Fluid and Electrolyte balance

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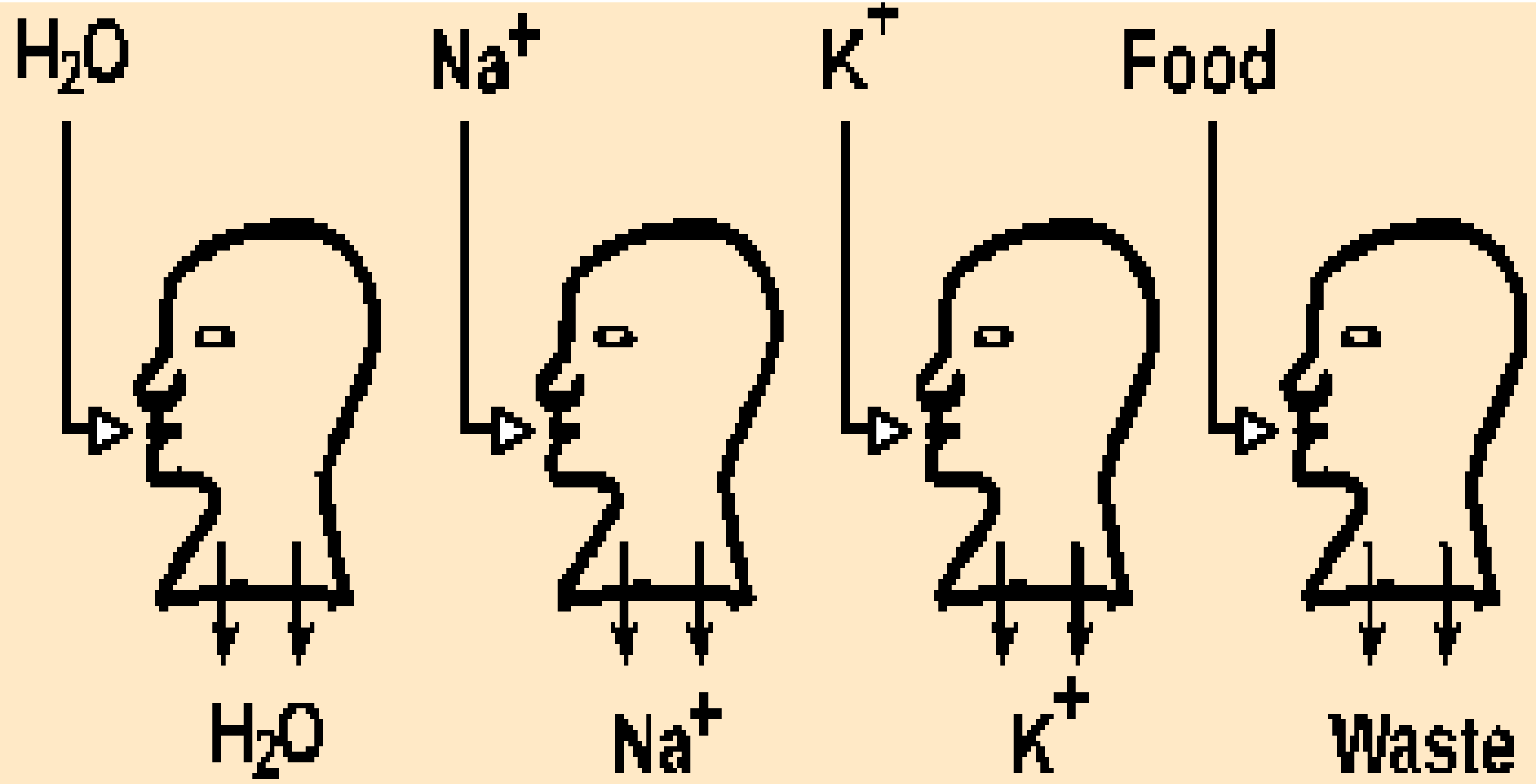
Body as an open sytem

