



437

PHYSIOLOGY TEAM



MED437
KING SAUD UNIVERSITY

PHYSIOLOGY

- Females & Males Slides
- Only Found in Males' slides
- Only Found in Females' slides
- Vary Important Notes
- Notes
- Extra Information

غيداء آل مسمع
عبدالرحمن الحيسوني

Revised by

Body fluids

محاضرة body fluids
من عند البنات والأولاد +
بداية محاضرة Homeostasis 2
من عند الأولاد

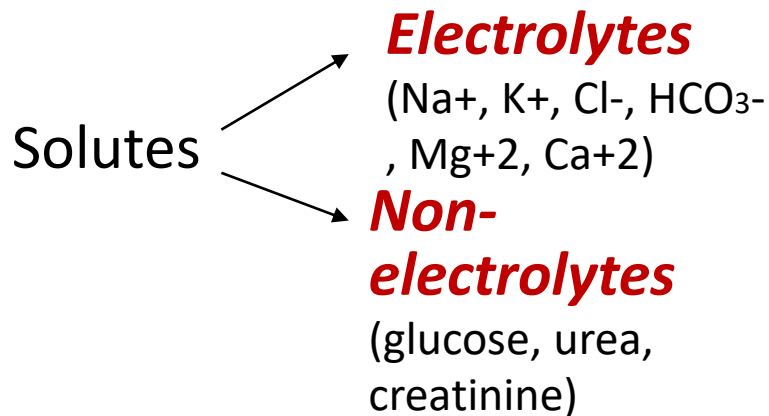
Objectives

- 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) and state their normal value.
- Describe the physiological and pathological factors influencing the body fluid.
- Identify and describe daily intake and output of water and maintenance of water balance
- Describe the composition of each fluid compartment, in terms of volume and ions and represent them in graphic forms.
- State the water content of the body.
- Discuss water balance in the body with regards to intake and output.
- Enumerate the different body fluid compartments and state their normal volume.
- Describe the physiologic mechanisms involved in water balance (the role of ADH hormone and thirst mechanism).
- Define osmolarity and state the normal osmolarity of body fluids.
- Explain the effects of placing a cell in solutions with varying tonicity on the cell volume.
- Enumerate fluids used in clinical practice and state their tonicity compare to that on normal body fluids.
- Describe the effects of infusing IV fluids with different tonicities on the

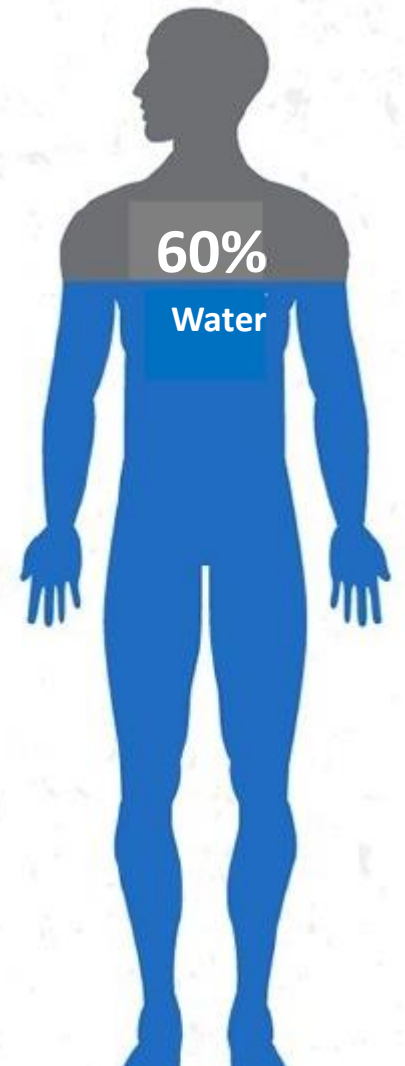
Body Fluid Content

هذه هي السلايد من البنات

- Total body fluids \approx 60% (50-70%) of total body weight (TBW).
- Body fluids = water + dissolved solutes.



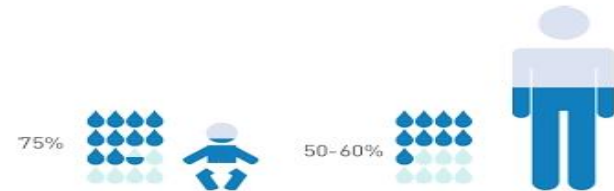
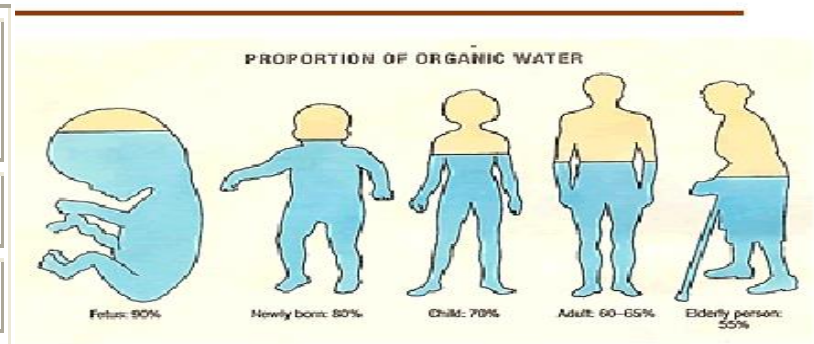
- Total body water \approx 60% of TBW.



Body Water

The human body made mainly of water, which constitutes about 60% of body weight in the adult, however the amount of water varies with age.

	Male (%)	Female (%)
At birth	82	82
Children and adolescents	70	70
18-20 years	59	57
20-40 years	61	51
40-60 years	55	47
Over 60 years	52	46



“Increase in age lead to decrease in the percentage of water”

Total Body Fluid

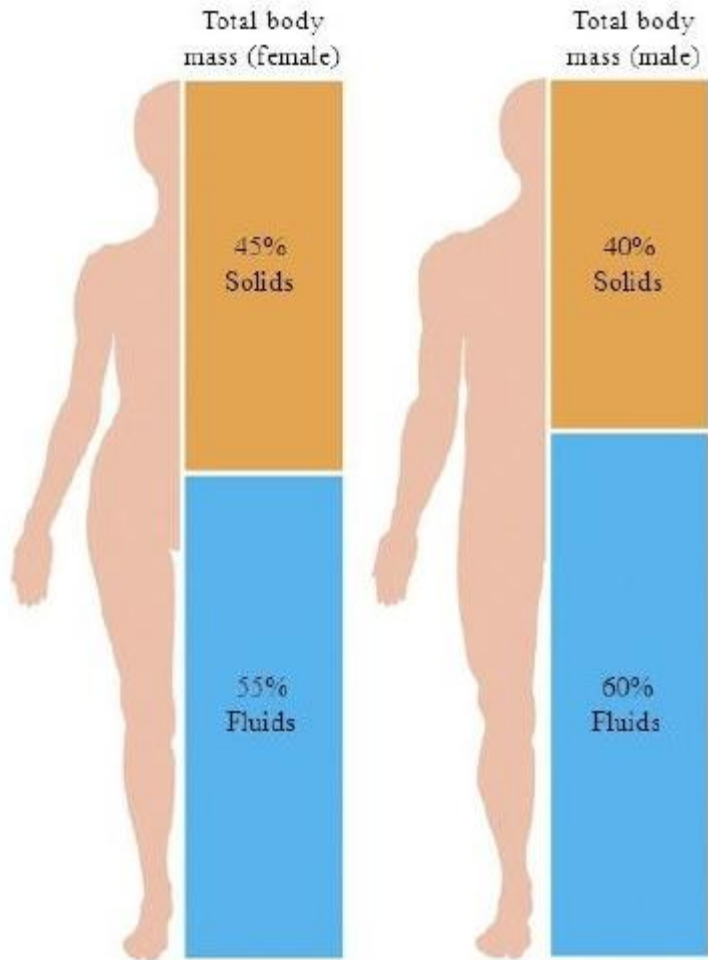
- Total body water (TBW):
constitutes 55-60% of the body weight in young men and 45-50% in young women.

Why the percentage is lower in women?

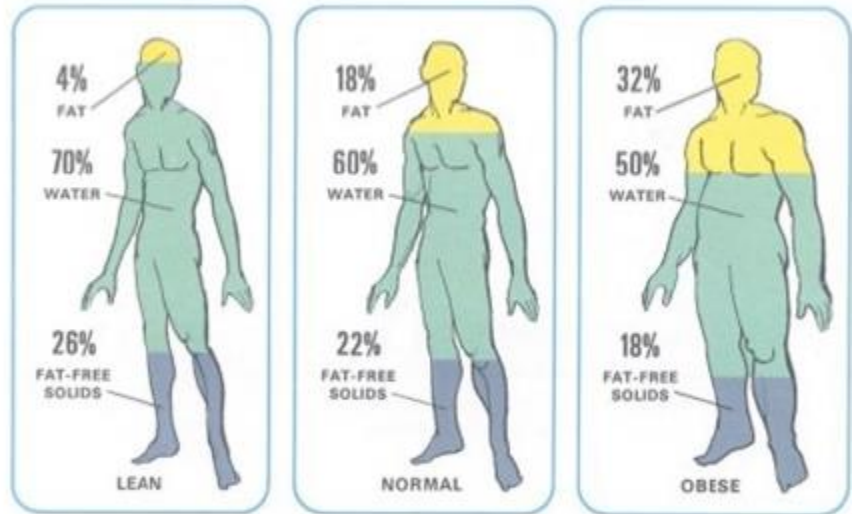
“The percentage of water is lower in women because they have higher fat content than men”

- The TBW is distributed as follows:
 - Muscle (50%)
 - Skin (20%)
 - Other organs (20%)
 - Blood (10%)

