BODY FLUID DISTRIBUTION AND COMPOSITION

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BODY COMPOSITION

- 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).

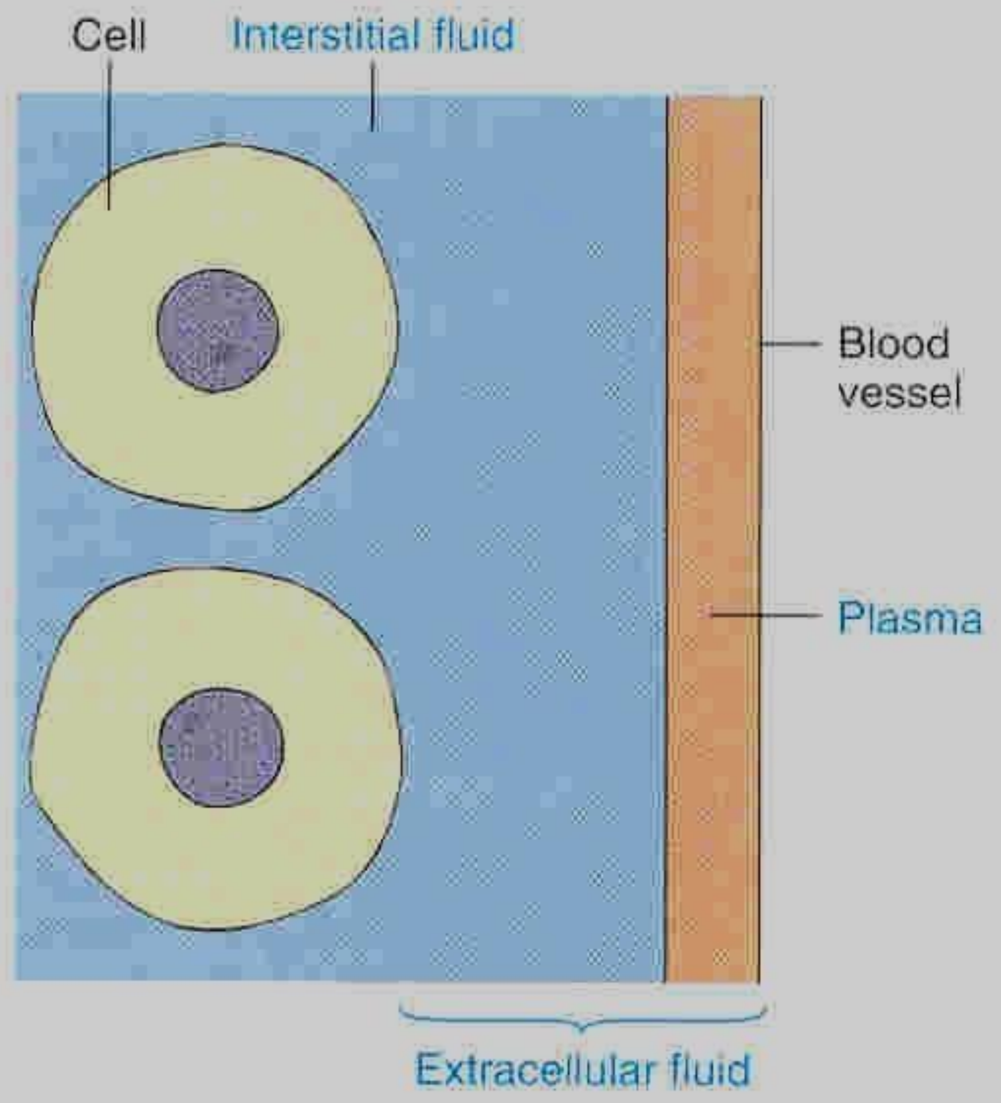
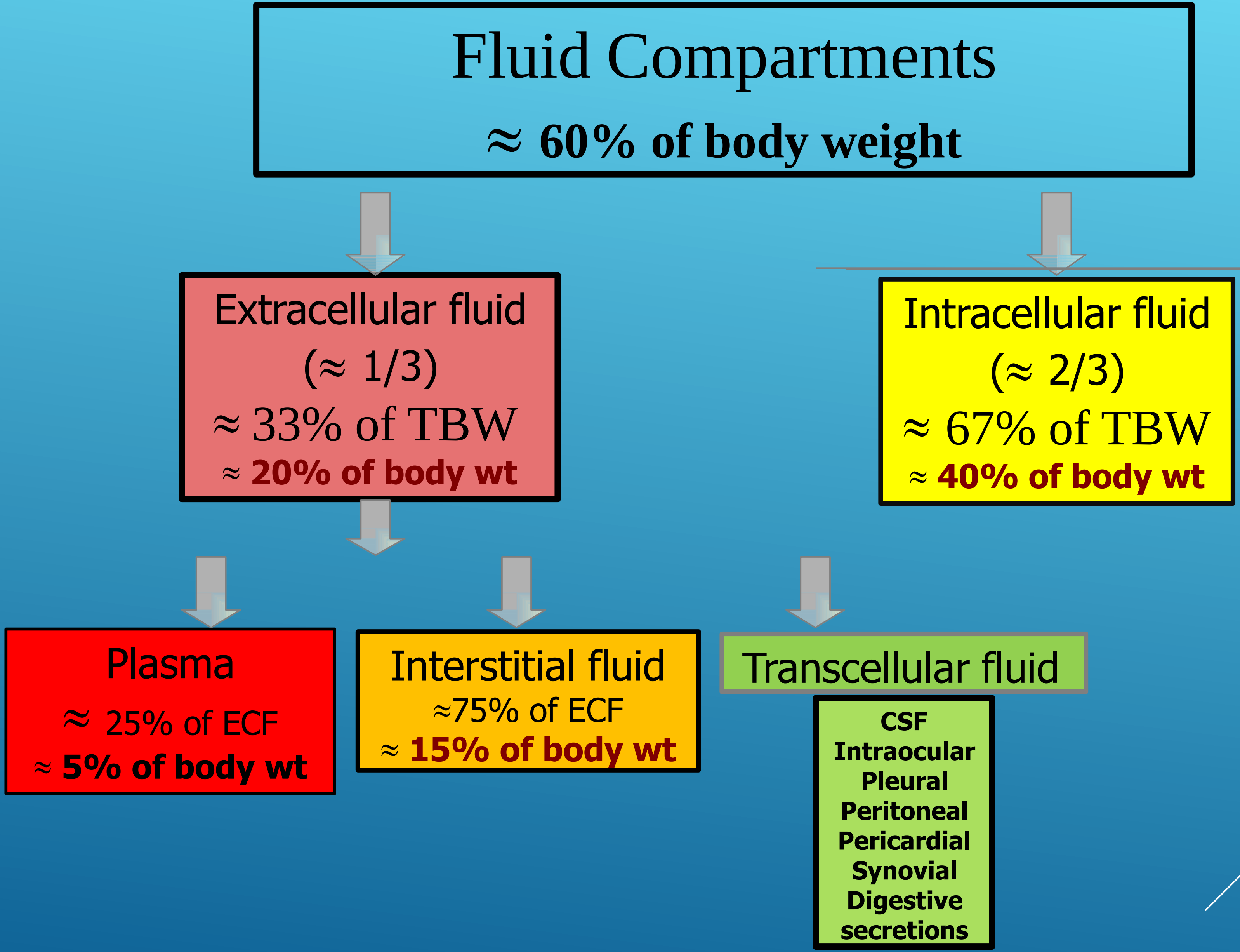

