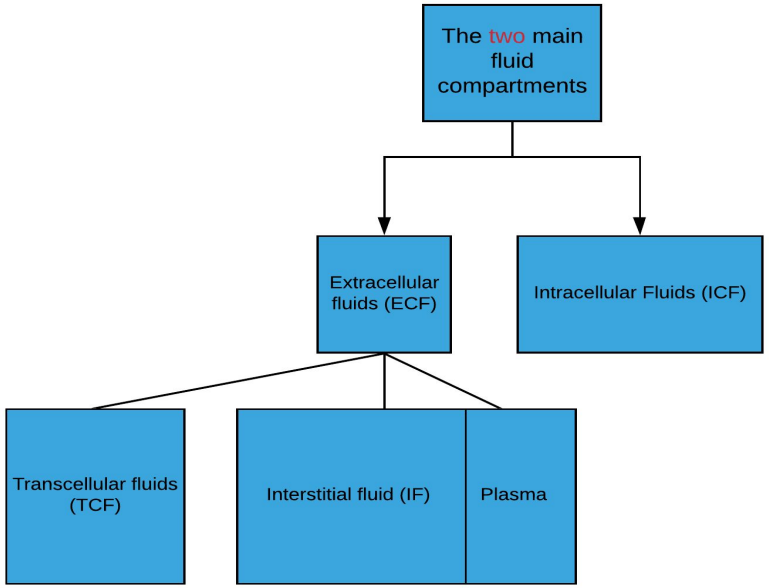
- **Physiologic regulation:**

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

The Hypothalamic thirst center is stimulated:
- By a decline in plasma volume of 10-15%
- By an increase in plasma osmolality of 1-2%
  (most sensitive to osmolality change)

Fluid Compartments

- The percentage of a specific fluid compartment to the body's mass = TBW percentage × fraction × 100
  Ex: male - TBW = 60% of body mass
  So, percentage of intracellular fluid to body mass = 0.6 × ⅔ × 100 = 40%



-Fluids distribution :
Intracellular fluids (ICF): ⅔ of TBW
Extracellular fluids (ECF): ⅓ of TBW
Interstitial fluids (IF): ¾ of ECF
Plasma: ¼ of ECF
Transcellular fluids:
- found in small amounts (CSF, Intraocular, Pleural, Peritoneal, Synovial, Digestive Secretions).
- Equal to 1-2 L

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

TBW = 42 litres

- *How many litres lie intracellularly?*
  - 42 X ⅔ = 28L ***OR*** 70 X 40/100 = 28L.
- *How many litres lie extracellularly?*
  - 42 X ⅓ = 14L ***OR*** 70 X 20/100 = 14L.
- *How many litres constitute the interstitial fluid?*
- *How many litres are plasma?*

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

-Interstitial fluids are composed from ultrafiltration of plasma in capillary walls.

Intracellular Fluids	Interstitial Fluids (internal environment)	Plasma	Transcellular fluids (specialized type of ECF)
Inside the cell	Outside the cell	Outside the cell	Outside the cell
HIGH concentration of protein	Fluid bathing the cell	Fluid circulating in the blood vessels	Small amount

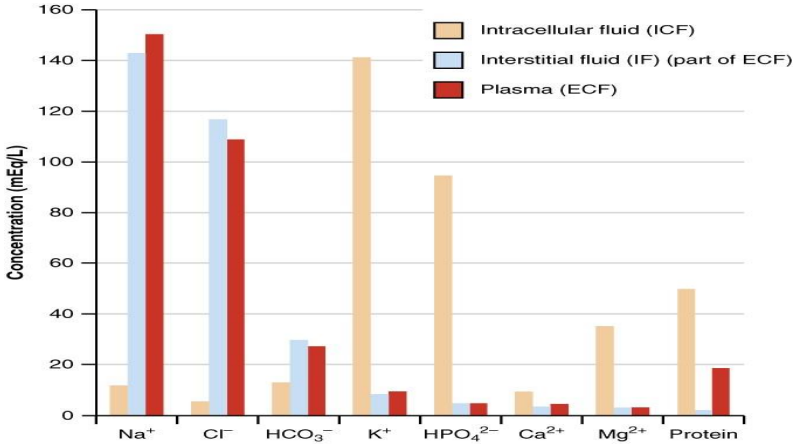
Composition of Body Fluids

*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.