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

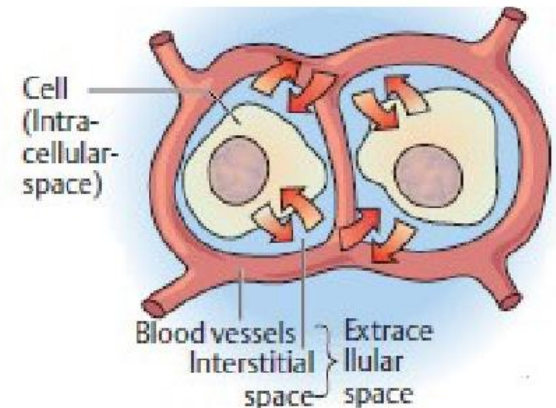


TOTAL BODY WATER VARIES IN EACH INDIVIDUAL BASED ON THE FAT CONTENT OF THE BODY

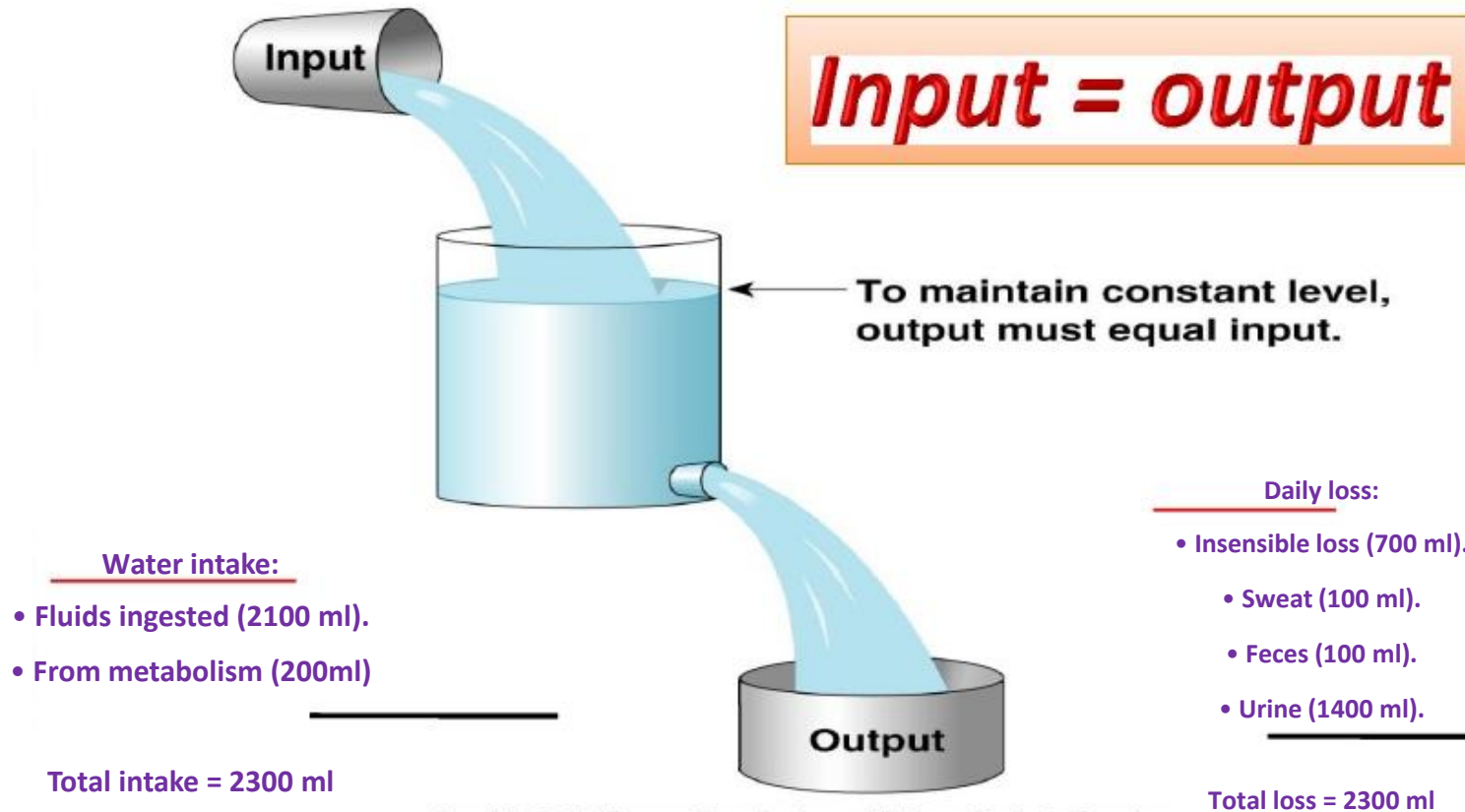


Water Balance

- Cells are largely made of water and are surrounded by a “sea” of water.
- Water is constantly being exchanged between the cells and surrounding environment.
- Keeping a constant volume of water is essential for homeostasis.



Maintenance of Fluid Balance



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Insensible loss:

يعني الماء اللي نخسره من أجسامنا بدون إدراك أو وعي مننا. وهو يحصل خلال:

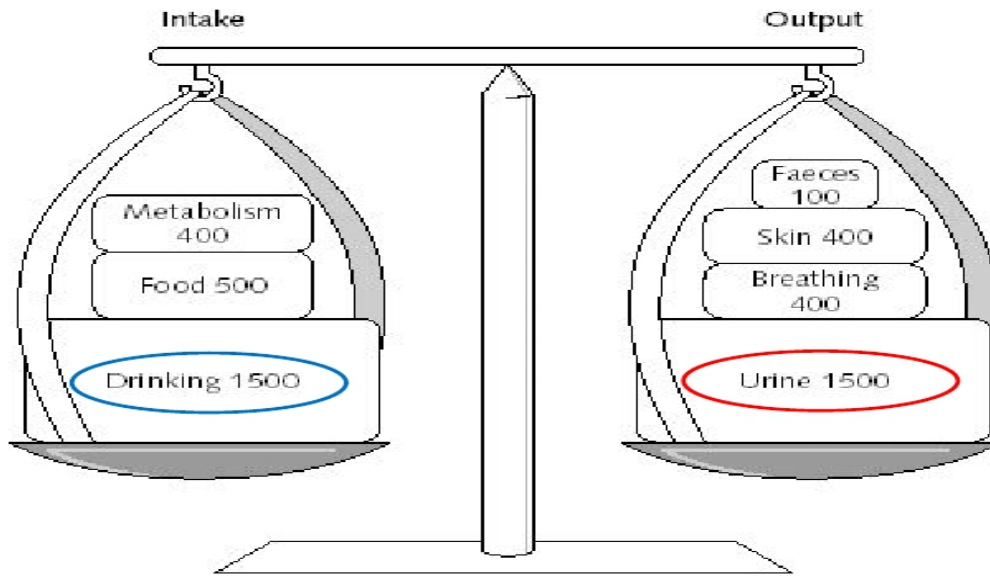
1. Evaporation through the respiratory tract. (breathing)
(تبخر الماء من الجهاز التنفسي أثناء عملية التنفس)
2. Diffusion through the skin (يختلف عن التعرق)

Regulation of Fluid Balance

Amount ingested = amount eliminated.

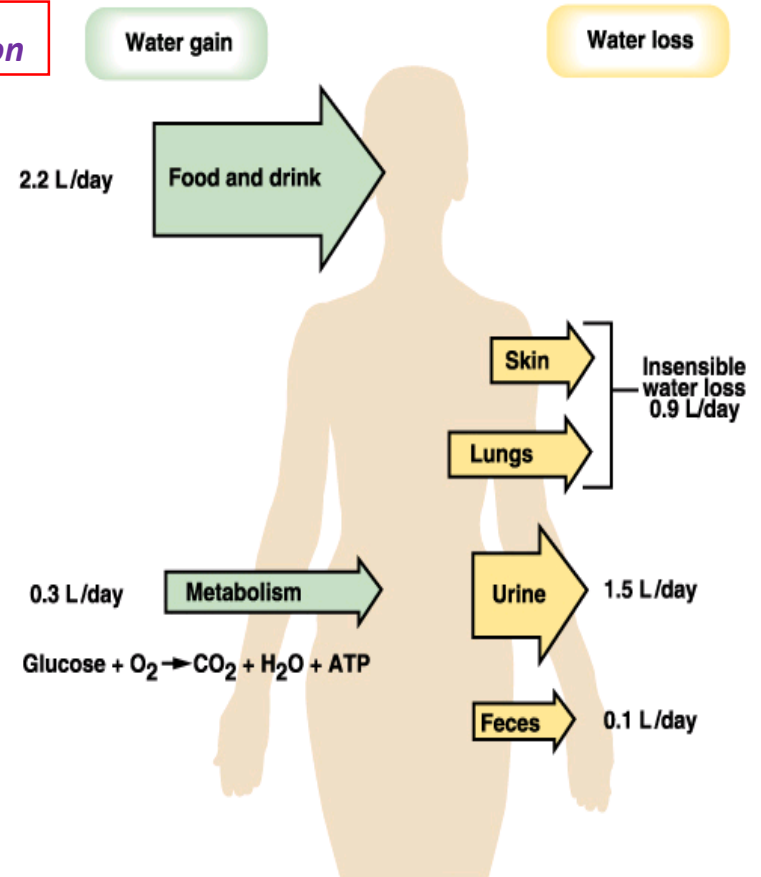
Modify intake → thirst

Modify output → Kidney excretion



Major input

Major output



$$\begin{array}{|c|} \hline \text{Intake} \\ \hline 2.2 \text{ L/day} \\ \hline \end{array} + \begin{array}{|c|} \hline \text{Metabolic} \\ \hline \text{production} \\ \hline 0.3 \text{ L/day} \\ \hline \end{array} - \begin{array}{|c|} \hline \text{Output} \\ \hline (0.9 + 1.5 + 0.1) \text{ L/day} \\ \hline \end{array} = 0$$

Disturbances in Fluid Balance

Water/fluid intake

- Intake is variable

Depends on:

- Climate.
- Habits.
- Physical activity.

Water/fluid output

- Burns
- Exercise
- Hot weather.
- Diarrhea
- Vomiting
- Blood loss
- Diabetes

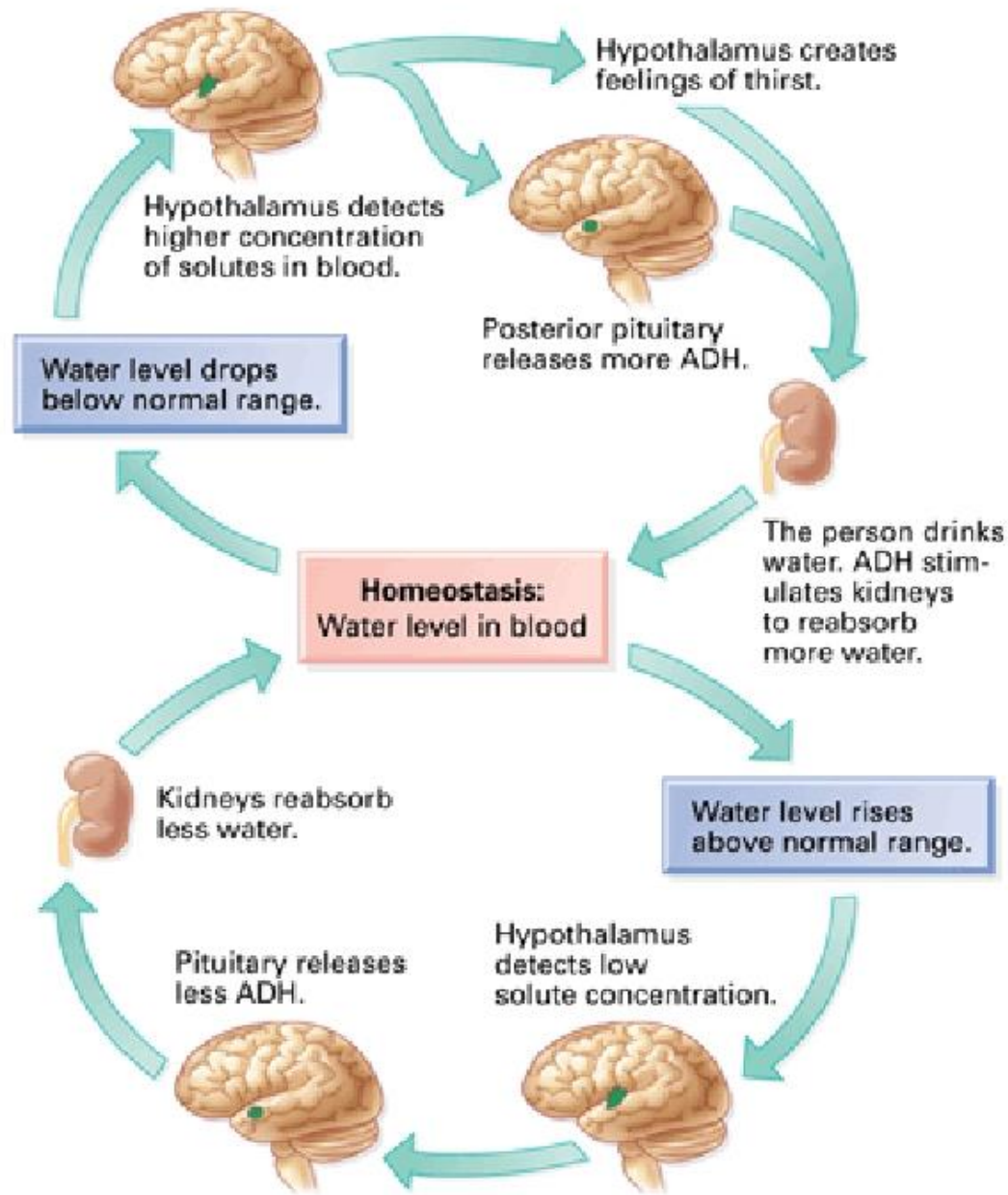
Regulation of Fluid Balance

Water deficit

- Input < output.
- Leads to:
 - Hypovolemia
 - Dehydration
- **Physiologic regulation:**
 - 1. *Activates Hypothalamic Thirst centre → ↑fluid intake***
 - The hypothalamic thirst centre is activated by:
 - ↓ ECF volume (10-15%)
 - ↑ ECF osmolarity (1-2%)
 - 2. *↑ ADH secretion by posterior pituitary → ↑ water reabsorption by the kidney.***

Water excess

- Input > output
- Leads to:
 - Hypervolemia
 - Edema.
- **Physiologic regulation:**
 - 1. *↓ ADH secretion → ↓water reabsorption → ↑water excretion by kidney.***
 - 2. *Decrease thirst***



“ADH hormone
هو هرمون يعيد :
امتصاص الماء في
الكلية”

Body Fluid Compartments

Total body water = 60% TBW

* $\frac{2}{3}$ (40% of TBW)
Intracellular

$\frac{1}{3}$ (20% of TBW)
Extracellular

Transcellular fluid (specialised type of ECF e.g. synovial, CSF, ocular, pericardial, pleural, peritoneal fluids)= 1-2L

$\frac{3}{4}$ (15%)
Interstitial Fluid

$\frac{1}{4}$ (5%)
Plasma

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

Body Weight)

Body Fluid Compartment

هذي من سلايدات الأولاد

The water content of the body is divided into two compartments.