Cell
Interstitial fluid
Blood
vessel
Plasma
Extracellular fluid

FIGURE 1-2



Fluid Compartments
≈ 60% of body weight
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

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

DIFFERENCES BETWEEN ECF & ICF

ECF		ICF	
Cations:	**Anions:**	**Cations:**	**Anions:**
Na^+ (142 mmol/L)	**Cl^-** (108)	Na^+ (14)	Cl^- (4)
K^+ (4.2)	**HCO_3^-** (24)	**K^+** (140)	HCO_3^- (10)
Mg^{2+} (0.8)		**Mg^{2+}** (20)	**Phosphate ions**
Nutrients: O_2, glucose, fatty acids, & amino acids.		**Nutrients:** High concentrations of proteins.	
Wastes: CO_2, Urea, uric acid, excess water, & ions.			

COMPOSITION OF BODY FLUIDS

CATIONS (mmol/l)	Plasma	Interstitial	Intracellular
Na	142	139	14
K	4.2	4.0	140
Ca	1.3	1.2	0
Mg	0.8	0.7	20
ANIONS (mmol/l)			
Cl	108	108	4.0
HCO3	24.0	28.3	10
Protein	1.2	0.2	4.0
HPO4	2.0	2.0	11

EXTRACELLULAR 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 FLUIDS

- Intracellular fluids have low sodium and chloride
  - Potassium is the chief cation
  - Phosphate is the chief anion

BODY FLUIDS

- Several principles control the distribution of water between the various fluid compartments.
- It is essential to understand ingestion and excretion of water and electrolytes are under tight regulation to maintain consistent total body water (TBW) and total body osmolarity (TBO).
- To manage these two parameters, body water will redistribute itself to maintain **a steady-state so that the osmolarity of all bodily fluid compartments is identical to total body osmolarity**.

IMPORTANCE

- Maintaining ECF volume is critical to maintaining blood pressure and body functions
- ECF Osmolarity is of primary importance in long-term regulation of ECF volume
- ECF Osmolarity maintained mainly by NaCl balance:
- intake: 10.5g/d output: 10g/d in urine

BASIC DEFINITIONS

- At steady state, TBW content and salt content remain constant.
- An increase or decrease in water and salt intake is paralleled by an equivalent change in renal water and salt excretion.
- Homeostasis is by glomerular filtration of plasma to produce an ultrafiltrate, tubules process ultrafiltrate so that the final urine flow rate and solute excretion meet the homeostatic needs of the body.

BASIC DEFINITIONS

- Osmolality and osmolarity are measurements of the solute concentration of a solution.
- In practice, there is negligible difference between the absolute values of the different measurements.
- For this reason, both terms are often used interchangeably, even though they refer to different units of measurement.

OSMOLALITY

- Osmolality is an estimation of the osmolar concentration of plasma **and is proportional to the number of particles per kilogram of solvent;**
- it is expressed as mOsmol/kg (the SI unit is mmol/kg but mOsmol/kg is still widely used).
- The normal osmolality of extracellular fluid is **280-295 mOsmol/kg.**
- Number of osmoles per unit of total weight of solvent (mOsm/kg H_2O)
- (NOT AFFECTED BY THE VOLUME OF SOLUTES IN SOLUTION)

OSMOLARITY

- Osmolarity is an estimation of the osmolar concentration of plasma and **is proportional to the number of particles per litre of solution;** it is expressed as mmol/L.
- It is derived from the measured Na+, K+, urea and glucose concentrations.
- The osmolarity is unreliable in various conditions - eg, pseudohyponatraemia such as hyperlipidaemia in nephrotic syndrome, or hyperproteinaemia.

OSMOLARITY

- The following equations can be used to calculate osmolarity:
- Calculated osmolarity = 2 (135-140mmol Na^+) + 2 (5mmol K^+) + 1 (5mmol Glucose) + 1 (5mmol Urea) (all in mmol/L); OR
- Calculated osmolarity = 2 (Na^+) + Glucose + Urea (all in mmol/L).
- The doubling of sodium accounts for the negative ions associated with sodium and the exclusion of potassium approximately allows for the incomplete dissociation of sodium chloride.