-Concentration: amount= in moles ,osmoles
- Molarity = moles/liter M/L
- Osmolarity = osmoles/liter osm/L
- Osmolality = osmoles/kg Osm/kg

-In biological solutions:
Millimoles per liter (mM/L)
Milliosmoles per (mOsm/L)
1mM=1/1000 Moles
1mOsm=1/1000 Osmoles



Extracellular Fluids	Intracellular fluids
Have low potassium and phosphate	have low sodium and chloride
Sodium is the major cation	Potassium is the major cation
Chloride is the major anion	Phosphate is the major anion

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

-Hypernatremia: increase in Na concentration in ECF.
-Hyponatremia: decrease in Na concentration in the ECF.

-Hypokalemia: decrease in k concentration in the ECF. (1-2 mEq/L).
-Hyperkalemia: increase in k 60%-100% above normal in the ECF.

- Hypo- = less
- hyper- = more

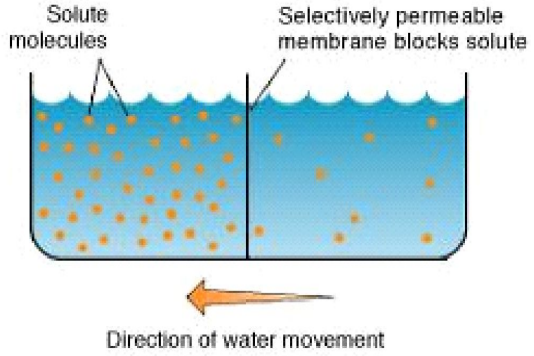
- **Regulation of fluid exchange between extracellular and intracellular fluids (Through cell membrane):**
  - Highly permeable to water .
  - Relatively impermeable to small ions i.e. (only water is moving).
  - Osmotic effect of electrolytes (K,Na,Cl).

Osmosis

- net diffusion of water is from a region of high water concentration to a 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.

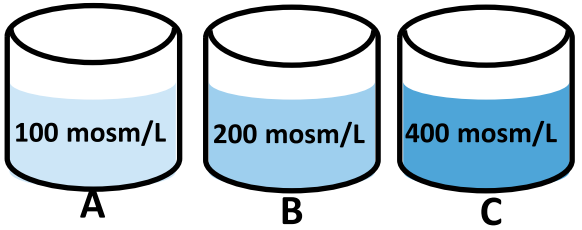
▷ Intracellular osmolarity = extracellular osmolarity .≈ 300 mosm/L

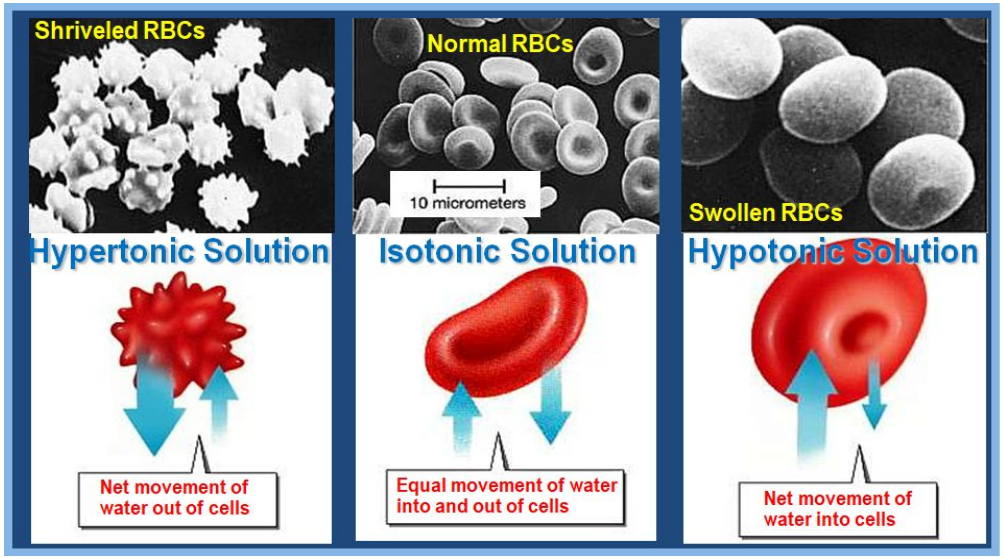
- What is the difference between osmolarity and tonicity?