1) Intracellular compartment (ICF)

Contained within the cell, represent approximately 67% of the total body water, 40% of total body weight.

2) Extracellular Compartment:(ECF)

Contained within the vessels of the cardiovascular system, is the remaining 33% of the total body water, about 20 % of total body weight.

the fluid portion of the blood, represents approximately 25% of the ECF. **Blood volume**, approximately 80 ml/kg of body weight (8%).

Plasma

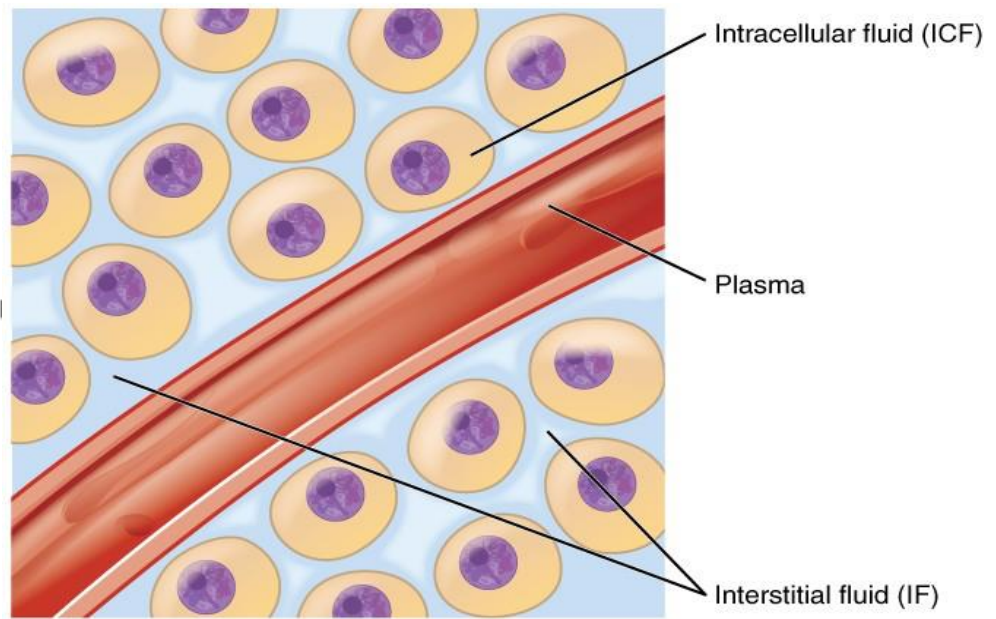
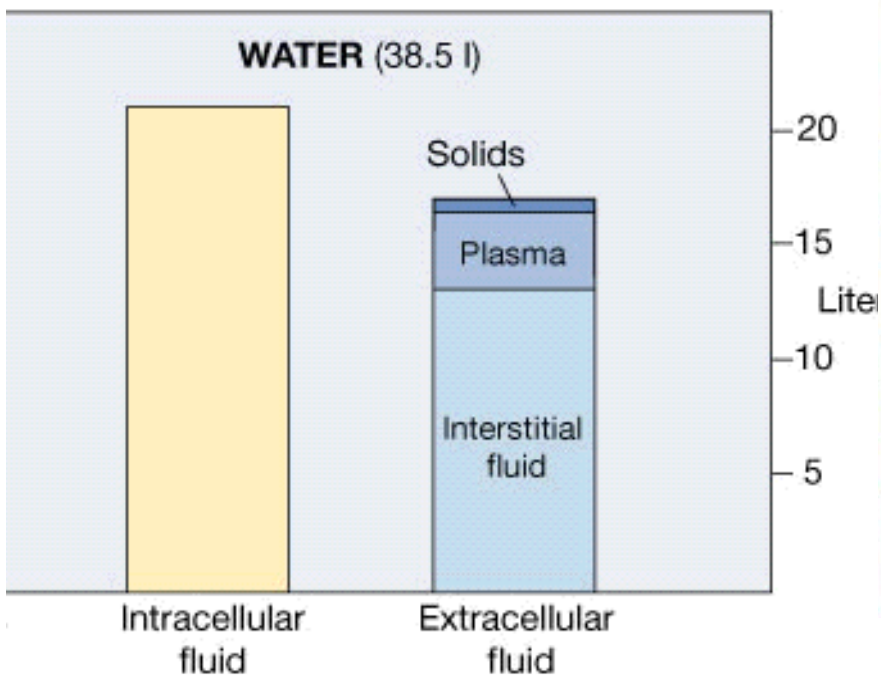
sourrounds all cells except blood cells and includes Lymph (2-3%) of total body weight.

The ISF represent approximately 15% of the total body weight and 75% of the ECF.

Interstitial fluid (ISF)

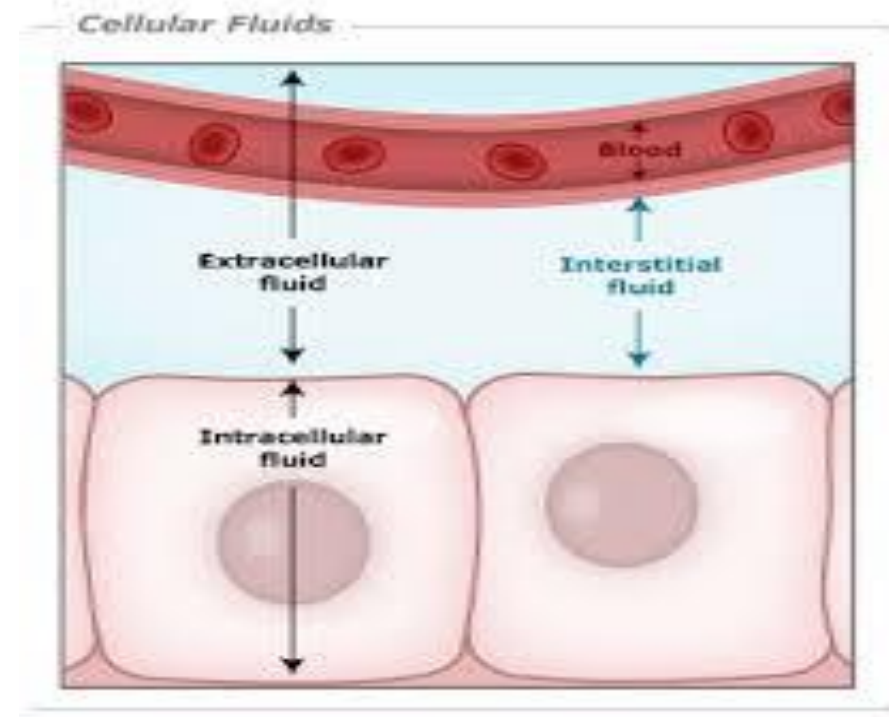
is about 1 L, occupies approximately 15 ml/kg of body weight (1.5%).* Represents fluid in the **lumen** of structures lined by epithelium and includes digestive secretions... etc.

Transcellular fluid volume

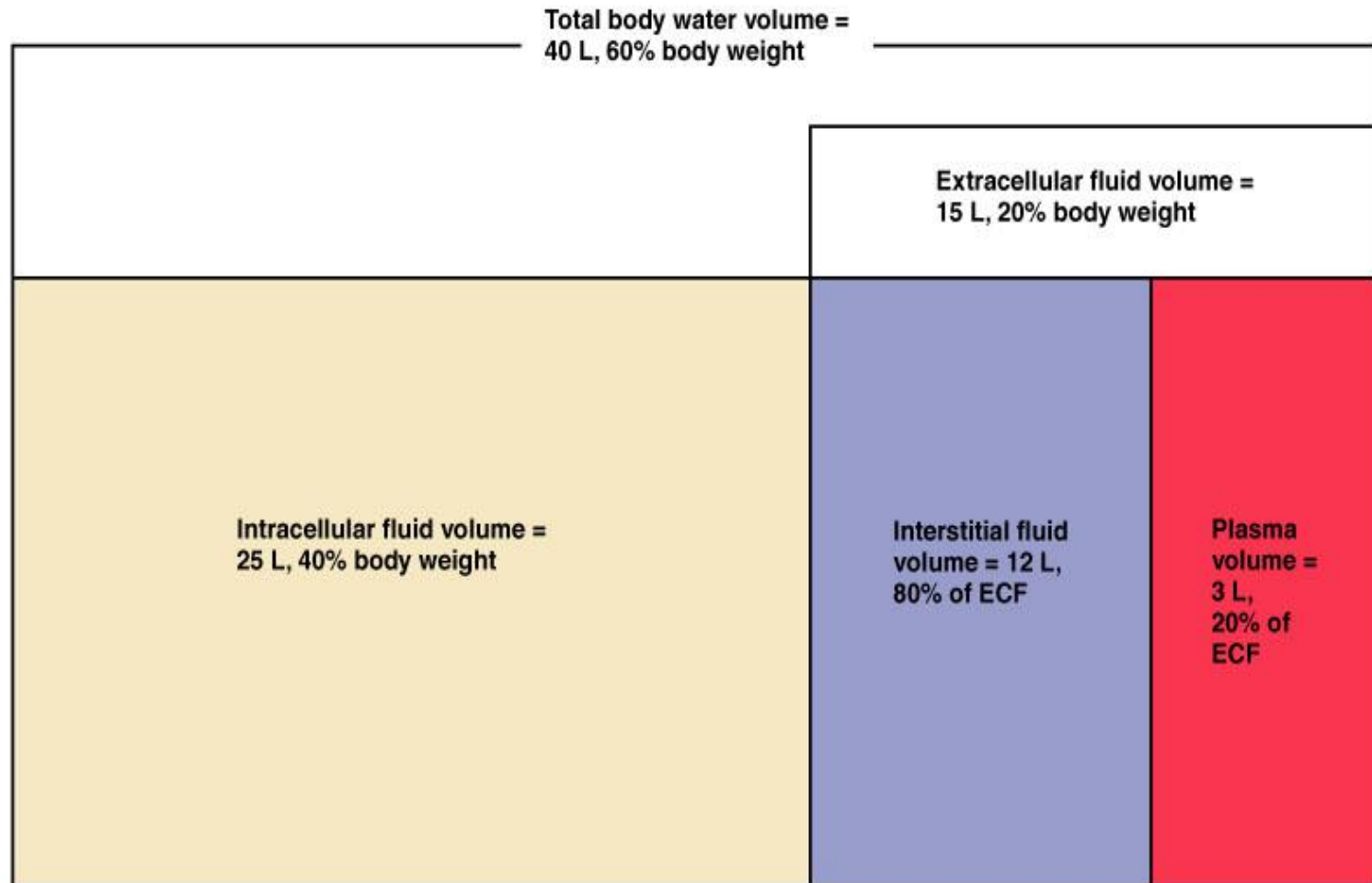


“intercellular space basically means the space between cells which is in essence The interstitial space (interstitium). While Extracellular comprises both the interstitium And the plasma” **Dr.Maha**

Don't mix up between Intracellular Fluid (inside the cell) and Intercellular fluid (space between cells)



Fluid Compartments



Let's go back to our 30-year-old man

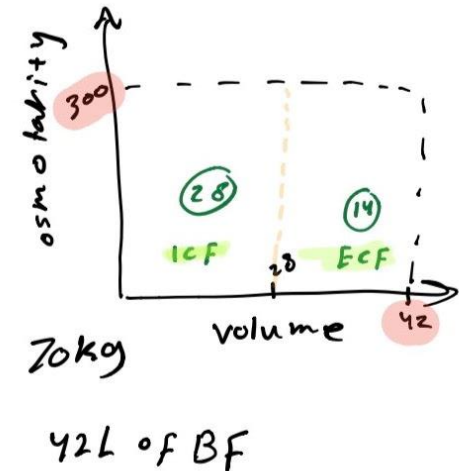
Calculate the total body water content
of a 40-year-old 70kg man?

