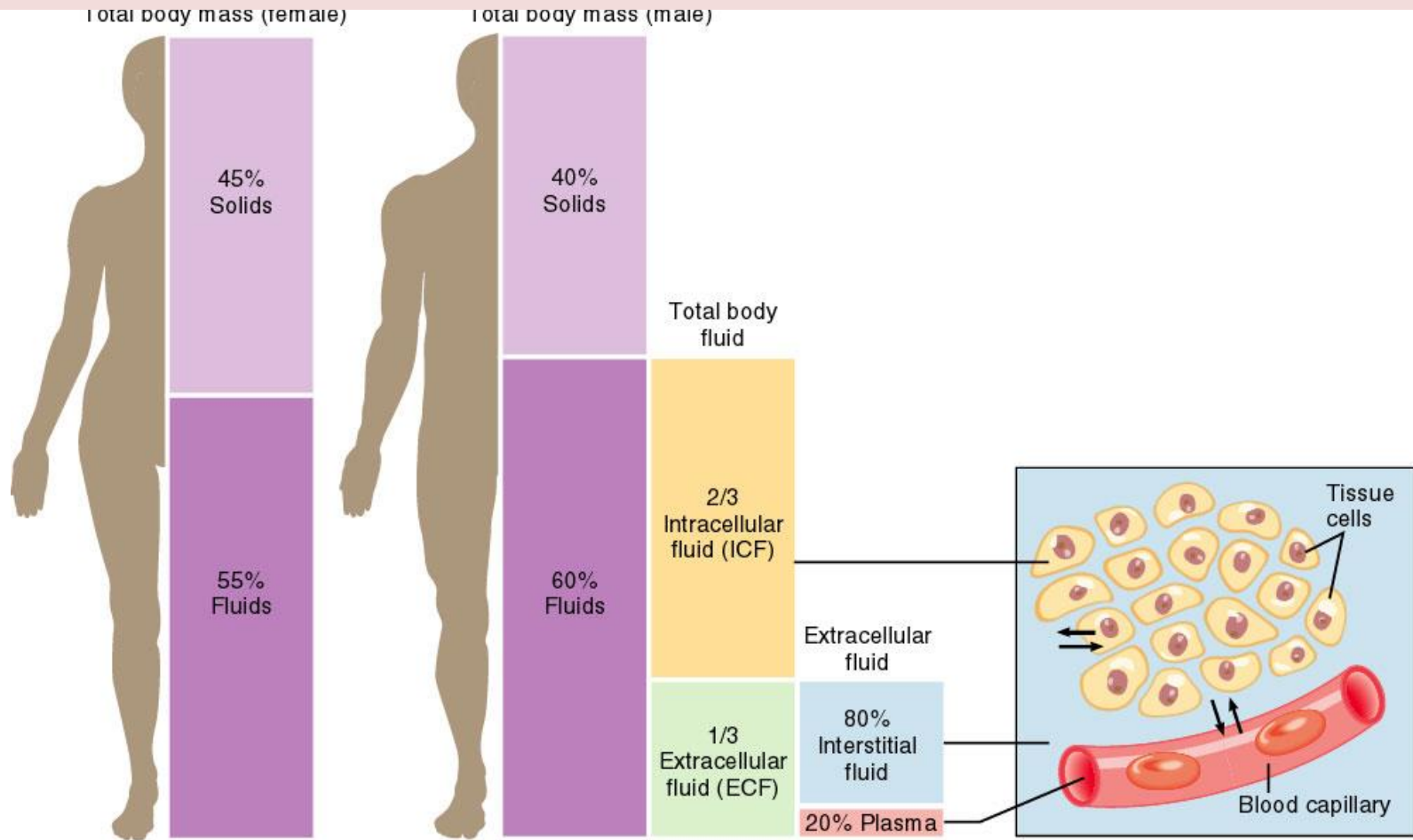


Body Fluids

Ref: Textbook of Medical Physiology
Guyton and Hall, 13th Edition 303-
321, 12th Edition
Pages: 285-297