Osmolarity	Tonicity
describes the concentration of one solution. Measure of one given solution Normal~300 mOsm/L	-is used to compare between the osmolarities of two or more solutions separated by a semipermeable membrane. -means effective osmolality in relation to plasma (=285 milliosmol/L) . Therefore: ➢ isotonic solutions [e.g.0.9%saline solution] have almost equal tonicity of the plasma. ➢ hypotonic solutions [e.g.0.45%saline solution] have<tonicity than plasma. ➢ Hypertonic solutions [e.g.3%saline solution] have>tonicity than plasma.

Which solution is hypertonic to B?





GLUCOSE AND OTHER SOLUTIONS ADMINISTERED FOR NUTRITIVE PURPOSES:

★ Who needs it? People who can not take adequate amount of food.

★ How to give it for them? Drip slowly.

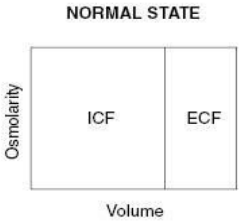
★ Where to prepare it?Prepared in an isotonic solution. And water is excreted.

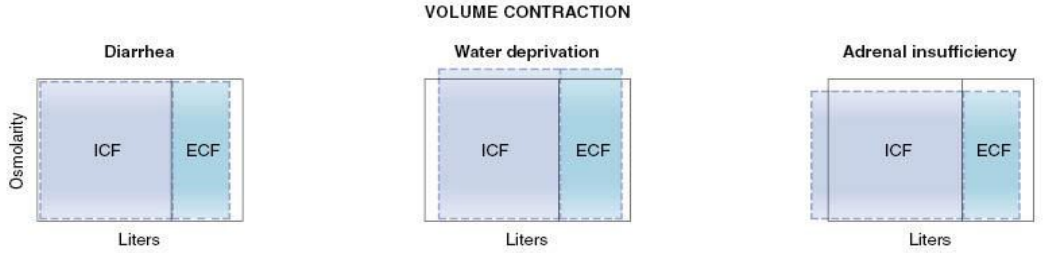
HYPERTONIC ENVIRONMENT (SOLUTION)	More solutes outside cell	Less solutes in cell = more water in cell	cell loses water	>0.9%
ISOTONIC ENVIRONMENT (SOLUTION)	same	same	No change in cell volume (don't swell or shrink)	0.9% solution of sodium chloride or 5% glucose .
HYPOTONIC ENVIRONMENT (SOLUTION)	Less solutes outside cell	More solutes in cell = less water in cell	Cell gains water	<0.9%

Changes in The Body Fluid Compartments (ECF & ICF) in abnormal state

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

Type of change in volume:
- volume contraction (removing).
- volume expansion (adding)



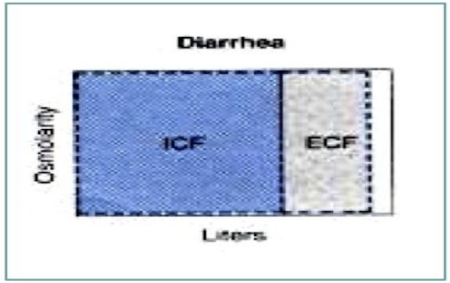


- In normal state osmolarity is always the same for ICF & ECF.