- TBW = 42 litres
- **How many litres lie intracellularly?**

$$42 \times \frac{2}{3} = 28\text{L} \text{ OR } 70 \times \frac{40}{100} = 28\text{L}.$$

- **How many litres lie extracellularly?**

$$42 \times \frac{1}{3} = 14\text{L} \text{ OR } 70 \times \frac{20}{100} = 14\text{L}.$$

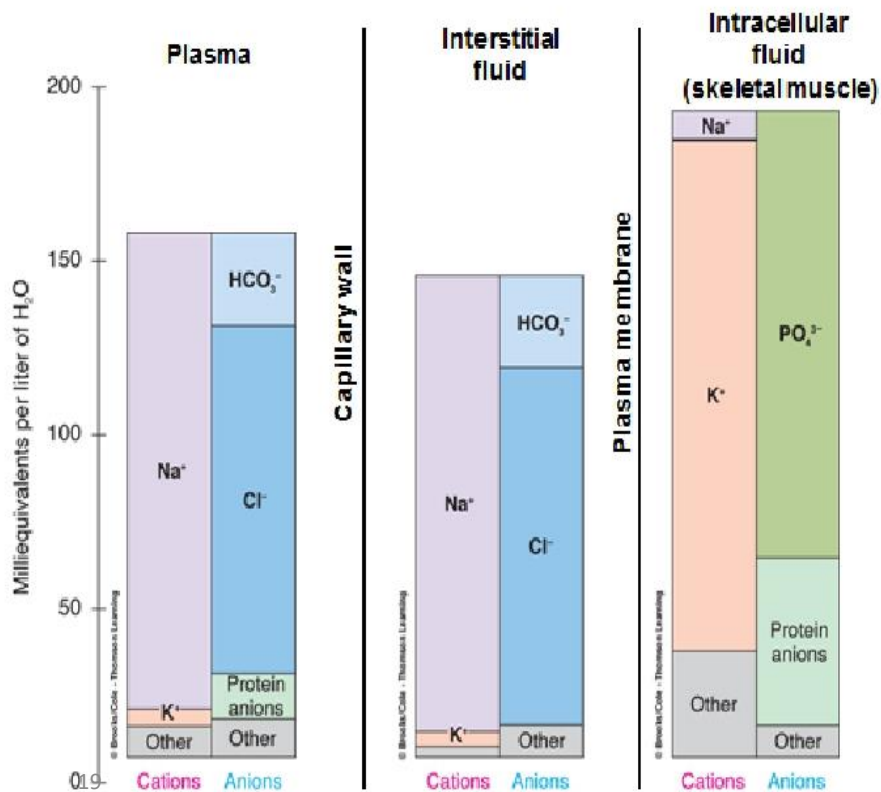


- **How many litres constitute the interstitial fluid?**
- **How many litres are plasma?**

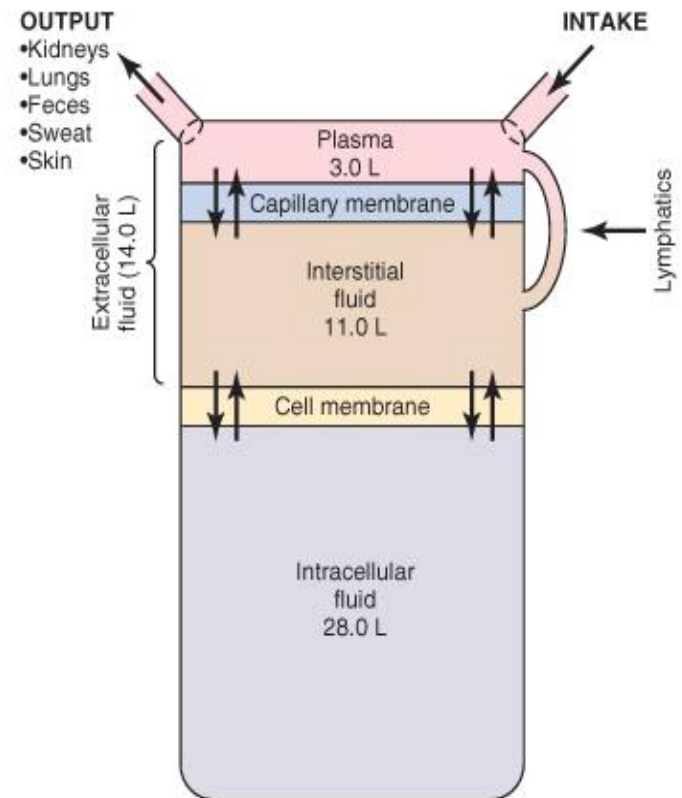
COMPOSITION OF BODY FLUIDS

❖ *Does the composition of the different body fluid compartments differ?*

❖ **The major body fluid compartment and membranes separate them**



[Figure 15-2; Sherwood]



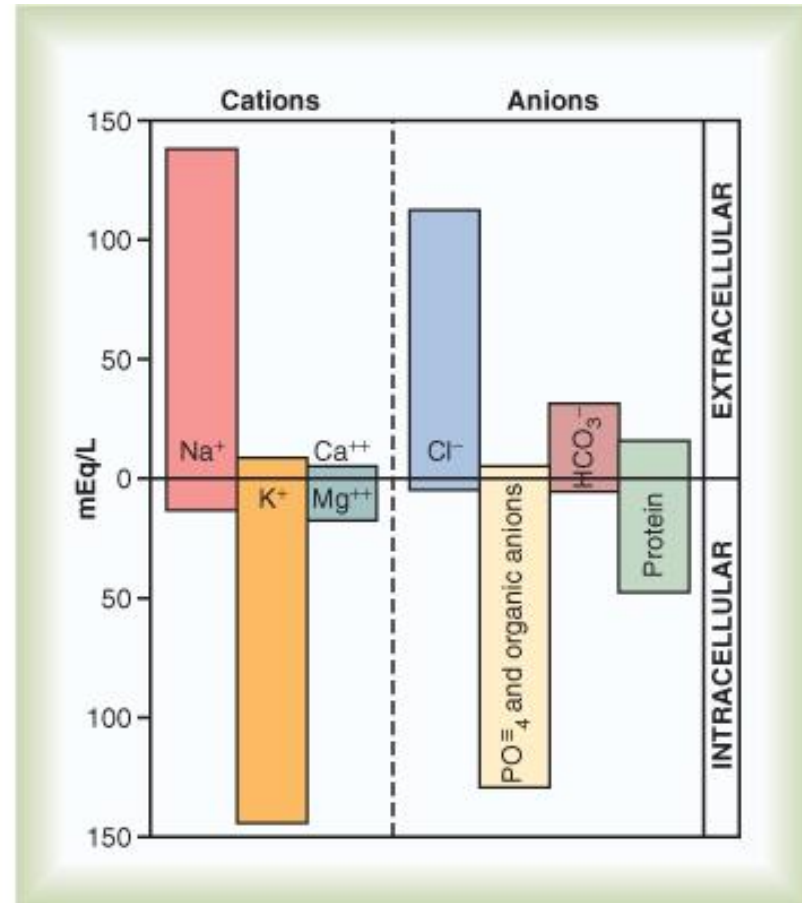
Constitutes of extracellular and intracellular fluids:

	Plasma (mOsm/L H ₂ O)	Interstitial (mOsm/L H ₂ O)	Intracellular (mOsm/L H ₂ O)
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 ₂ PO 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/L	301.8	300.8	301.2
Corrected osmolar activity (mOsm/L)	282.0	281.0	281.0
Total osmotic pressure at 37°C (mm Hg)	5443	5423	5423

- The plasma and interstitial fluid are separated only by highly permeable capillary membranes, their ionic composition is similar but protein is higher in the plasma.
- the intracellular fluid is separated from extracellular fluid by a cell membrane that is highly permeable to water but not to most of the electrolytes in the body.

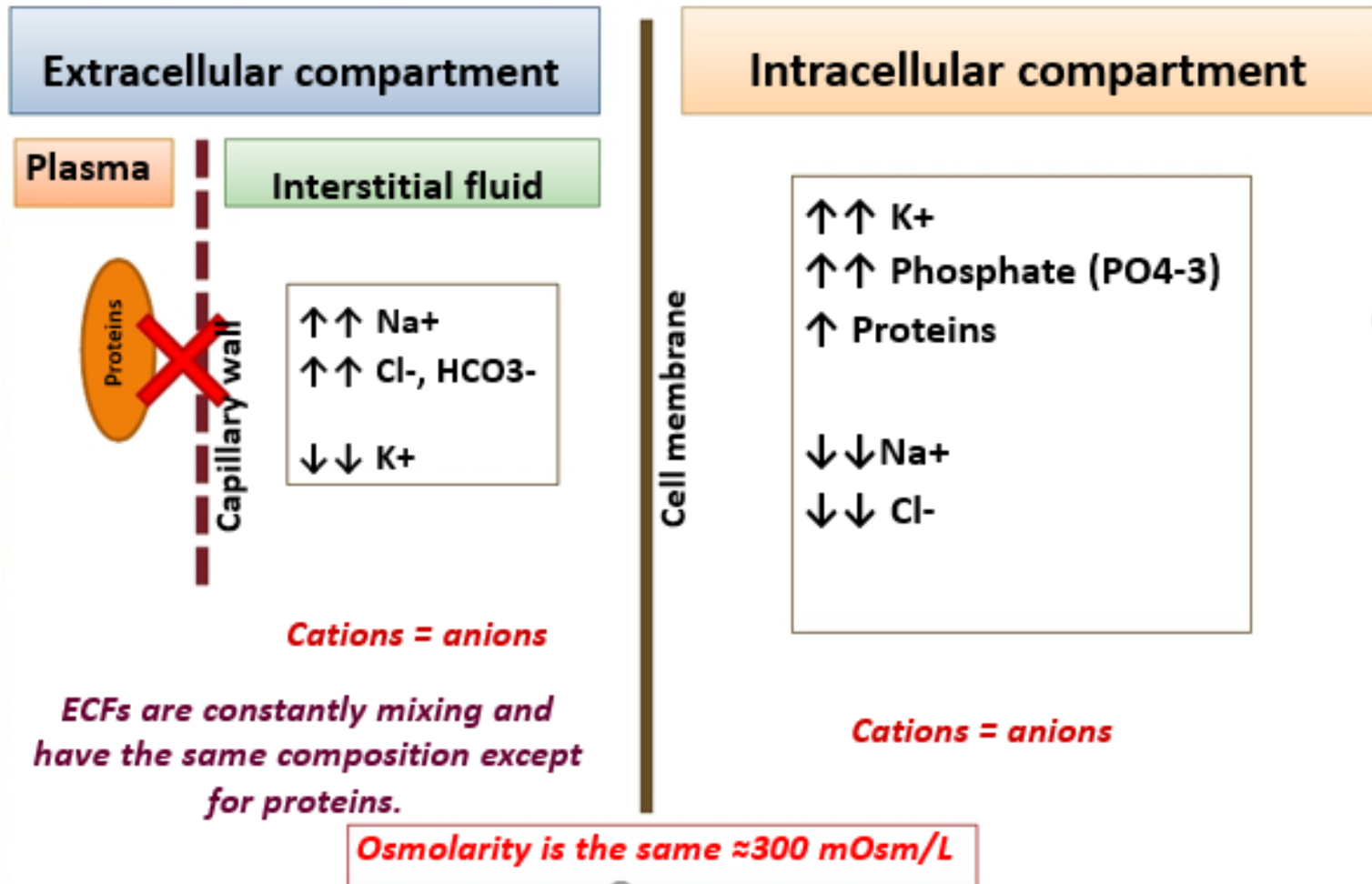
Solute Overview: Intracellular vs. Extracellular