Body exchanges materials and energy with its surroundings



Water

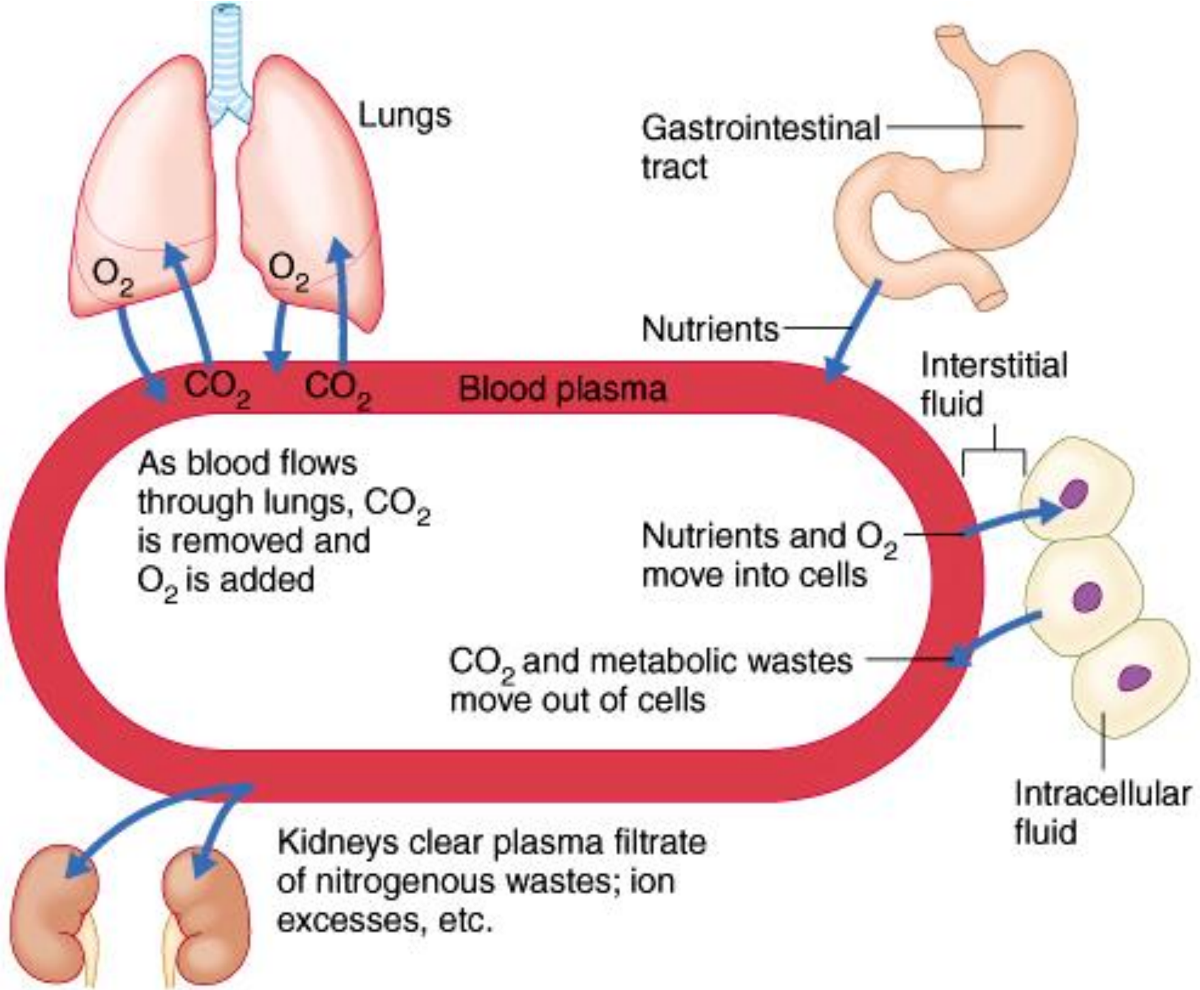
General

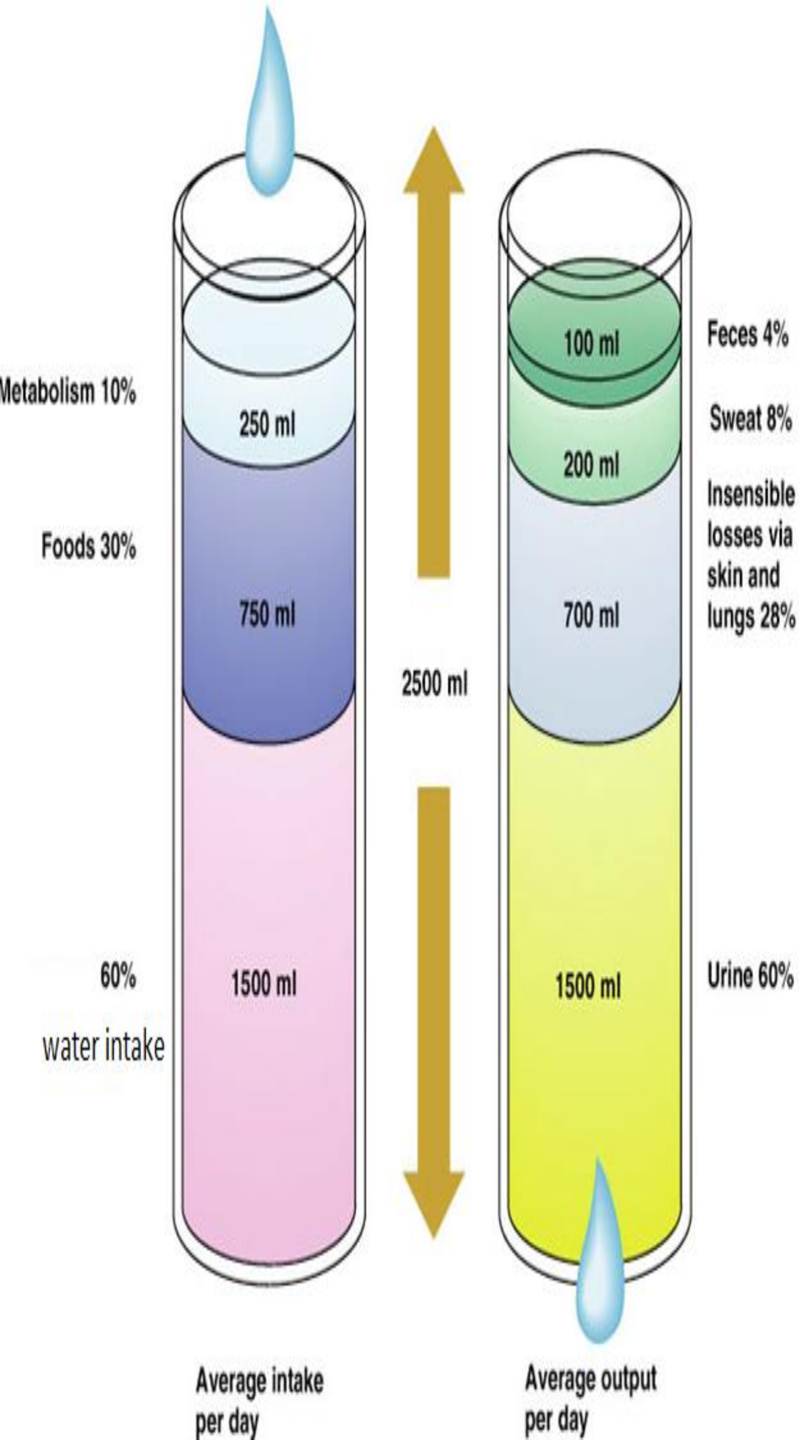
- Largest single chemical component of the body: 45-75% of body mass
- Fat (adipose tissue) is essentially water free, so there is relatively more or less water in the body depending on % fat composition
- Water is the solvent for most biological molecules within the body
- Water also participates in a variety of biochemical reactions, both anabolic and catabolic