BASIC DEFINITIONS

Tonicity	Osmolality
Physiological term (effective Os P relative to plasma) Solutes that do not cross the cell membrane only counts	Chemical term All solutes contributes to Osmolality
2 x Na^+ + Glucose 285 mOsm/kg	Na^+ x 2 + glucose + BUN 290 mOsm/kg

OSMOTIC GAP

- The osmotic gap (also called osmolal gap) is an arbitrary measure of the difference between the actual osmolality (measured by the laboratory) and the calculated osmolality.
- It is normally less than 10-15 mOsmol/kg
- Where the osmotic gap is increased, it indicates the presence of other osmotically active solutes which are not taken into account in the calculated osmolality - eg, in methanol or ethylene glycol ingestion.

CLINICAL RELEVANCE OF OSMOLALITY

- Cell membranes in general are freely permeable to water, the osmolality of the extracellular fluid (ECF) is approximately equal to that of the intracellular fluid (ICF). Therefore, plasma osmolality is a guide to intracellular osmolality.
- This is important, as it shows that changes in ECF osmolality have a great affect on ICF osmolality - changes that can cause problems with normal cell functioning and volume (may even induce cytolysis).

CLINICAL RELEVANCE OF OSMOLALITY

- Increased osmolality in the blood will stimulate secretion of antidiuretic hormone (ADH). This will result in increased water reabsorption, more concentrated urine and less concentrated blood plasma.
- Diabetes insipidus is a condition caused by hyposecretion of, or insensitivity to, the effects of ADH. Elevation may be associated with stroke mortality.

CLINICAL RELEVANCE OF OSMOLALITY

- A low serum osmolality will suppress the release of ADH, resulting in decreased water reabsorption and more concentrated plasma.
- An increase of only 2% to 3% in plasma osmolality will produce a strong desire to drink. A change of 10% to 15% in blood volume and arterial pressure is required to produce the same response.

VOLUME OF BODY FLUIDS IN 70 KG MAN

TOTAL VOLUME

42 L

INTRA CELLUAR FLUID
28 L(ROUGHLY 2/3 OF TBW)

EXTRA CELLULAR FLUID
14 L(ROUGHLY 1/3 OF TBW)

PLASMA
4 L (ROUGHLY ¼ OF ECF)

VOLUME MEASUREMENT OF VARIOUS FLUIDS COMPARTMETNS

INTERSTITIAL FLUID

ECF – Plasma Volume

INTRACELLULAR FLUID

TBW – ECF

FACTORS AFFECTING TBW

- **Physiological**
  - **Adipose Tissue**
  - **Sex**
  - **Age**
- **Pathological**
  - **Dehydration**
  - **Overhydration**

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 with fluid replacement (orally, or IV).

DISORDERS OF WATER BALANCE: HYPOTONIC HYDRATION

- Renal insufficiency or an extraordinary amount of water ingested quickly can lead to cellular overhydration, or water intoxication
- ECF is diluted – sodium content is normal but excess water is present
- The resulting hyponatremia promotes net osmosis into tissue cells, causing swelling
- These events must be quickly reversed to prevent severe metabolic disturbances, particularly in neurons

DISORDERS OF WATER BALANCE: EDEMA

- Atypical accumulation of fluid in the interstitial space, leading to tissue swelling
- Factors that accelerate fluid loss include:
  - Increased blood pressure, capillary permeability
  - Incompetent venous valves, localized blood vessel blockage
  - Congestive heart failure, hypertension, high blood volume.
  - Hindered fluid return usually reflects an imbalance in colloid osmotic pressures.
  - Hypoproteinemia – low levels of plasma proteins

REGULATION OF ECF VOLUME

- Mechanisms
  - Neural
  - Renin-angiotensin-aldosterone
  - Atrial natriuretic hormone (ANH)
  - Antidiuretic hormone (ADH)