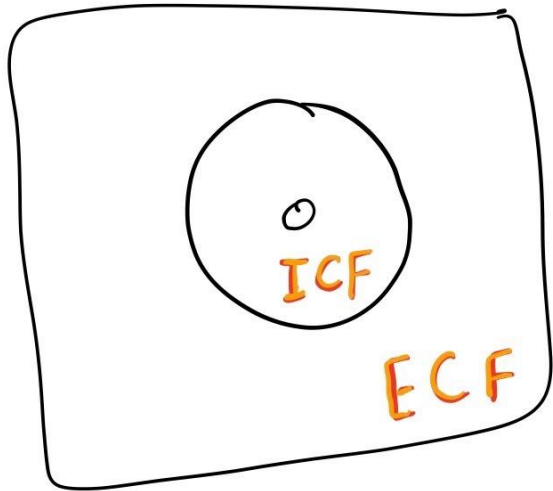
- Ionic composition very different
- Total ionic concentration very similar
- Total osmotic concentrations virtually identical



Constituents of the Different Body Fluid

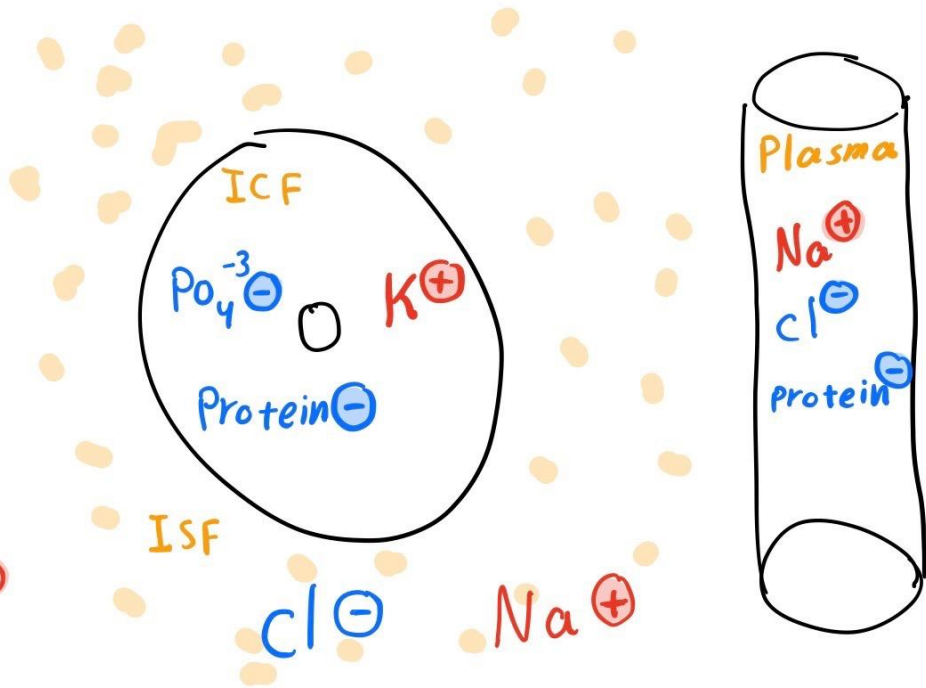
Compartments





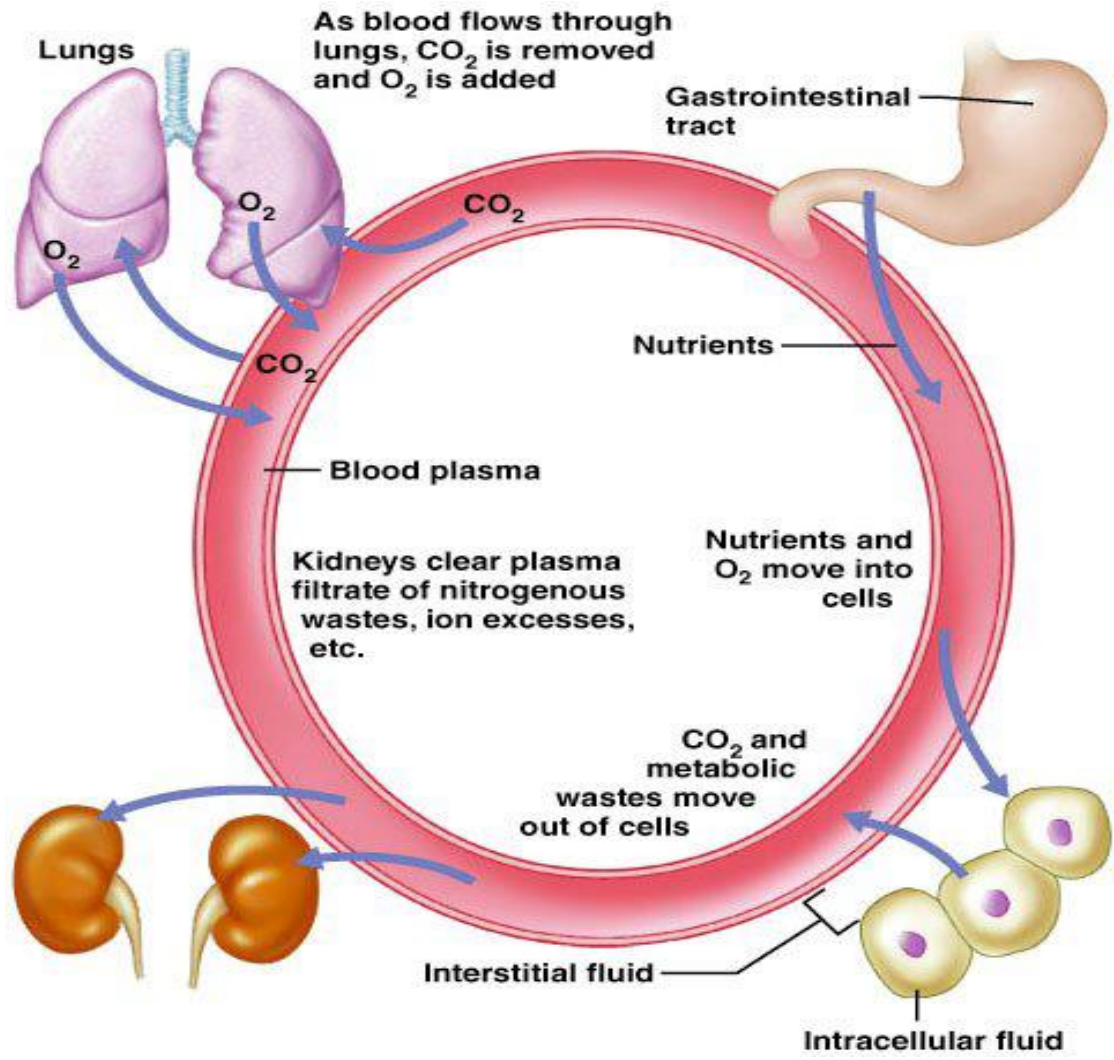
Cations \oplus

Anions \ominus



Extracellular and Intracellular Fluids

- Ion fluxes are restricted and move selectively by active transport.
- Nutrients, respiratory gases, and wastes move Unidirectionally.
- Plasma is the only fluid that circulates throughout the body and links external and internal Environments.
- Osmolarities of all body fluids are equal; changes in solute concentrations are quickly followed by osmotic changes.



Continuous exchange of Body Fluids

Factors That Affect TBW:

Physiological factor:

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

Pathological factors:

- Vomiting
- Diarrhea
- Diseases with excessive loss of water (DM, excessive sweating, etc)
- Blood loss

Osmolarity vs Tonicity?

Osmolarity:

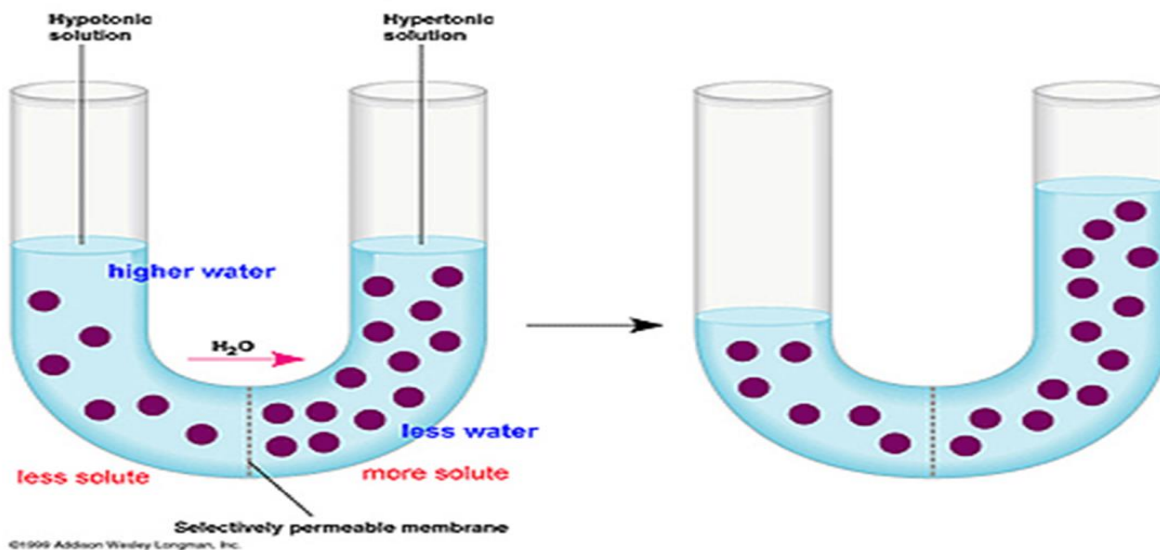
- A unit of concentration.
- It measures how concentrated or diluted a solution is.
- Defined as, the number of osmoles of a solute per litre of solution.
- The normal osmolarity of body fluids is ≈ 300 mOsm/L
- describes the concentration of one solution
- It is the movement of water across a semi-permeable membrane from a region of low solute concentration to a region of high solute concentration.

Tonicity:

- Ability of a solution to change the volume or pressure of the cell by osmosis
- is used to compare between the osmolarities of two or more solutions separated by a semi-permeable membrane.

Why Is tonicity important?

- The difference in tonicity between two different solutions separated by a semi-permeable membrane determines the movement of water.