Fluid Balance

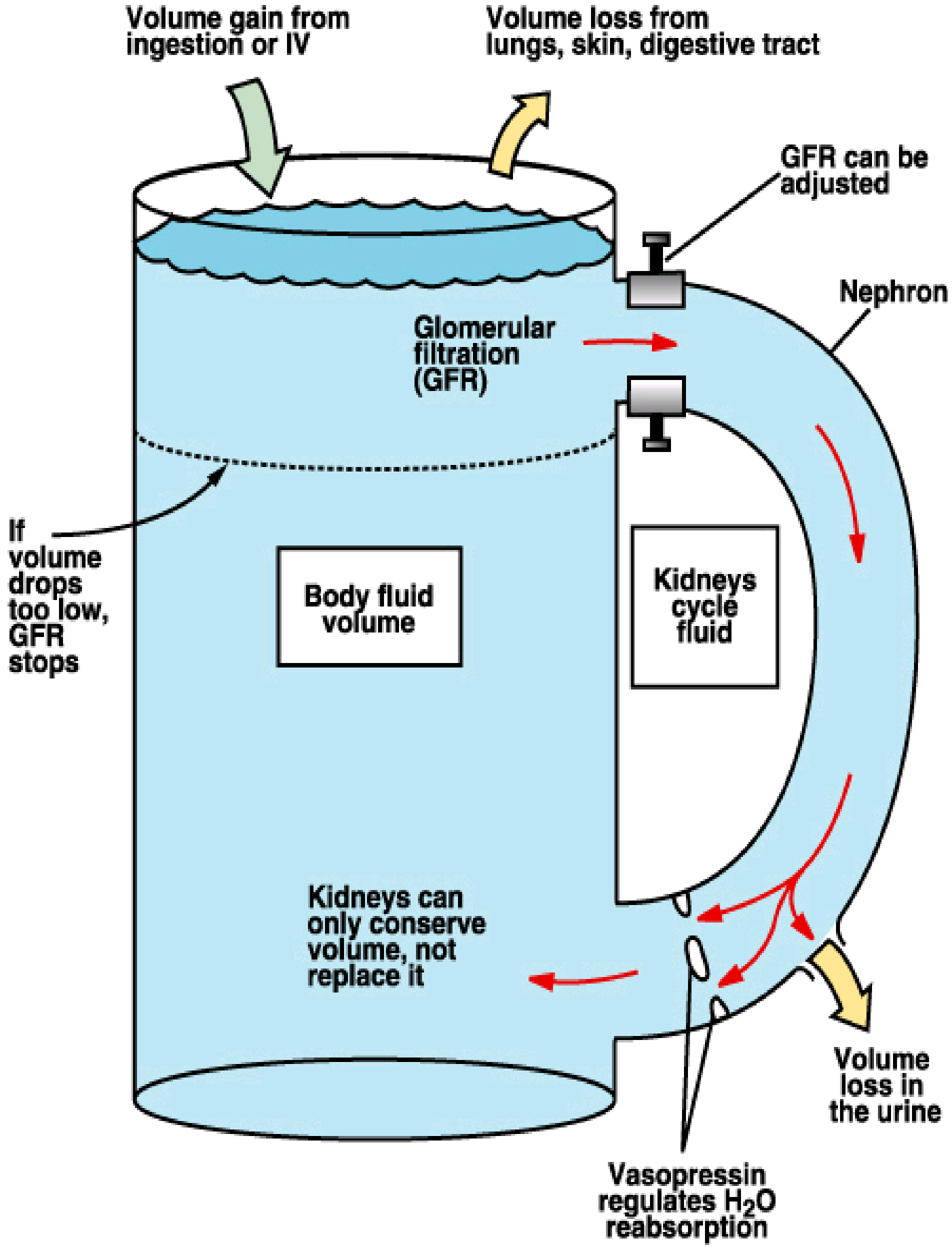
Fluid balance

- When in balance, adequate water is present and is distributed among the various compartments according to the body's needs
- Many things are freely exchanged between fluid compartments, especially water
- Fluid movements by:
  - bulk flow (i.e., blood & lymph circulation)
  - diffusion & osmosis – in most regions