Volume contraction

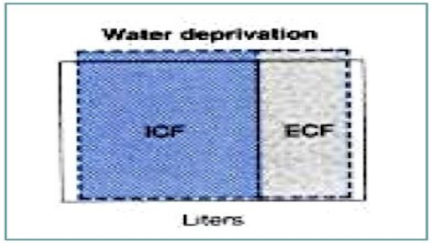
Removing

Loss of iso-osmatic fluid
e.g. Diarrhea



- osmolarity of fluid lost ≈ osmolarity of ECF (loss of isosmotic fluid).
- ↓volume in ECF.
- ↓arterial pressure.

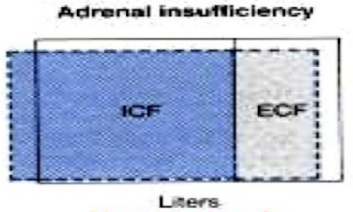
Loss of hypotonic solution
e.g. water deprivation



Hyperosmotic dehydration

- Osmolarity and volume will change .
- ↑Osmolarity in both ECF and ICF.
- ↓Volume in both ECF and ICF.

Loss of hypertonic sol
e.g. adrenal insufficiency



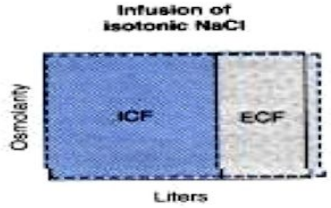
Hypo-osmotic dehydration
i.e. Aldosterone deficiency

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

Volume expansion

Adding

1- Adding of isotonic NaCl.

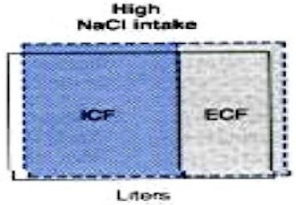


↑ in ECF volume.

- No change in osmolarity.

- Isomotic expansion

2- High NaCl intake



↑ - eating salt.

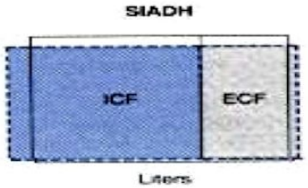
↑ - osmolarity in both.

↓ - volume of ICF .

↑ - volume of ECF .

- hyperosmotic volume expansion.

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



- ↑ Volume

- ↓ osmolarity

volume contraction (decrease in ECF volume) Removing…	Volume expansion (increase in ECF volume) Adding…
Isotonic solution	
Diarrhea (Osmolarity of fluid lost ≈ osmolarity of ECF)	Infusion of isotonic NaCl.
Decrease in ECF volume **(isosmotic contraction)**	Increase in ECF volume **(isosmotic expansion)**
• ECF osmolarity doesn't change → no water shift from intracellular compartment. • Intracellular compartment remains unchanged.	
Decrease in arterial pressure.	-
Hypotonic solution	
Water deprivation (an individual running in the desert without drinking water → experience excessive sweating without fluid replenishment)	Syndrome of inappropriate antidiurtichormone (SIADH) (too much water reabsorbtion)
Increase of Osmolarity in both ECF and ICF.	decrease of Osmolarity in both ECF and ICF.
Decrease of Volume in both ECF and ICF (cell shrinks). **(hyperosmotic volume contraction)**	Increase of volume in both ECF and ICF (cell swell). **(hypoosmotic volume expansion)**

volume contraction (decrease in ECF volume) Removing…	Volume expansion (increase in ECF volume) Adding…
Hypertonic solution	
Adrenal insufficiency (aldosterone deficiency excess salt is exerted in the urine Na+ in the ECF)	High intake NaCl (eat salt).
decrease of Osmolarity in both ECF and ICF.	Increase of Osmolarity in both ECF and ICF.
• ICF volume increase(cell swell). • ECF volume decrease **(hypoosmotic volume contraction)**	• ICF volume decrease (cell shrink). • ECF volume increase **(hyperosmotic volume expansion)**

*sweat is hyperosmotic -(small NaCl , large water).
*aldosterone promotes sodium reabsorption.
* green rectangles are extra information.