“Water move from low Concentration to high concentration”

Tonicity

Isotonic:

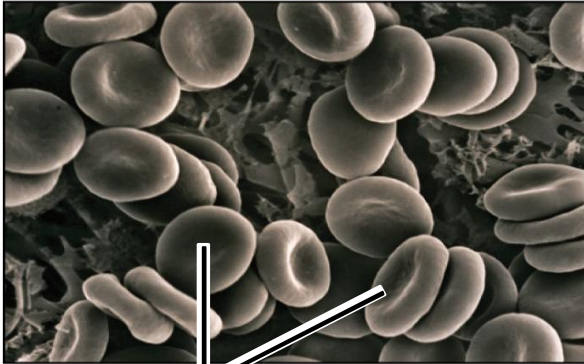
Equal tension to plasma.
RBCs will not gain or lose
 H_2O .

Isotonic solution

Interstitial fluid is the same
concentration as cytosol.

No net
movement
of water.

Erythrocyte



Normal erythrocytes

Hypotonic:

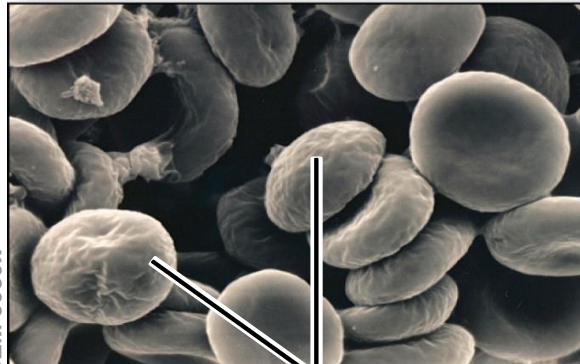
Osmotically active solutes in a
lower osmolality and osmotic
pressure than plasma. RBC will
hemolyse.

Hypotonic solution

Interstitial fluid is less
concentrated than cytosol.

Water
enters
cell.

Erythrocyte



Erythrocytes nearing hemolysis

Hypertonic:

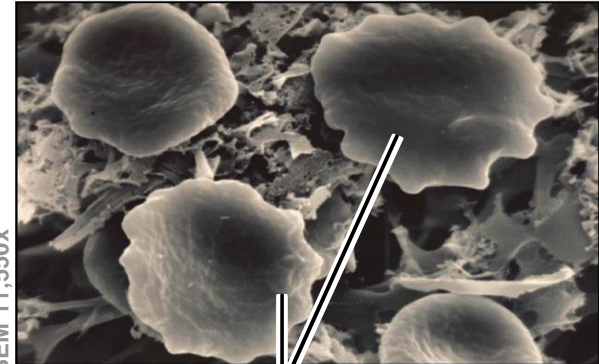
Osmotically active solutes in
a higher osmolality and
osmotic pressure than
plasma. RBC will crenate.

Hypertonic solution

Interstitial fluid is more
concentrated than cytosol.

Water
leaves
cell.

Erythrocyte

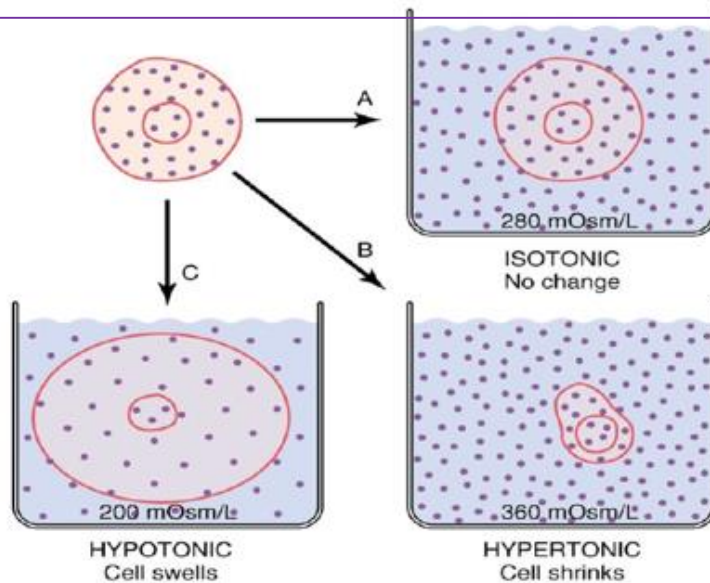


Erythrocytes undergoing crenation

How does it apply to

The cell membrane is a semi-permeable membrane (Allows only water to move freely across it)

physiology?



Some factors can cause the change:

- dehydration
- intravenous infusion (IV)
- abnormal sweating.
- etc..

How is it related to

1. Physicians administer fluids to patients for various reasons that may change the osmolarity of ECF.
2. Abnormalities in electrolytes can change the osmolarity of ECF and can affect the cells

a. Hypernatremia

(↑ Na conc. In ECF)

b. Hyponatremia

(↓ Na conc. In ECF)

- There are many types of IV fluids with different tonicities.

Clinical Manifestations of Hypo- & Hypernatremia

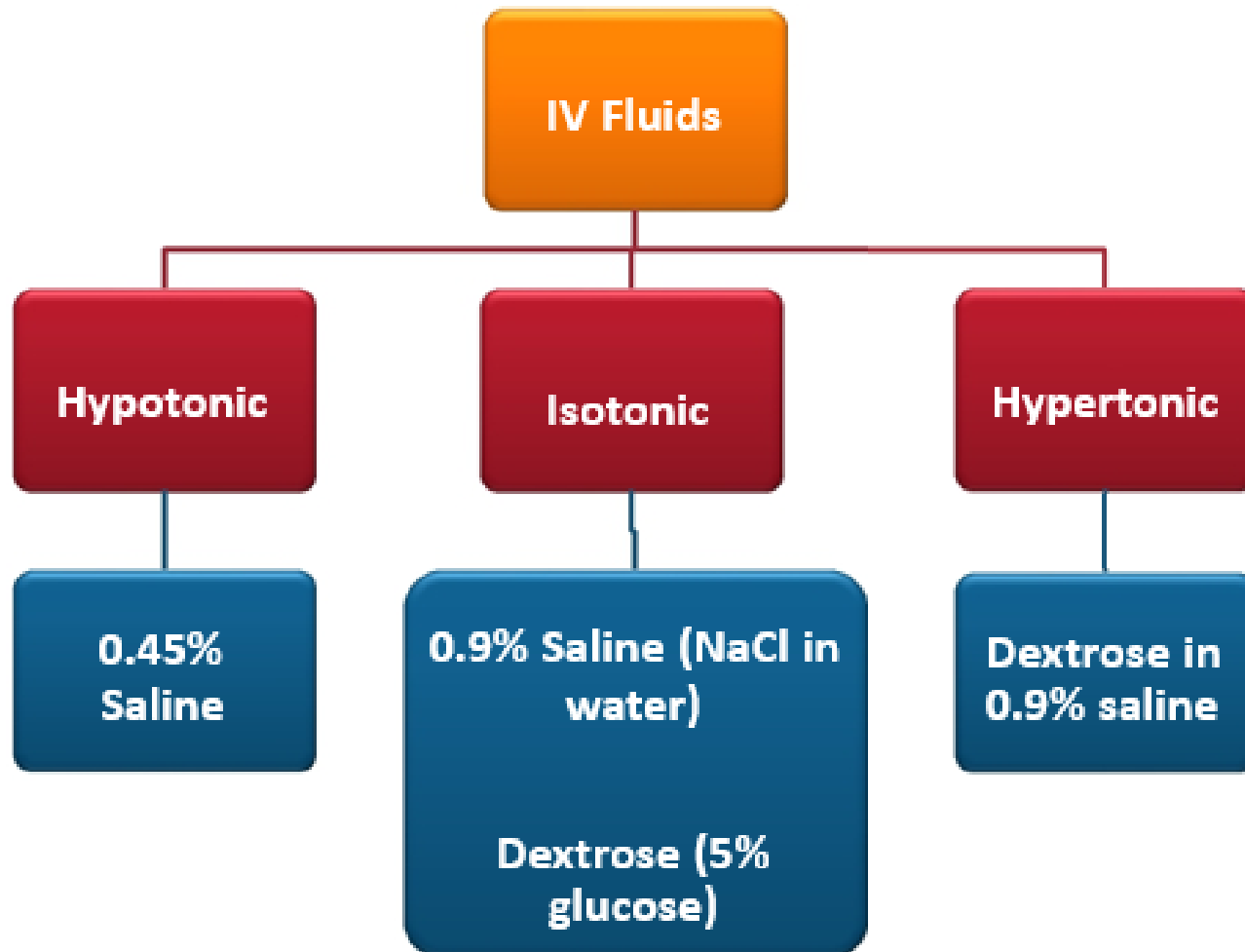
Hyponatremia

- $\downarrow\downarrow$ Plasma $[\text{Na}^+]$ \rightarrow $\downarrow\downarrow$ ECF osmolarity causing cells to swell.
- Brain cell edema leads to neurologic symptoms;
 - Headache.
 - Nausea.
 - Lethargy & disorientation.
- $[\text{Na}^+] < 115\text{-}120\text{mmol/L}$ \rightarrow seizures, coma, permanent brain damage & death.

Hypernatremia

- $\uparrow\uparrow$ Plasma $[\text{Na}^+]$ \rightarrow $\uparrow\uparrow$ ECF osmolarity causing cells to shrink.

Types of IV Fluids



Changes in volume

Volume contraction (Removing):

1- *isotonic* solution.

e.g. Diarrhea

osmolarity of fluid lost \approx osmolarity of ECF
(loss of isosmotic fluid)

- ▼ volume in ECF.
- ▼ arterial pressure

2- *hypertonic* solution.

e.g. Water deprivation

Osmolarity and volume will change .

- ▲ Osmolarity in both ECF and ICF.
- ▼ Volume in both ECF and ICF.

3- *hypotonic* solution.

e.g. Adrenal insufficiency
i.e. Aldosterone deficiency.

- ▼ Na⁺ in the ECF.
- ▼ osmolarity in both .
- ▼ in ECF volume.
- ▲ in ICF volume.

Volume expansion (Adding):

1- *isotonic* solution.

e.g. Infusion of isotonic NaCl.

- ▲ in ECF volume.

No change in osmolarity.

(Isosmotic expansion)

2- *hypertonic* solution.

e.g. High NaCl intake

- ▲ eating salt.
- ▲ osmolarity in both.
- ▼ volume of ICF .
- ▲ volume of ECF .