Route	Range (l/day)	Regulatory influences
Insensible - lungs	0.3-0.4	Atmospheric vapor pressure (temperature)
Insensible - skin	0.35-0.4	10x increase in burn victims
Sweat	0.1-2 (per hour)	Temperature, exercise
Feces	0.1-0.2	Diarrheal disease
Urine	0.5-1.4-20	Body fluid composition


Volume gain from ingestion or IV
Volume loss from lungs, skin, digestive tract
GFR can be adjusted
Nephron
Glomerular filtration (GFR)
If volume drops too low, GFR stops
Body fluid volume
Kidneys cycle fluid
Kidneys can only conserve volume, not replace it
Volume loss in the urine
Vasopressin regulates H_2O reabsorption

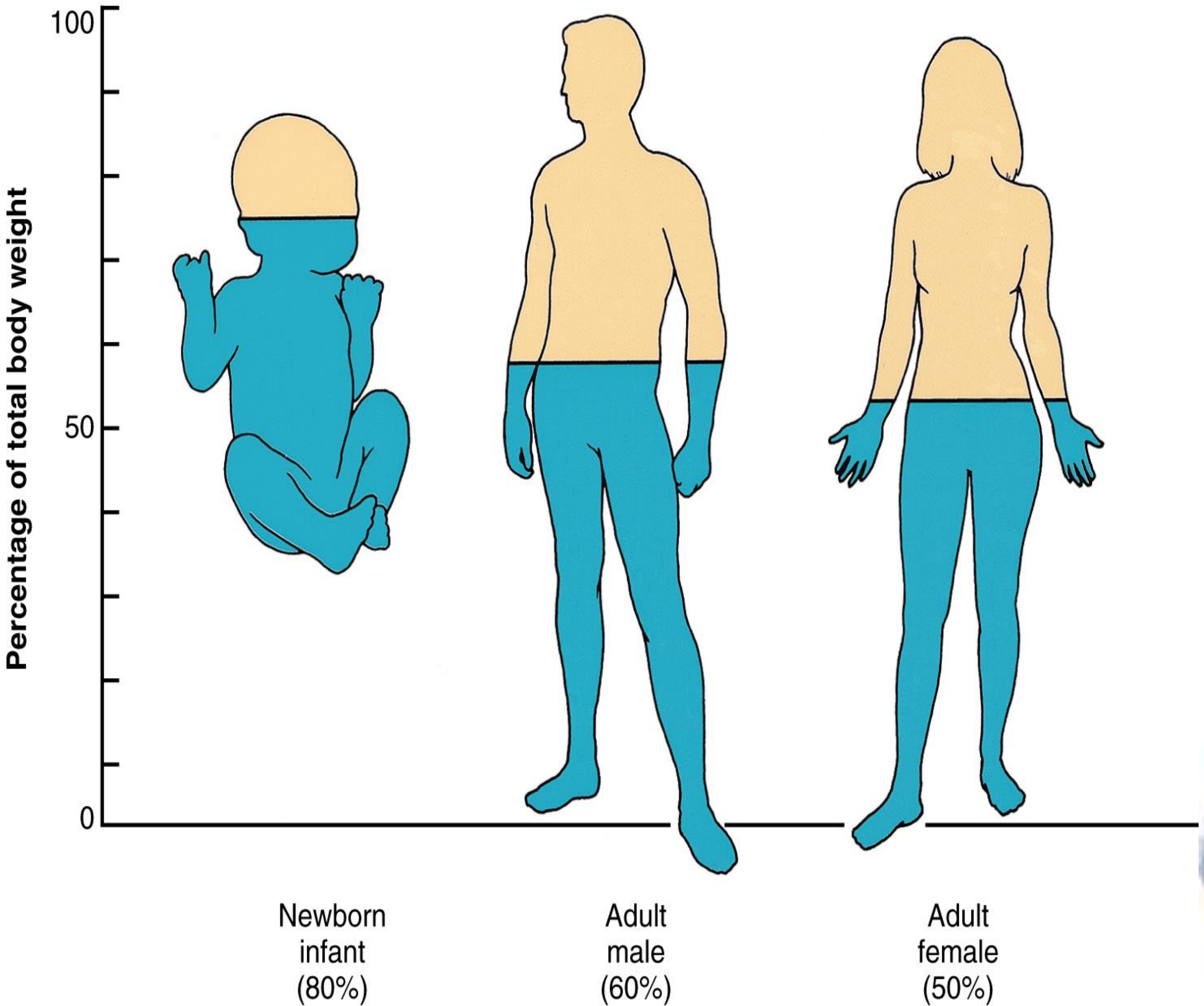
FACTORS AFFECTING

Total Body H_2O

varies depending on body fat:

1. Infant: 73-80%
2. Male adult: 60%
3. Female adult: 40-50%
4. Effects of obesity
5. Old age 45%
6. Climate Level of physical activity

PERCENTAGE OF H2O IN TISSUES



FLUID COMPARTMENTS

- Extracellular Fluid
  - Plasma
  - Interstitial Fluid
  - Transcellular Fluid
    - **CSF**
    - **Intra ocular**
    - **Pleural**
    - **Peritoneal**
    - **Synovial**
    - **Digestive Secretions**
- Intra cellular Fluid (Cytosol)

PERCENTAGE OF WATER IN TISSUES

Average 70 kg person total body weight

42 litres total H_2O 60%

28 l. Intracellular fluid (ICF) 40% (2/3)