Edema

Normally, fluid is constantly moving in & out of the interstitial space to allow ECF to distribute between plasma and IF (Through capillary walls).

What is edema?

-**Edema** is excessive fluid in the tissues which leads **swelling** i.e the presence of abnormally large amounts of fluid in the intercellular tissue spaces of the body.

-Edema occurs mainly in the ECF compartment

Edema (swelling) of the ankles and feet

Click

Edema

Intracellular Edema
Caused by:

- inflammation of tissues
- Membrane permeability increases
- Higher sodium concentration
- Water shift (from extracellular to intracellular)
- **Edema**

Extracellular Edema
(more common clinically)

- Heart failure increases
- Capillary pressure increases
- Filtration
- Edema

Extracellular Edema

This slide was found only in female slides

Increase capillary filtration (excessive) (common clinical cause)	**Decrease lymph uptake** (Failure of lymphatic uptake)
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.	Lymphatic obstruction - Infection (filaria). - Surgery. - Congenital absence. - Cancer.

Fluid Filtration Across Capillaries

- Fluid exchange between blood and tissue cells occurs at the level of the capillaries.

- The capillaries are the smallest blood vessels in the vascular tree .

- These vessels are very small and have a very thin wall allowing easy exchange of fluid across the walls.

As blood passes through capillaries:

- Fluid filters from plasma to interstitial fluid.
- Fluid is reabsorbed from interstitial fluid to plasma (back and forth).

- **Net driving pressure = [Pc-Pi] - [ϖc-ϖi]**
- **Hydrostatic pressure : physical force of fluids against their enclosing barriers.**
- **oncotic pressure : is the osmotic pressure generated by the presence of proteinaceous solutes.**

-Factors Controlling Fluid Filtration:
the balance of starling forces acting across the capillary wall.

Starling forces
(Forces that control movement of fluid in/out of a capillary)

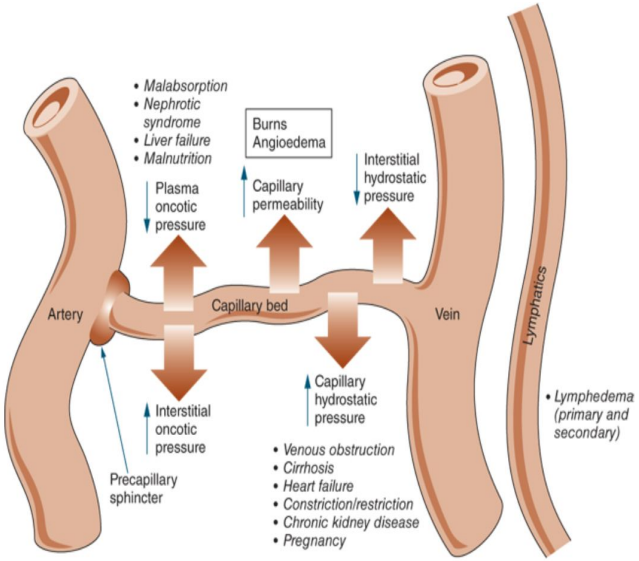
Hydrostatic pressure in the capillary (Pc) (blood hydrostatic pressure)	**Oncotic pressure in the capillary** (ϖc) (Plasma *colloid osmotic pressure)*	***Hydrostatic pressure in the interstitium*** (Pi) (IF hydrostatic pressure)	***Oncotic pressure in the interstitium*** (ϖi) (IF *colloid osmotic pressure)*
Pressure exerted by blood on the blood vessel walls	Osmotic pressure created by non diffusible plasma proteins inside the blood vessel	-	-
Pushes fluid ***OUTSIDE*** *of capillary (favors filtration)*	*(Pulls* fluid ***INSIDE*** *capillary) (favors reabsorption)*	Depends if : - Positive : favors reabsorption ***(INSIDE)*** - Negative: favors filtration ***(OUTSIDE)***	*Pushes* fluid ***OUTSIDE*** *of capillary (favors filtration)*
• Pc decreases along the length of capillary. • Arterial end = 30 mmHg • Venous end = 10 mmHg (usually 15-25 mmHg less than arterial end).	• constant along capillary. = 28 mmHg	• is usually sub atmospheric in loose connective tissue (≈ -3 mmHg) -because it's negative it favors filtration.	= 8 mmHg.