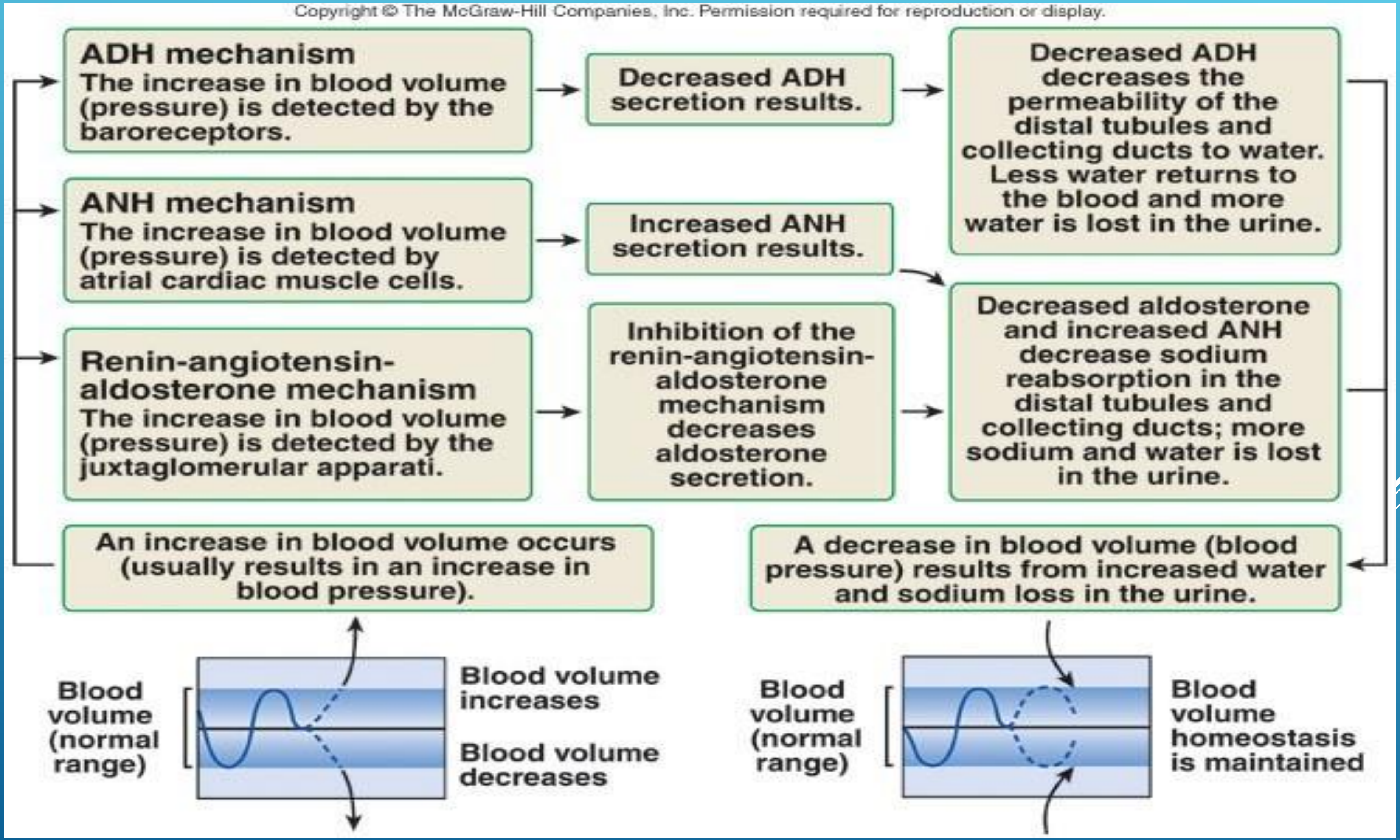
- Increased ECF results in
  - Decreased aldosterone secretion
  - Increased ANH secretion
  - Decreased ADH secretion
  - Decreased sympathetic stimulation
- Decreased ECF results in
  - Increased aldosterone secretion
  - Decreased ANH secretion
  - Increased ADH secretion
  - Increased sympathetic stimulation