14 l. Extracellular fluid (ECF) 20% (1/3)

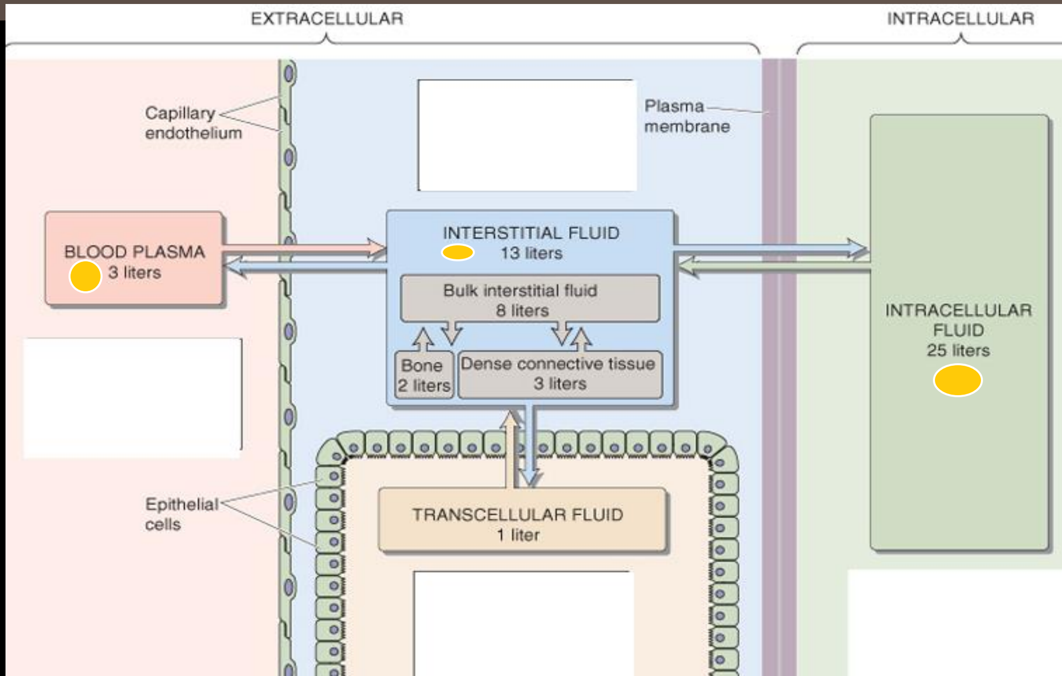
% is important in fluid therapy

divided into ¾ ISF and ¼ plasma water

10.5 l. Interstitial fluid (ISF) 15%

3.5 l. Plasma water 5%

TISSUE	% WATER	% BODY Wt.	L of H_2O
Skin	72	18	9.1
Muscle	76	41.7	22.1
Skeleton	22	16	2.5
Brain	74.8	2.0	1.0
Liver	68.3	2.3	1.0
Blood	83.0	8.0	4.65
Intestine	74.5	1.8	1.0
Adipose Tissue	10.0	10+	0.7



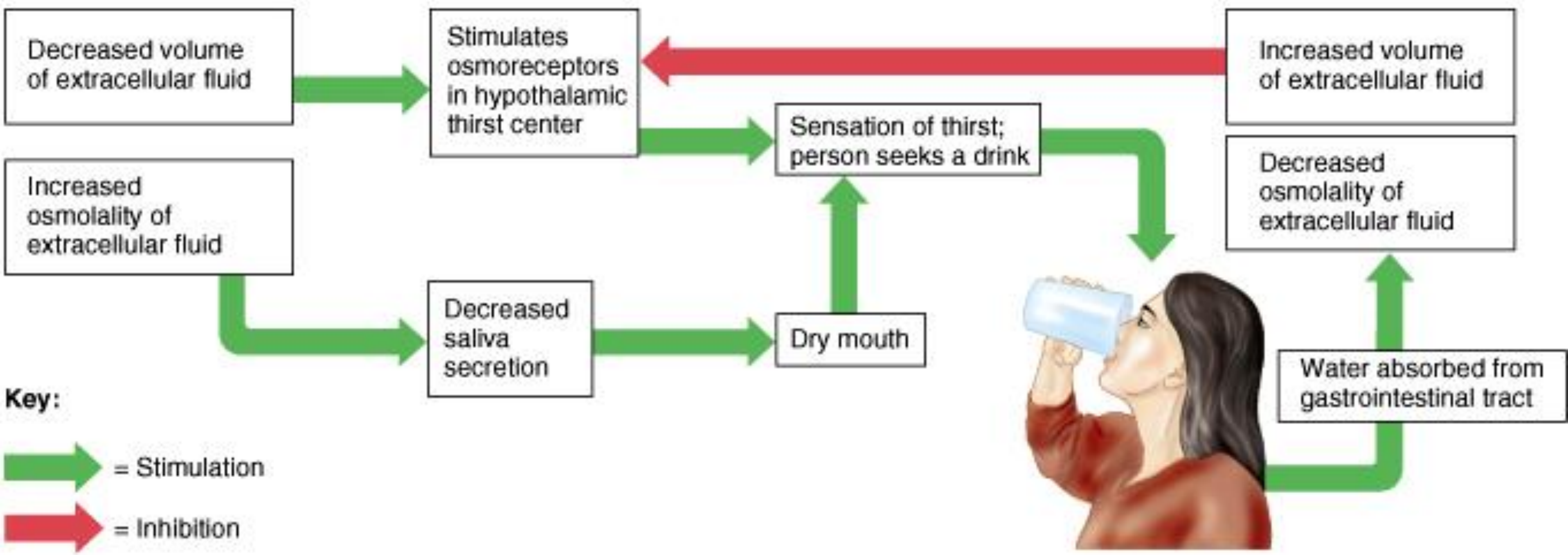
Regulation of H_2O Intake

The hypothalamic thirst center is stimulated:

1. By a decline in plasma volume of 10%–15%
2. By increases in plasma osmolality of 1–2%
3. Via baroreceptor input, angiotensin II, and other stimuli

Regulating Fluid Intake - Thirst

Recall the role of the Renin-Angiotensin System in regulating thirst along with the Autonomic NS reflexes diagramed below



Regulating Fluid Intake - Thirst Quenching

Wetting the oral mucosa (temporary)

Stretching of the stomach

Decreased blood/body fluid osmolarity = increased hydration (dilution) of the blood is the most important

Regulation of Fluid Output

Hormonal control
- AntiDiuretic Hormone (ADH) [neurohypophysis]
- Aldosterone [adrenal cortex]
- Atrial Natriuretic Peptide (ANP) [heart atrial walls]

Physiologic fluid imbalances
- Dehydration: ↓ blood pressure, ↓ GFR
- Overhydration: ↑ blood pressure, ↑ GFR
- Hyperventilation - water loss through lungs
- Vomiting & Diarrhea - excessive water loss
- Fever - heavy perspiration
- Burns - initial fluid loss; may persist in severe burns
- Hemorrhage – if blood loss is severe

Concentrations of Solutes

Non-electrolytes

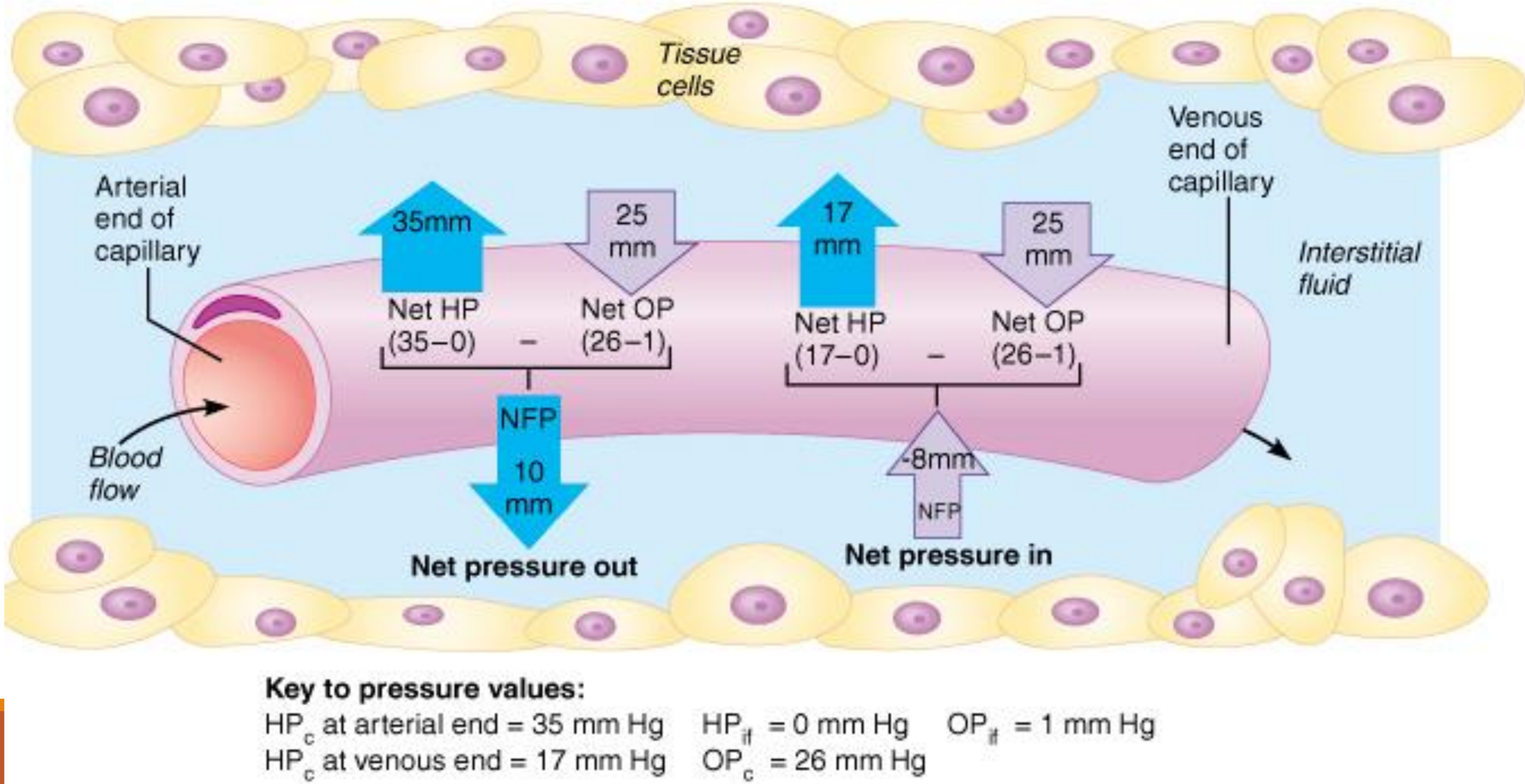
- molecules formed by only covalent bonds
- do not form charged ions in solution