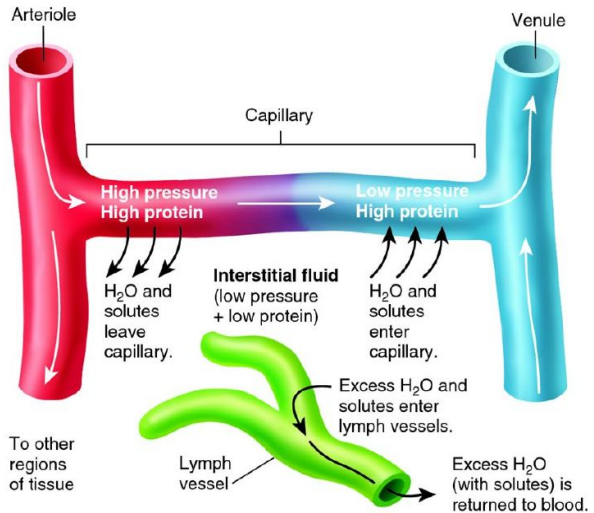
This slide was found only in female slides

Lymphatic uptake

- The reabsorption pressure causes 9\10 of the filtered fluid to be reabsorbed while 1\10 enters lymph vessels -> returned to blood.
- The total quantity of lymph ~ 2-3 L\day.

*Recall that fluid **-ultrafiltered from plasma-** is reabsorbed from **Interstitial fluid** back to plasma, this is just a metaphor to explain how the ultrafiltration works





QUIZ!

MCQs

Q1: Composed of ultrafiltration of plasma			
A) Intracellular fluid	B) Interstitial fluid	C) Transcellular Fluid	D) Both A and B
Q2: Which of the following is considered the "Internal Environment" of the body?			
A) Capillary walls	B) Interstitial fluid	C) Intracellular fluid	D) Transcellular fluid
Q3:The major cation in extracellular fluid?			
A) Potassium	B) Chloride	C) Phosphate	D) Sodium
Q4 :Which of these fluids have high concentration of protein?			
A) Intracellular fluid	B) Plasma	C) Interstitial fluid	D) Both A and B