ECF VOLUME RECEPTORS

- “Central vascular sensors
  - *Low pressure (very important)*
    - Cardiac atria
    - Pulmonary vasculature
  - *High pressure (less important)*
    - Carotid sinus
    - Aortic arch
    - Juxtaglomerular apparatus (renal afferent arteriole)
- Sensors in the CNS (less important)
- Sensors in the liver (less important)

N.B. Regulation of ECF volume = Regulation of body Na^+. Thus, regulation of Na^+ also dependent upon baroreceptors.

HORMONAL REGULATION OF BLOOD VOLUME



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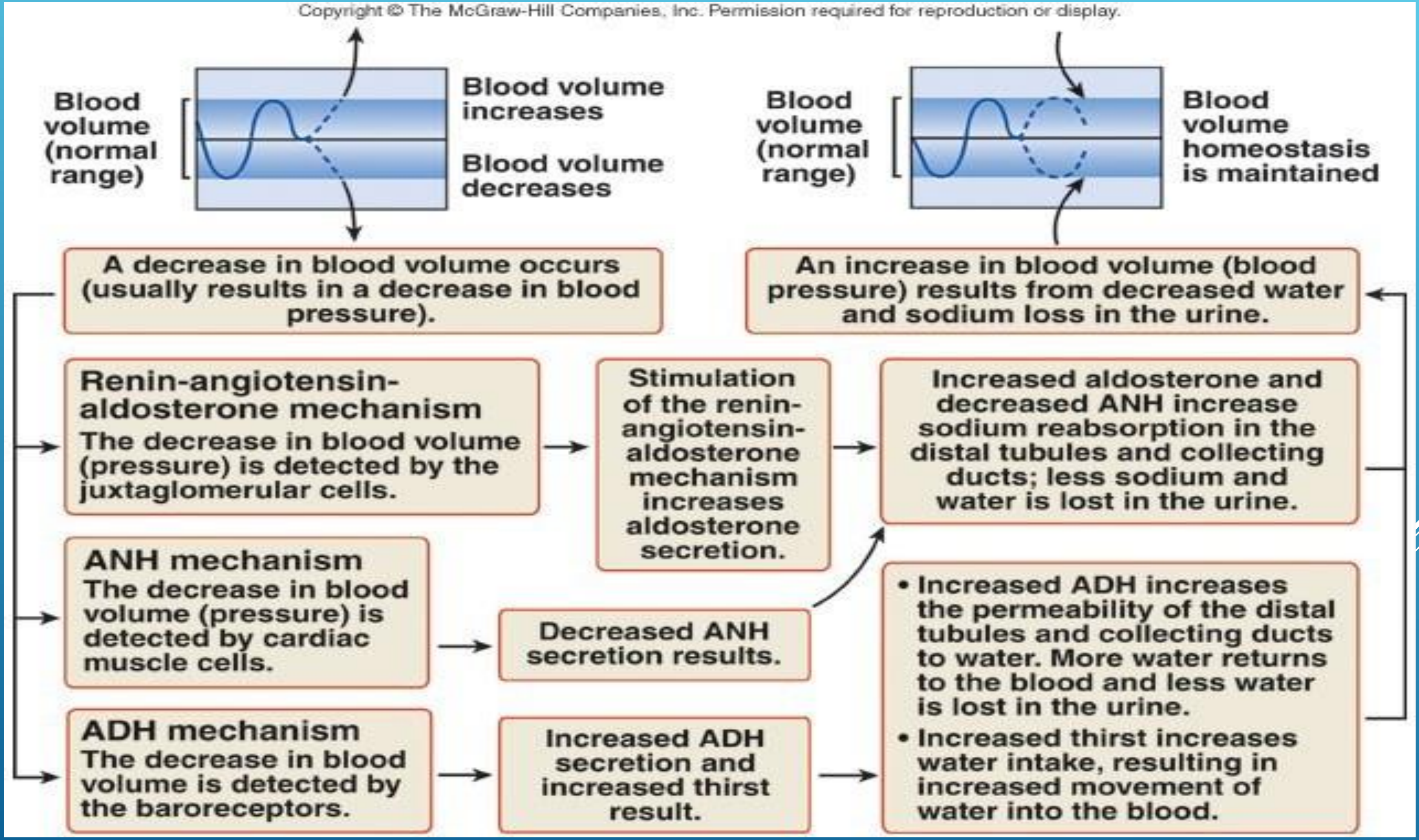
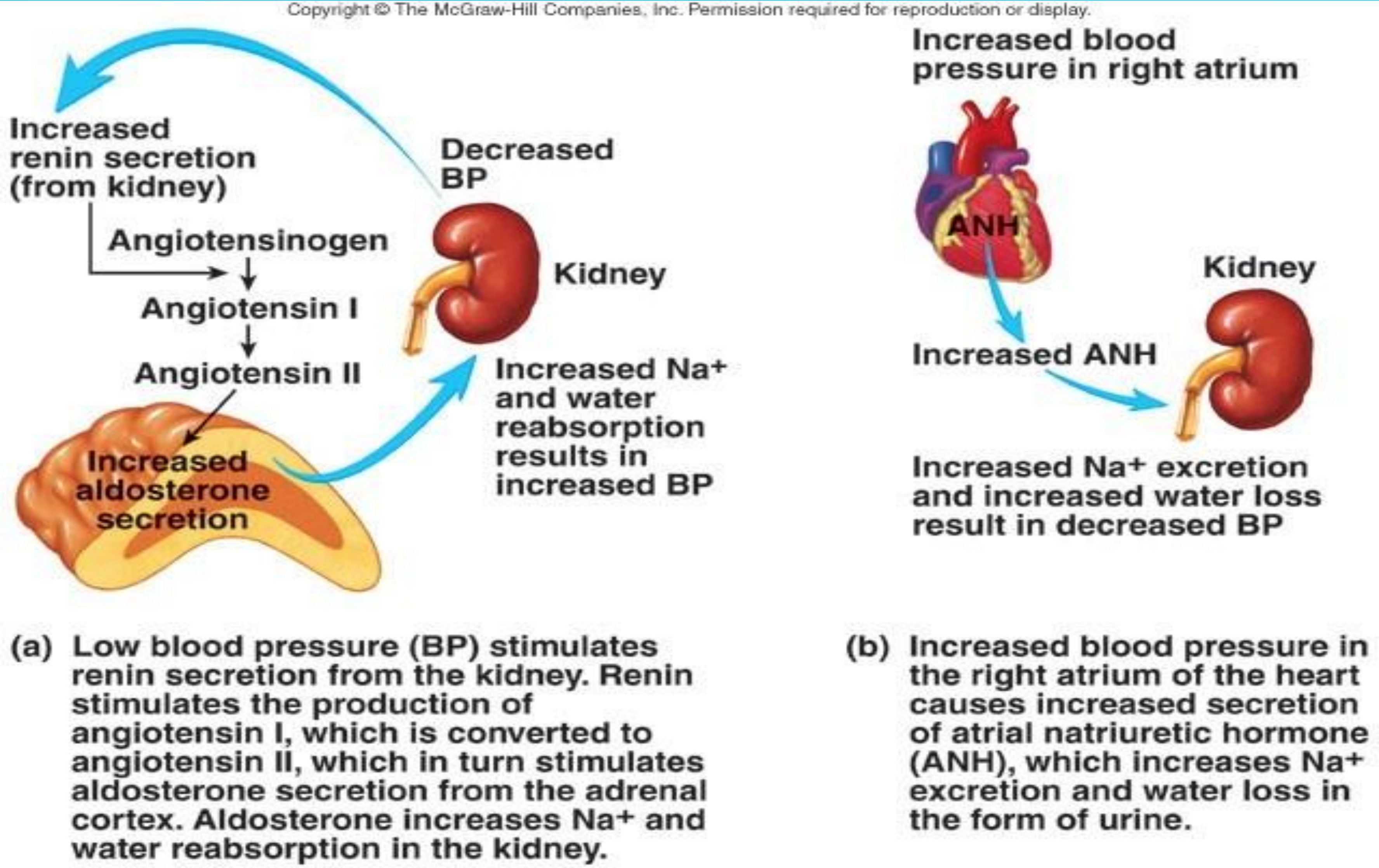