Electrolytes

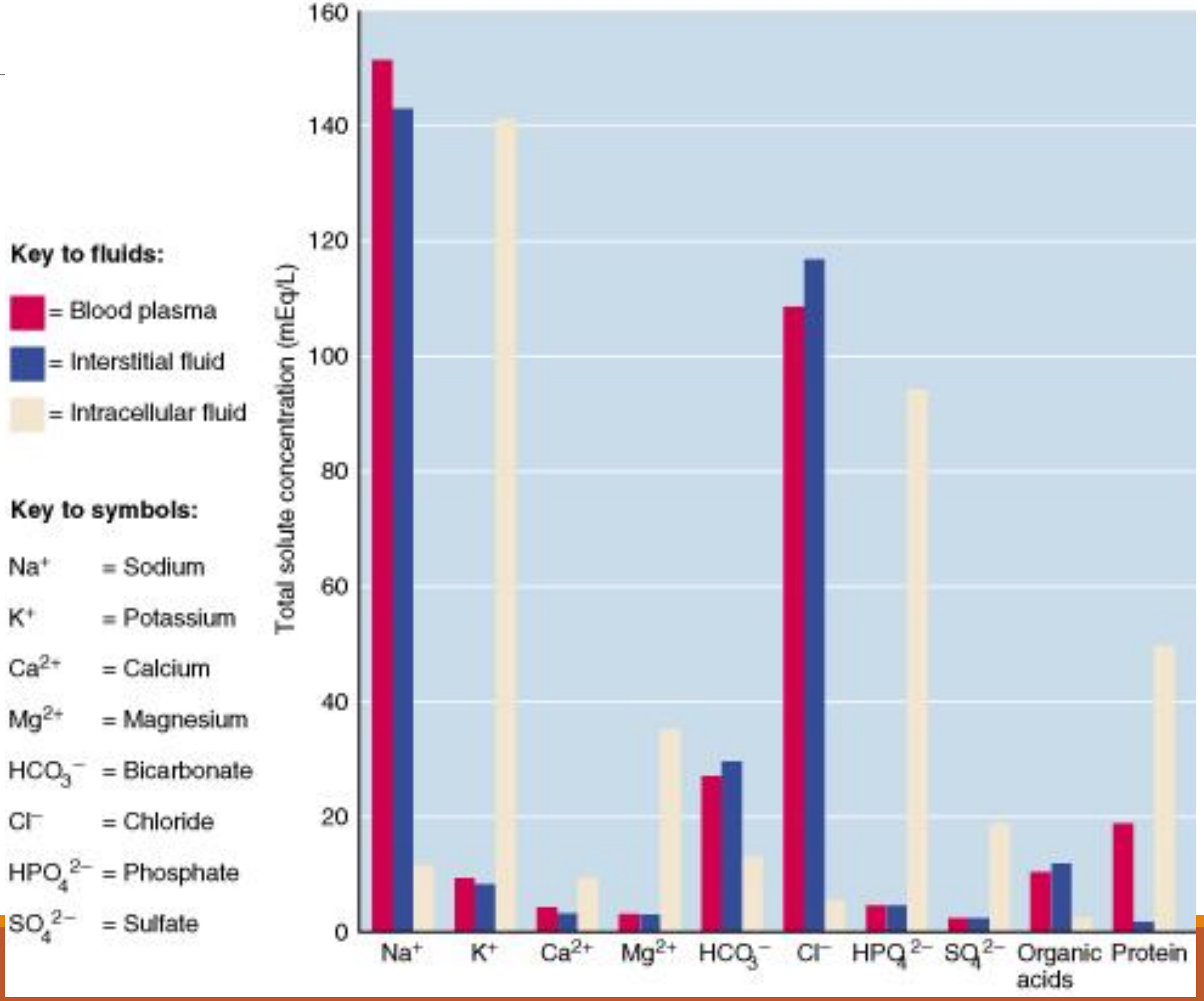
- Molecules formed with some ionic bonds;
- Disassociate into cations (+) & anions (-) in solutions (acids, bases, salts)
- 4 important physiological functions in the body
  - essential minerals in certain biochemical reactions
  - control osmosis = control the movement of water between compartments
  - maintain acid-base balance
  - conduct electrical currents (depolarization events)

Distribution of H_2O & Electrolytes

Recall Starling's Law of the Capillaries which explains fluid and solute movements



Distribution of Electrolytes



APPROXIMATE IONIC COMPOSITION OF THE BODY H2O COMPARTMENTS

Ion	Plasma, mmoles/L	Interstitial fluid, mmoles/L	Skeletal muscle cell, mmoles/L
Cations			
Na^+	142.0	145.1	10.0
K^+	4.3	4.4	140.0
Ca^{2+}(ionized)	2.5	2.4	1.0
Mg^{2+}(ionized)	1.1	1.1	17
Others	4.0		
Total	154	153	168
Anions			
Cl^-	114.0	117.4	4.0
HCO_3^-	24.0	27.1	7.0
HPO_4^{2-}, $H_2PO_4^-$	1.0	1.2	40.0
Proteins	1.5	0.1	3.0
Other	10.0	6.2	84.0
Total	154	153	138