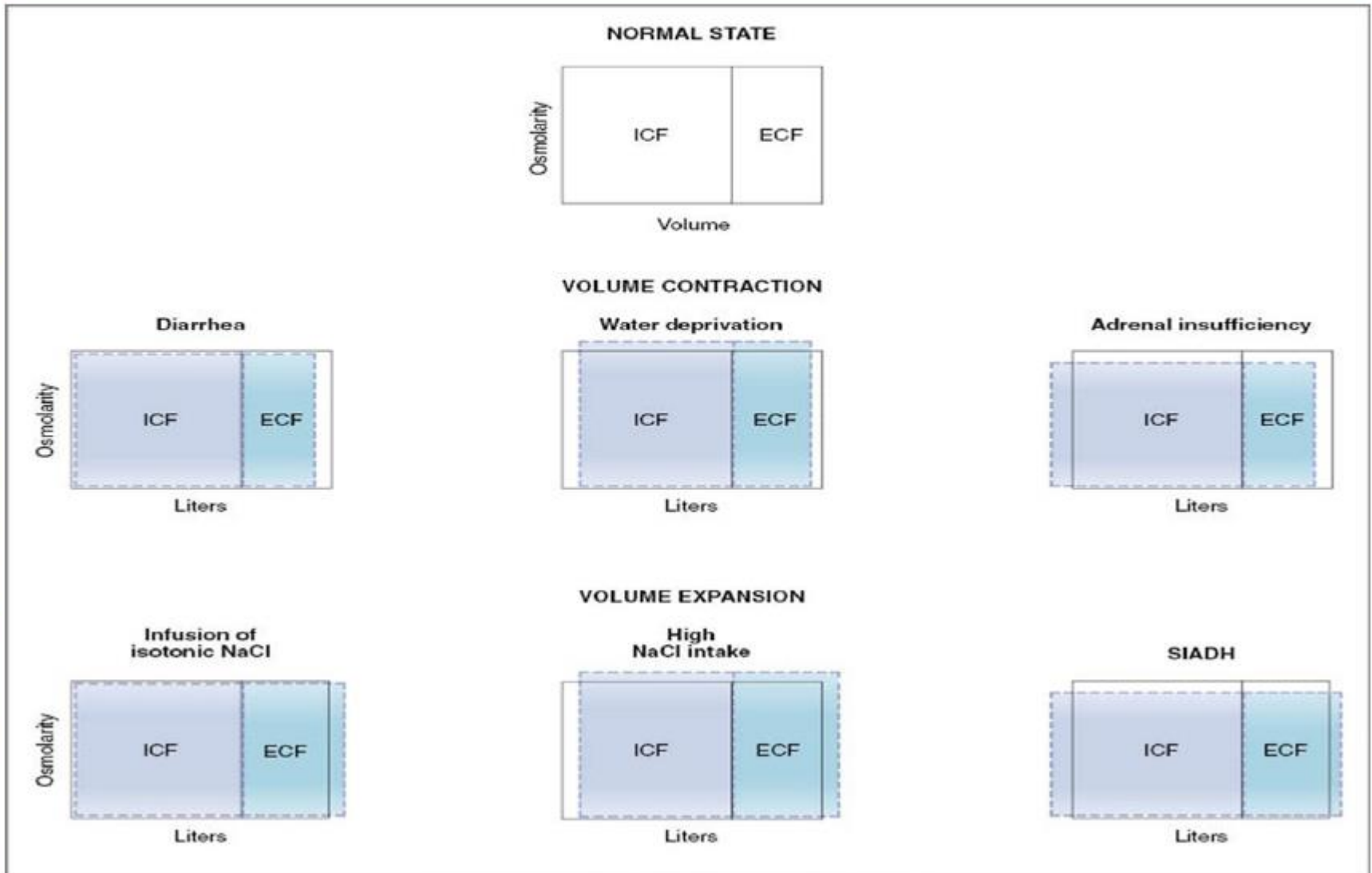
(hyperosmotic volume expansion).

3- *hypotonic* solution.

e.g. Syndrome of inappropriate antidiuretic hormone
(SIADH)

- ▲ volume
- ▼ osmolarity

What happens to body fluid compartments in different clinical situations?



What happens to the different compartments with the administration of IV fluids?

Adding *hypertonic* solution

- ↑ ECF osmolarity
- Water moves out of cells into ECF.
- ICF volume decreases.
- ECF volume increases.
- ↑ ICF osmolarity

Adding *isotonic* solution

- No change in ECF osmolarity.
- No osmosis occurs through cell membrane.
- ECF volume increases.

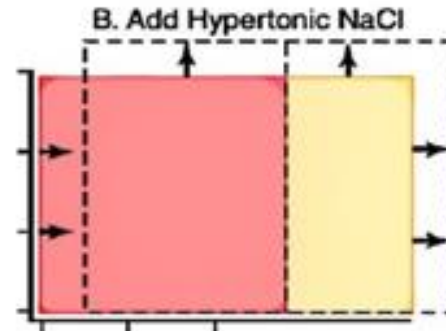
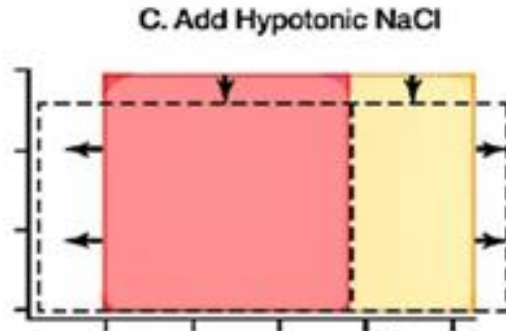
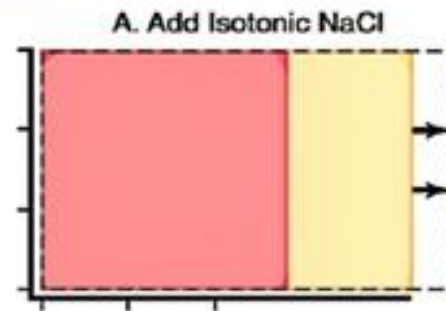
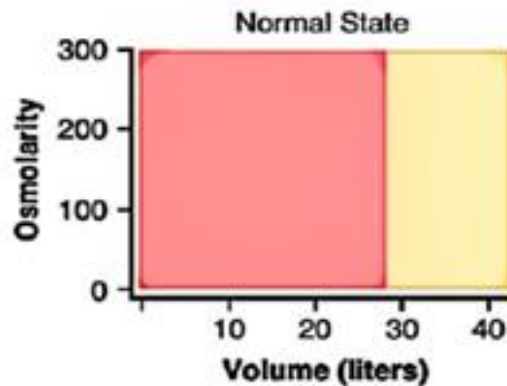
Adding *hypotonic* solution

- ↓ ECF osmolarity
- Water moves from ECF into ICF.
- ICF volume increases.
- ECF volume increase.
- ↓ ICF osmolarity

What happens to the different compartments with the administration of IV fluids?

Effect of adding isotonic, hypertonic, and hypotonic solutions to the extracellular fluid after osmotic equilibrium. The normal state is indicated by the solid lines, and the shifts from normal are shown by the shaded areas.

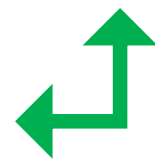
■ Intracellular fluid ■ Extracellular fluid



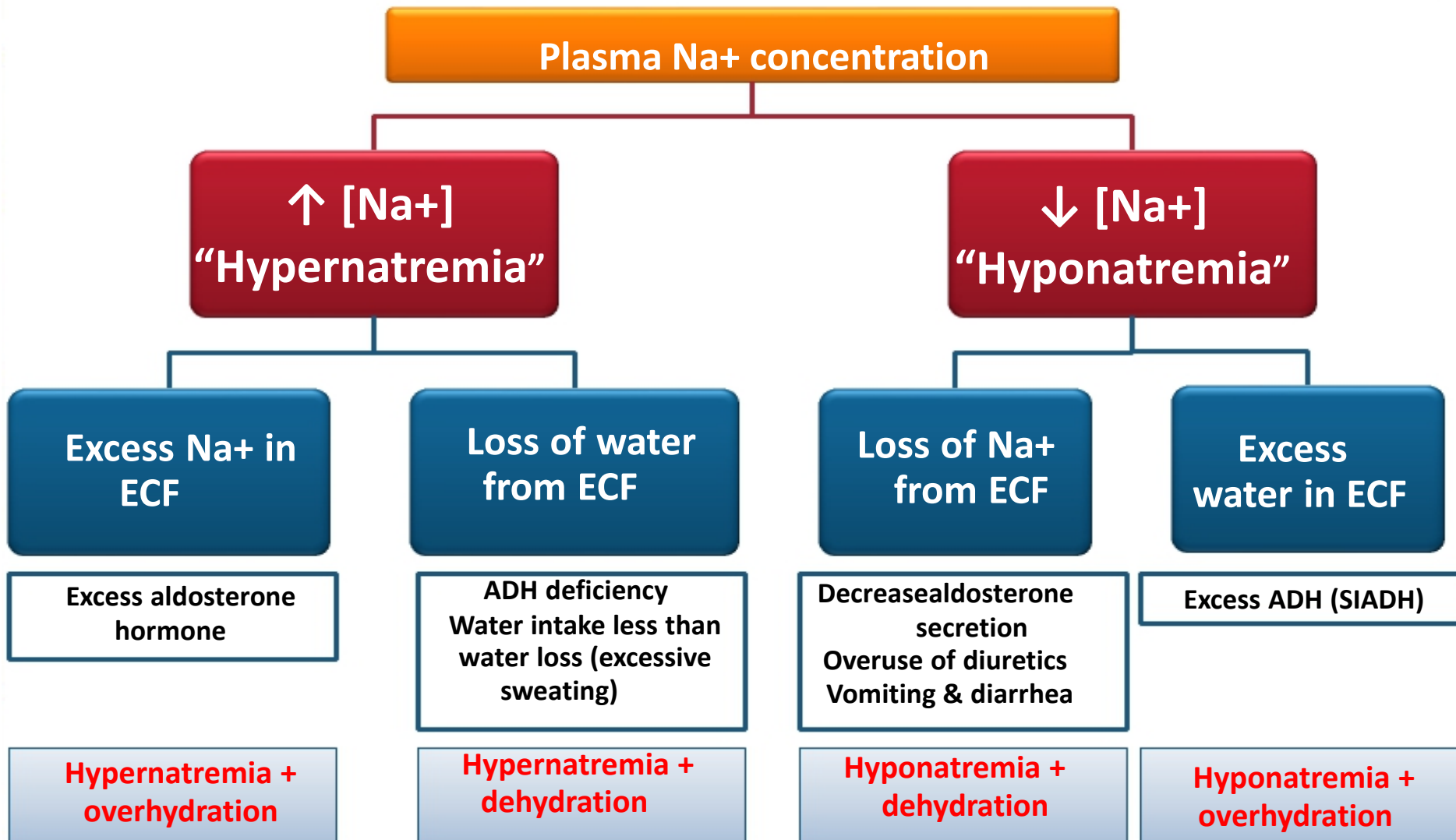
1- the concentration of salt decreases so the vertical axis (osmolarity) will decrease
 2- The ECF will move to the ICF and that's why the cell swelled



1-The concentration of salt will increase, that's why vertical axis (osmolarity) will increase
 2- the ICF will move outside to ECF that's why the cell shrinks



Clinical abnormalities of fluid volume regulation hypo- & hypernatremia



Regulation of fluids and electrolytes:

- Homeostatic mechanisms respond to changes in ECF
- No receptors directly monitor fluid or electrolyte balance
 - Respond to changes in plasma volume or osmotic concentrations.
 - All water moves passively in response to osmotic gradients.
 - Body content of water or electrolytes rises if intake exceeds outflow.

Primary regulatory hormones:

- Antidiuretic hormone (ADH):
 - Stimulates water conservation and the thirst center.
 - Regulates the concentration of body fluid.
- Aldosterone:
 - Controls Na⁺ absorption and K⁺ loss by kidney.
 - Regulates the volume of body fluid compartment .
- Natriuretic peptides:
 - Reduce thirst and block the release of ADH and aldosterone .