REGULATION OF ECF VOLUME



REGULATION OF WATER INTAKE

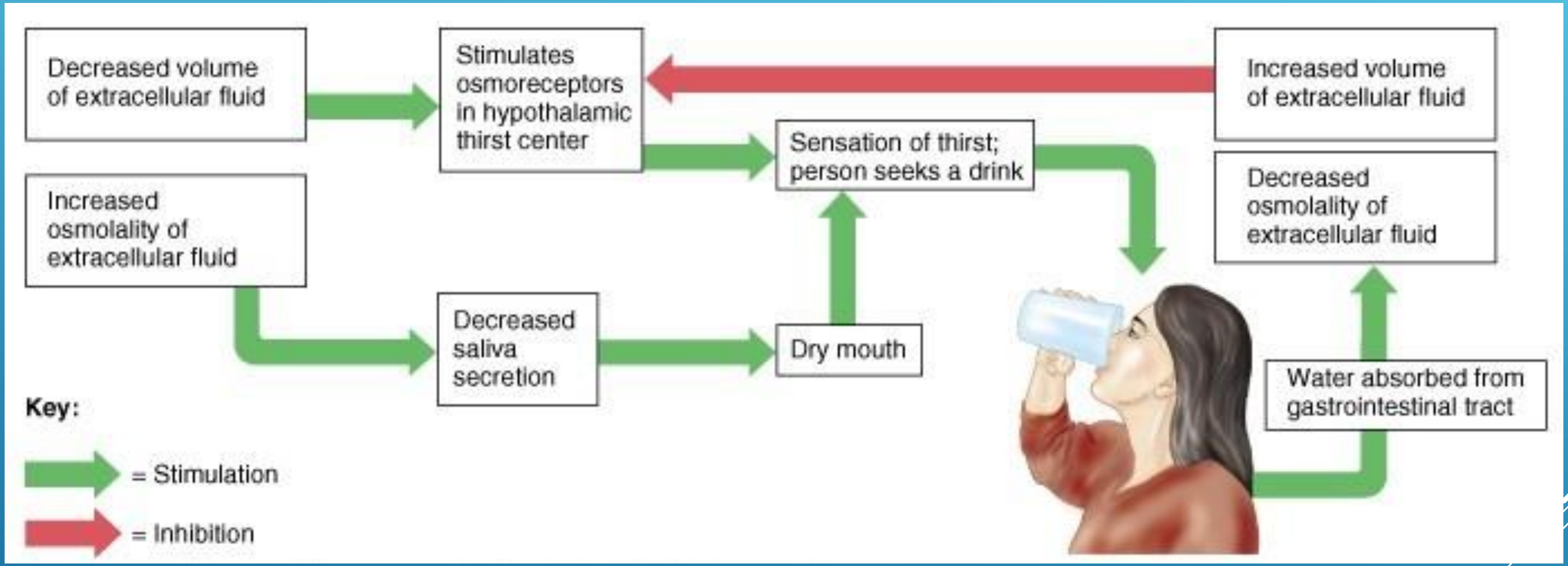


Figure 27.5

THANKS