Fluid Compartments



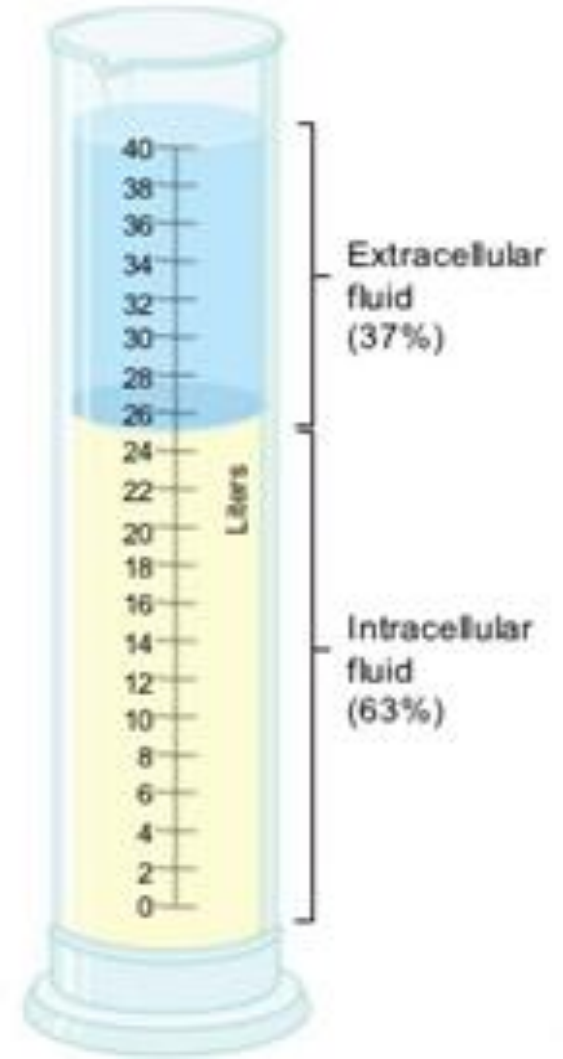
(a) Distribution of body solids and fluids in an average lean, adult female and male

(b) Exchange of water among body fluid compartments

Fluid Compartments

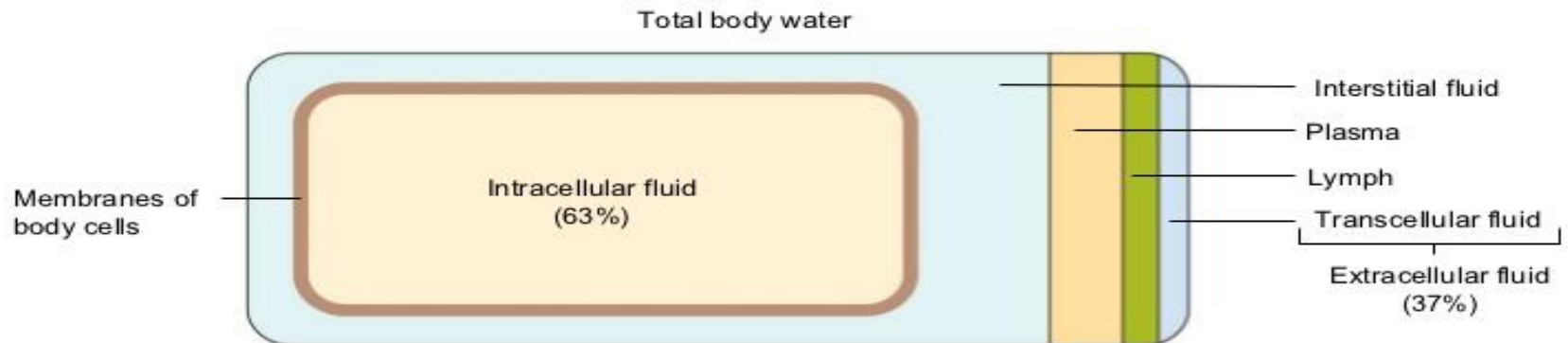
- Of the 40 liters of water in the body of an average adult, about two-thirds is intracellular fluid and one-third is extracellular fluid
- An average adult female is about 52% water by weight, and an average male about 63% water by weight