Sodium balance:

- Rate of sodium uptake across digestive tract directly proportional to dietary intake
- Sodium losses occur through urine and perspiration
- Shifts in sodium balance result in expansion or contraction of ECF
- Large variations corrected by homeostatic mechanisms
 - Too low, ADH / aldosterone secreted
 - Too high, ANP secreted

Potassium balance:

- Potassium ion concentrations in ECF are low
- Not as closely regulated as sodium
- Potassium ion excretion increases as
 - ECF concentrations rise
 - Aldosterone secreted
 - pH rises
- Potassium retention occurs when pH falls

Calcium balance

Bone reserves,
absorption in the
digestive tract, and loss
at kidneys

Magnesium balance

Absorbed by the PCT to
keep pace with urinary
losses

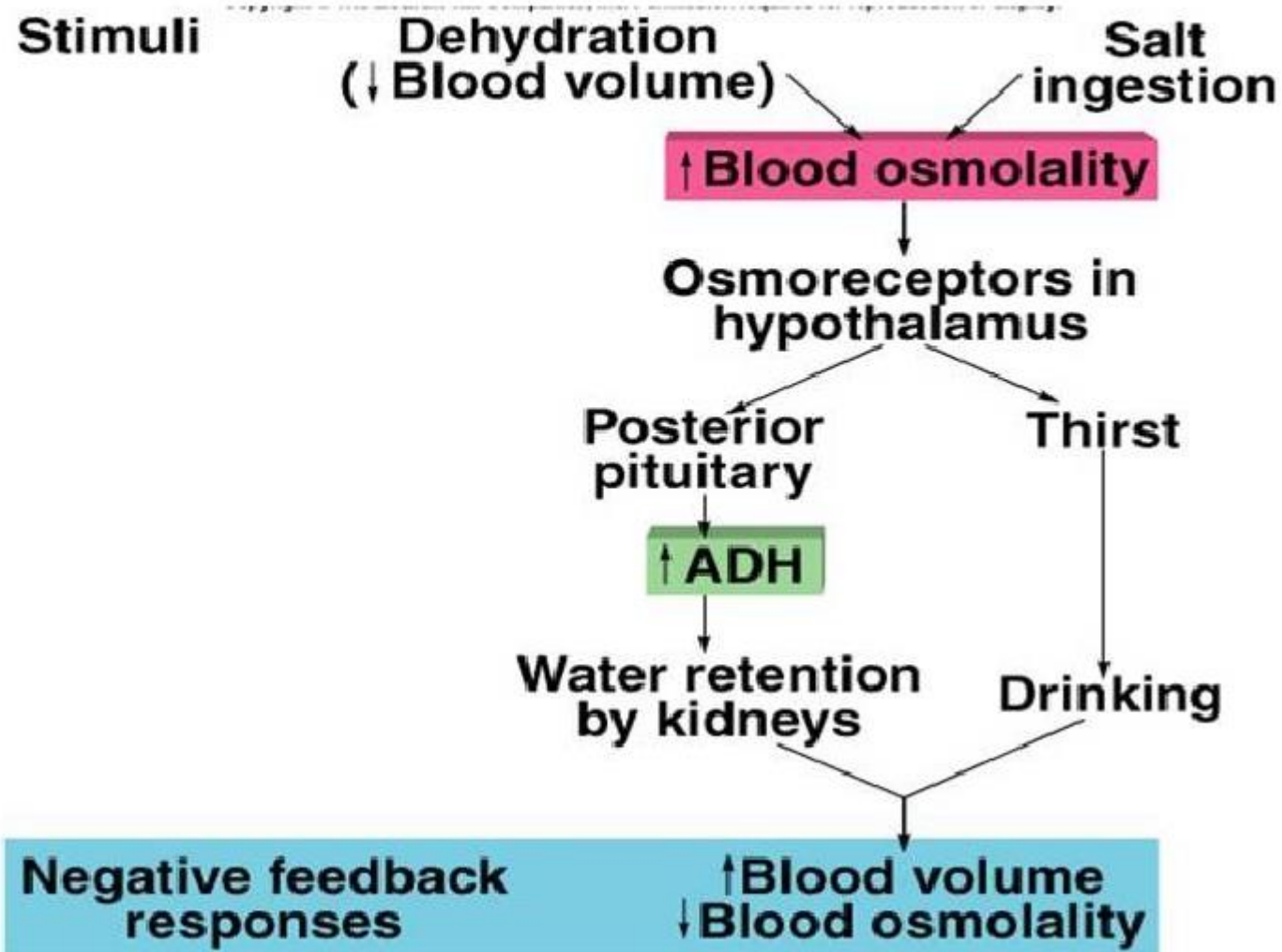
Phosphate balance

Absorbed by the PCT in
response to calcitriol

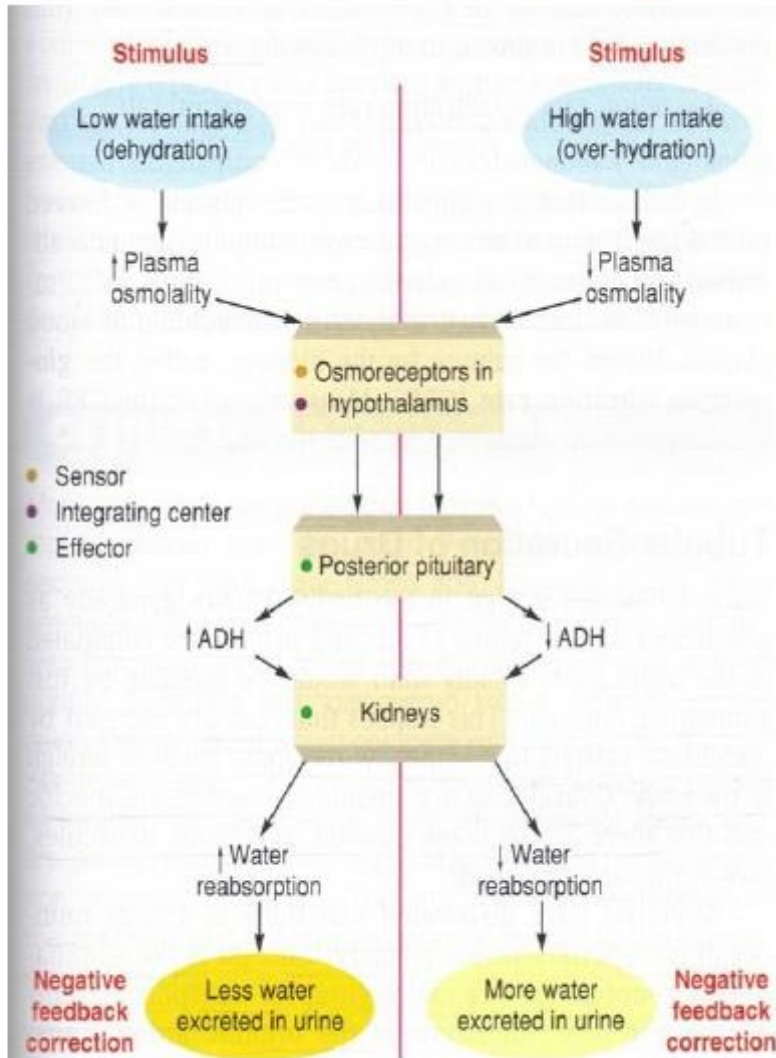
Chloride balance

Absorbed at digestive
tract to balance losses in
urine and sweat

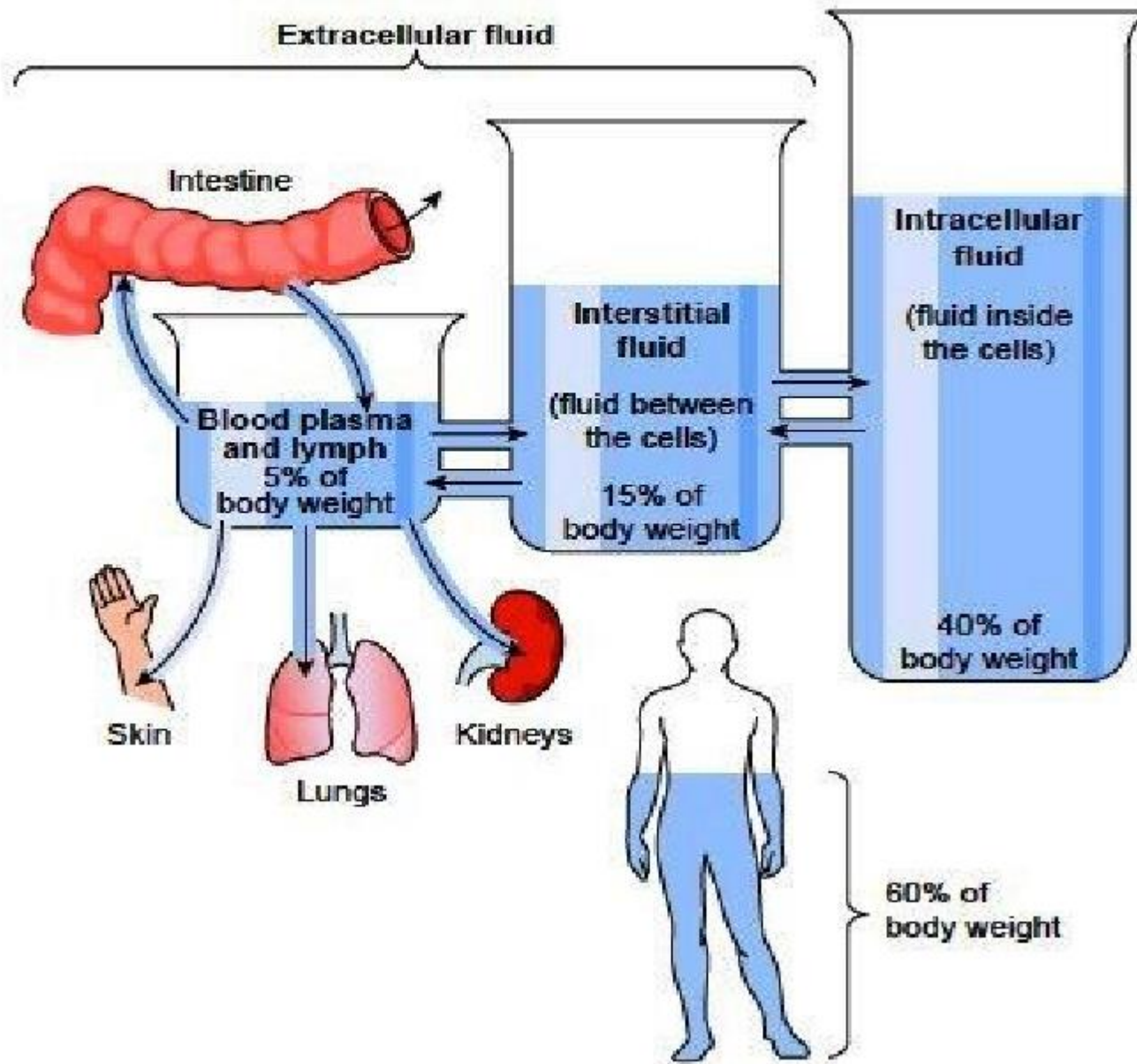
What are the feedback mechanisms operating in fluid balance control?



Feedback Mechanisms Controlling Fluid Balance



In summary



Water distribution in the body

An exercise

- After learning about water content of the human body, a **60kg** medical student was curious to calculate her own body water content. What would you expect the Total volume of her body water to be? 36 L

- And what is the volume of the following compartments?

-ICF 26 L

-ECF 12 L

-IF 9 L

-Plasma 3 L

Chick your understanding !

1- Calculate the total body water content of a 30 year old 60kg man ?

a/ 40 L b/ 25 L c/36 L d/ 33 L

2- ECFs are constantly mixing and have the same composition except for proteins T/F

3- Which of the following isn't physiological factors?

a/ blood lose b/age c/sex d/body fat

**4-Which of the following is incorrect:
(by adding isotonic solution)**

a/ No change in ECF Osmolarity.

b/ECF volume increases.

c/ Osmolarity of ECF increase.

5-The Osmolarity describe the concentration of two solution

T/F

**6- Intracellular compartment represent 33% of the total
body water, about 20 % of total body weight**

T/F

**Answers / 1-c , 2-T , 3-
a , 4-c , 5-F , 6- F**



Thank you & good luck

Boys team members: ▶

- ▶ هشام الشايع
- ▶ سعود الاحمري
- ▶ عبدالرحمن آل الشيخ
- ▶ فايز الدرسوني
- ▶ محمد الحسن
- ▶ محمد الصويغ
- ▶ محمد المنجومي
- ▶ معاذ الحمود
- ▶ منصور العبرة
- ▶ احمد الصبي
- ▶ خالد العقيلي
- ▶ عبدالجبار اليماني
- ▶ عمر الفوزان

Girls team members: •

- مها العمري
- هديل عورتاني
- ريما العنزي
- روتانا خطيب
- لجين عزيز الرحمن
- العنود المفرج
- ريم القرني
- عهد القرين
- العنود المنصور
- مها النهدي
- بلقيس الراجحي
- سارة البليهد
- ميعاد النقيعي
- نورة البسام
- عبير العبدالجبار
- وجدان الشامري
- الجوهرة الشنيقي

together everyone
TEAM
achieves more

Team Leaders:

-طارق العميم

-مها بركة