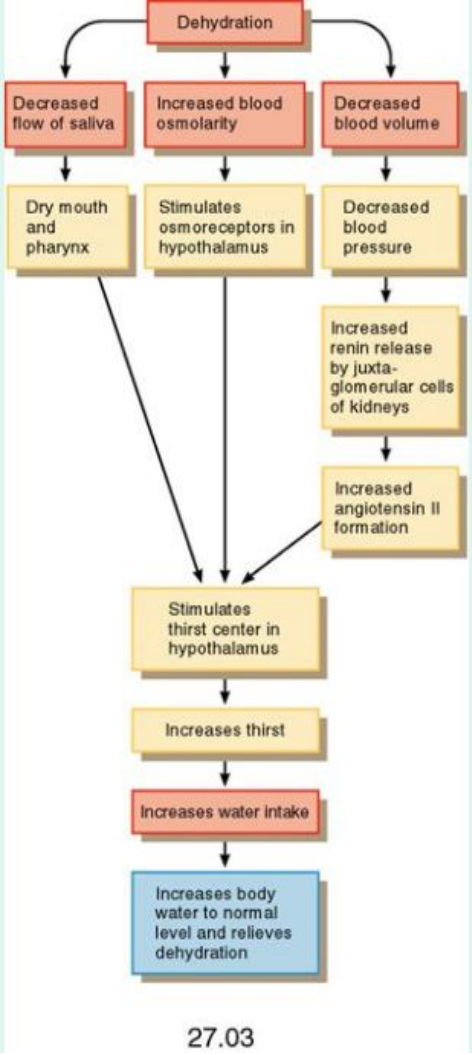
SAQ

Q1: Distinguish between Osmolarity and Tonicity?

Q2: Demonstrate the fluid filtration mechanism? (across capillary walls)

MCQs key answer :
1) B
2) B
3) D
4) D

SAQ answer key :
1) Osmolarity describes the concentration of one solution while tonicity is used to compare between two or more solutions
2)As blood passes through capillaries fluid filters from plasma to interstitial fluid then fluid is reabsorbed from interstitial fluid to plasma



27.03

An increase of 2 – 3% in plasma osmolality triggers the thirst center of the hypothalamus. Secondarily, a 10 – 15% drop in blood volume also triggers thirst. This is a significantly weaker stimulus.

The Thirst Mechanism

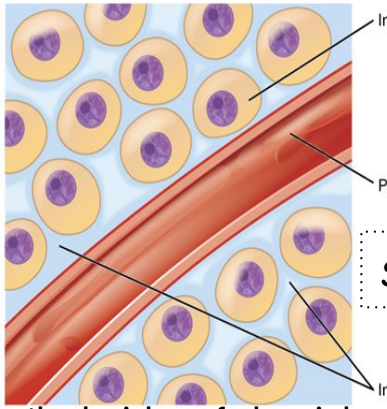
Slide 5

*Extra visuals

TABLE 20–2 OSMOLAR SUBSTANCES IN EXTRACELLULAR AND INTRACELLULAR FLUIDS

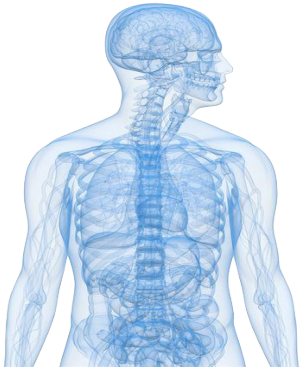
	Plasma (mOsm/liter of H_2O)	Interstitial	Intracellular
Na^+	142	139	14
K^+	4.2	4.0	140
Ca^{++}	1.3	1.2	0
Mg^{++}	0.8	0.7	20
Cl^-	108	108	4
HCO_3^-	24	28.3	10
HPO_4^{--}, $H_2PO_4^-$	2	2	11
SO_4^{--}	0.5	0.5	1
Phosphocreatine			45
Carnosine			14
Amino acids	2	2	8
Creatine	0.2	0.2	9
Lactate	1.2	1.2	1.5
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

(Slide 7)



Slide 6

pathophysiology of edema in heart failure



Thank You

Team members:

- ماجد العسكر
- مشعل الثنيان
- عبد العزيز الربيعة
- باسل فقيها
- محمد بياري
- محمد السلمان
- عبد الرحمن الدويش
- نايف الشهري
- فيصل العمري
- مرشد الحربي
- عبد العزيز الغليقة
- منيب الخطيب
- عبد العزيز السحيم
- حصة العليان
- شذى الظهير
- سمو الزير
- نورة الشثري
- سارة القحطاني
- ريناد الحميدي
- ياسمين القرني
- يارا الزهراني
- لمى الأحمدي
- ألاء السلمي
- سارة العيدروس
- فرح البكر
- بدور المبارك
- سارة العبيد

Physiology 439

- Made by

Contact info:physiology439@gmail.com

Editing file

Physiology 439 file