Distribution of Major Electrolytes

Na^+ and CL^- predominate in extracellular fluids (interstitial fluid and plasma) but are very low in the intracellular fluid (cytoplasm)

K^+ and HPO_4^{2-} predominate in intracellular fluid (cytoplasm) but are in very low concentration in the extracellular fluids (interstitial fluid and plasma)

At body fluid pH, proteins [P^-] act as anions; total protein concentration [P^-] is relatively high, the second most important "anion," in the cytoplasm, [P^-] is intermediate in blood plasma, but [P^-] is very low in the interstitial fluid

Distribution of Minor Electrolytes

HCO_3^- is in intermediate concentrations in all fluids, a bit lower in the intracellular fluid (cytoplasm); it is an important pH buffer in the extracellular compartments

Ca^{++} is in low concentration in all fluid compartments, but it must be tightly regulated, as small shifts in Ca^{++} concentration in any compartment have serious effects

Mg^{++} is in low concentration in all fluid compartments, but Mg^{++} is a bit higher in the intracellular fluid (cytoplasm), where it is a component of many cellular enzymes

Electrolyte Balance

Aldosterone ↑ $[Na^+]$ $[Cl^-]$ $[H_2O]$ ↓ $[K^+]$

Atrial Natriuretic Peptide (opposite effect)

Antidiuretic Hormone ↑ $[H_2O]$ (↓ [solutes])

Parathyroid Hormone ↑ $[Ca^{++}]$ ↓ $[HPO_4^-]$

Calcitonin (opposite effect)

Female sex hormones ↑ $[H_2O]$

Plasma Osmolarity Measures ECF Osmolarity

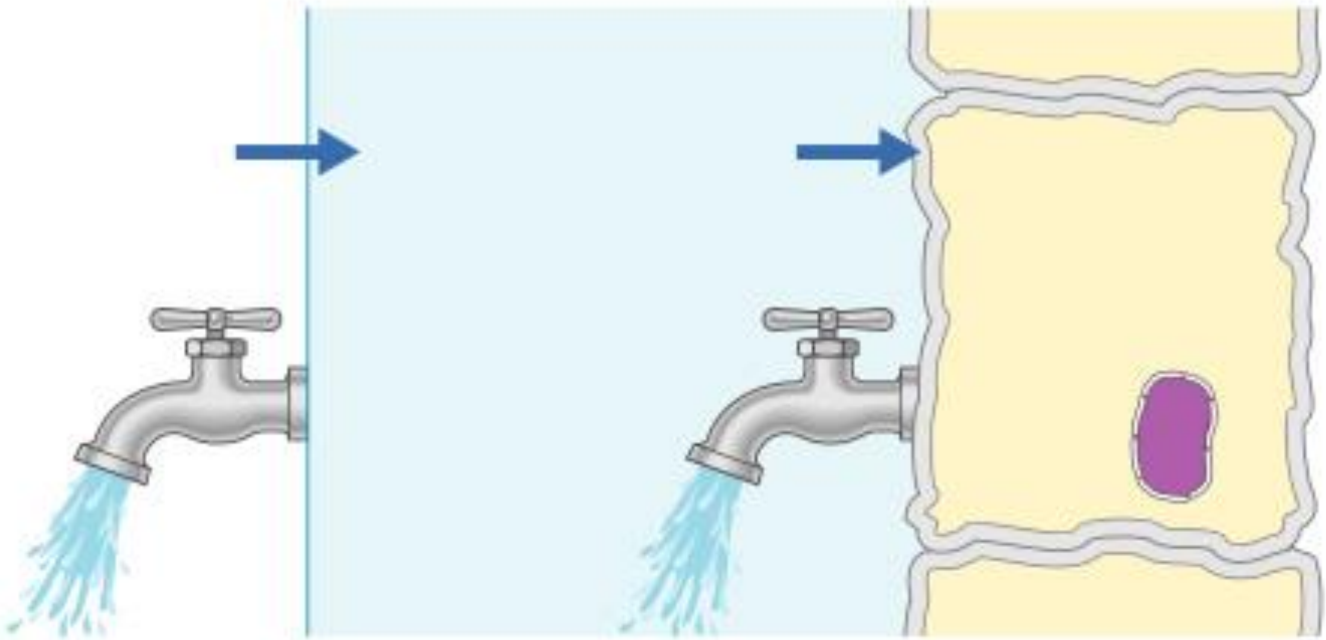
Plasma is clinically accessible

Dominated by $[Na^+]$ and the associated anions

Under normal conditions, ECF osmolarity can be roughly estimated as:

$$P_{OSM} = 2\,[Na^+]_p \quad 270\text{-}290 \text{ mOSM}$$

Disorders of H_2O Balance: Dehydration



(a) Mechanism of dehydration

Primary Disturbance

Water Loss

ECF OSMOLARITY ?

1. H_2O moves out of cells
2. ICF Volume decreases (Cells shrink)
3. ICF Osmolarity increases
4. Total body osmolarity remains higher than normal

Over Hydration

ECF OSMOLARITY ?

1. H_2O moves into the cells
2. ICF Volume increases (Cells swell)
3. ICF Osmolarity decreases
4. Total body osmolarity remains lower than normal