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Water Distribution

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Water Distribution

Transcellular Fluids

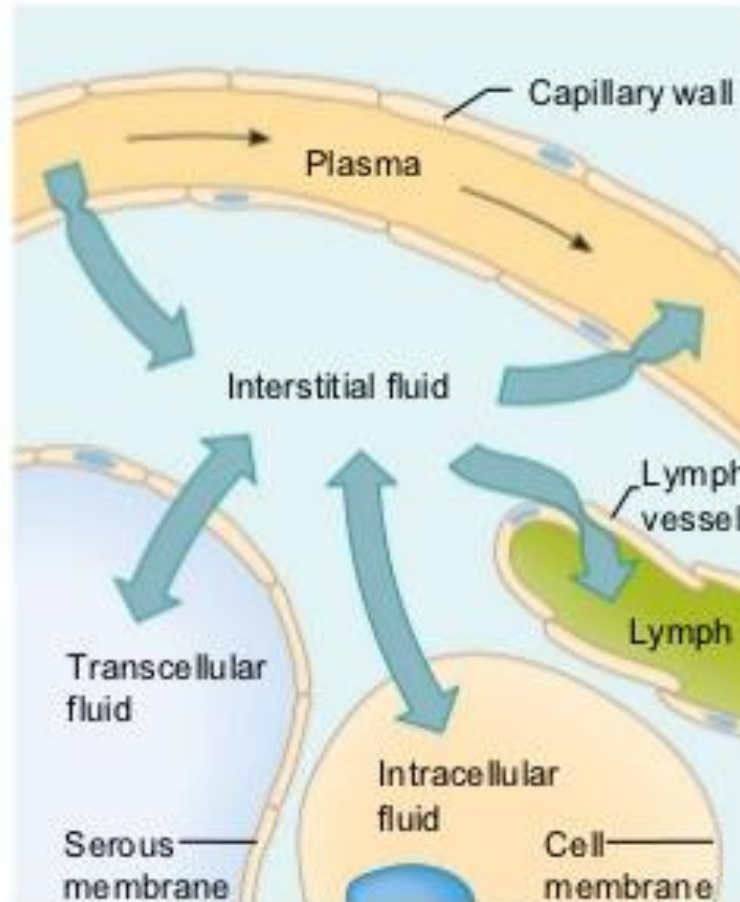
- Synovial
- Pericardial
- Pleural
- Peritoneal
- Ocular
- Cerebrospinal

Movement of Fluids between Compartments

Major factors that regulate movements:

- Osmotic pressure
- Hydrostatic pressure

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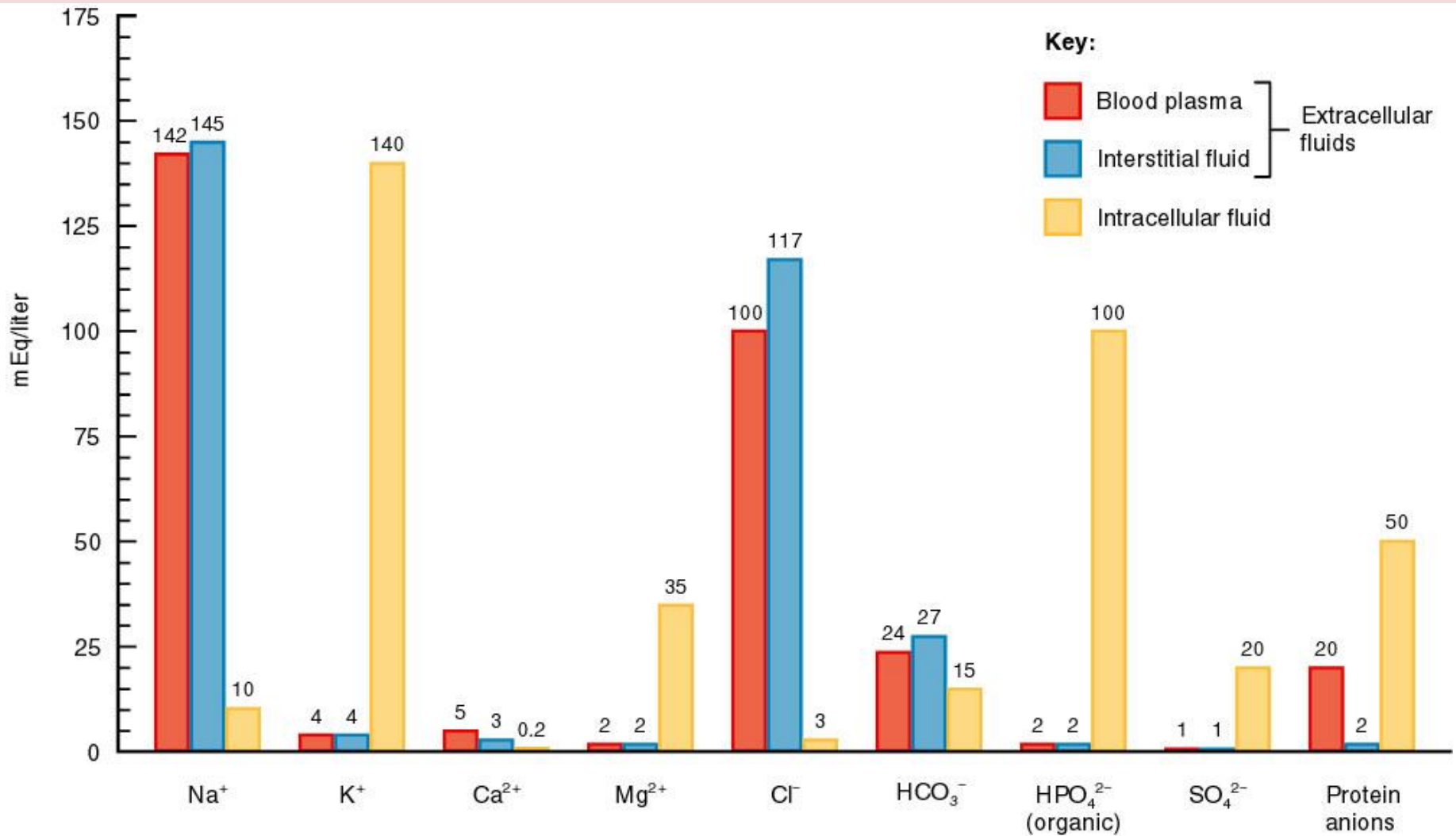
Fluid leaves plasma at arteriolar end of capillaries because outward force of hydrostatic pressure predominates

Fluid returns to plasma at venular ends of capillaries because inward force of colloid osmotic pressure predominates

Hydrostatic pressure within interstitial spaces forces fluid into lymph capillaries

Interstitial fluid is in equilibrium with transcellular and intracellular fluids

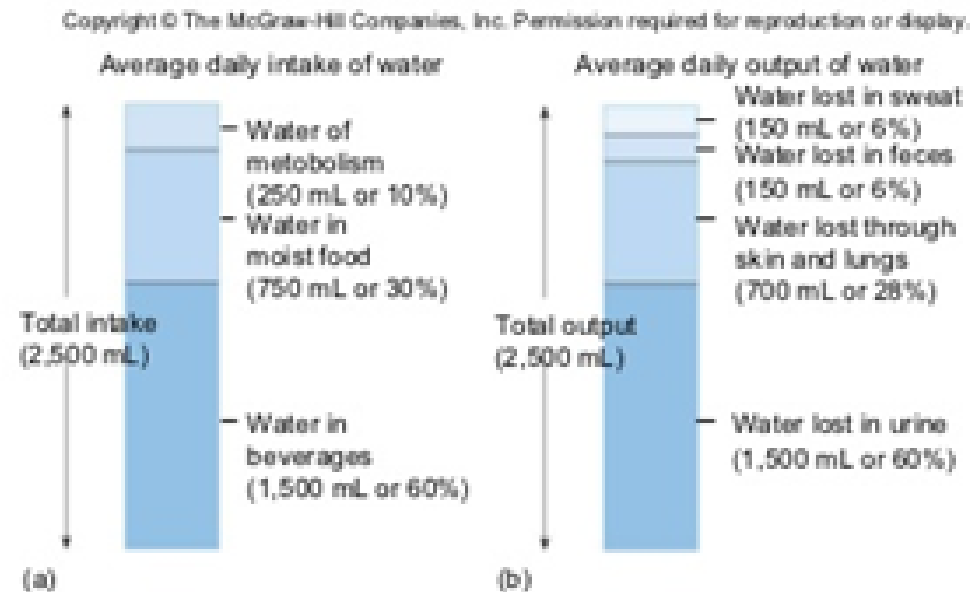
Composition of Body Fluids



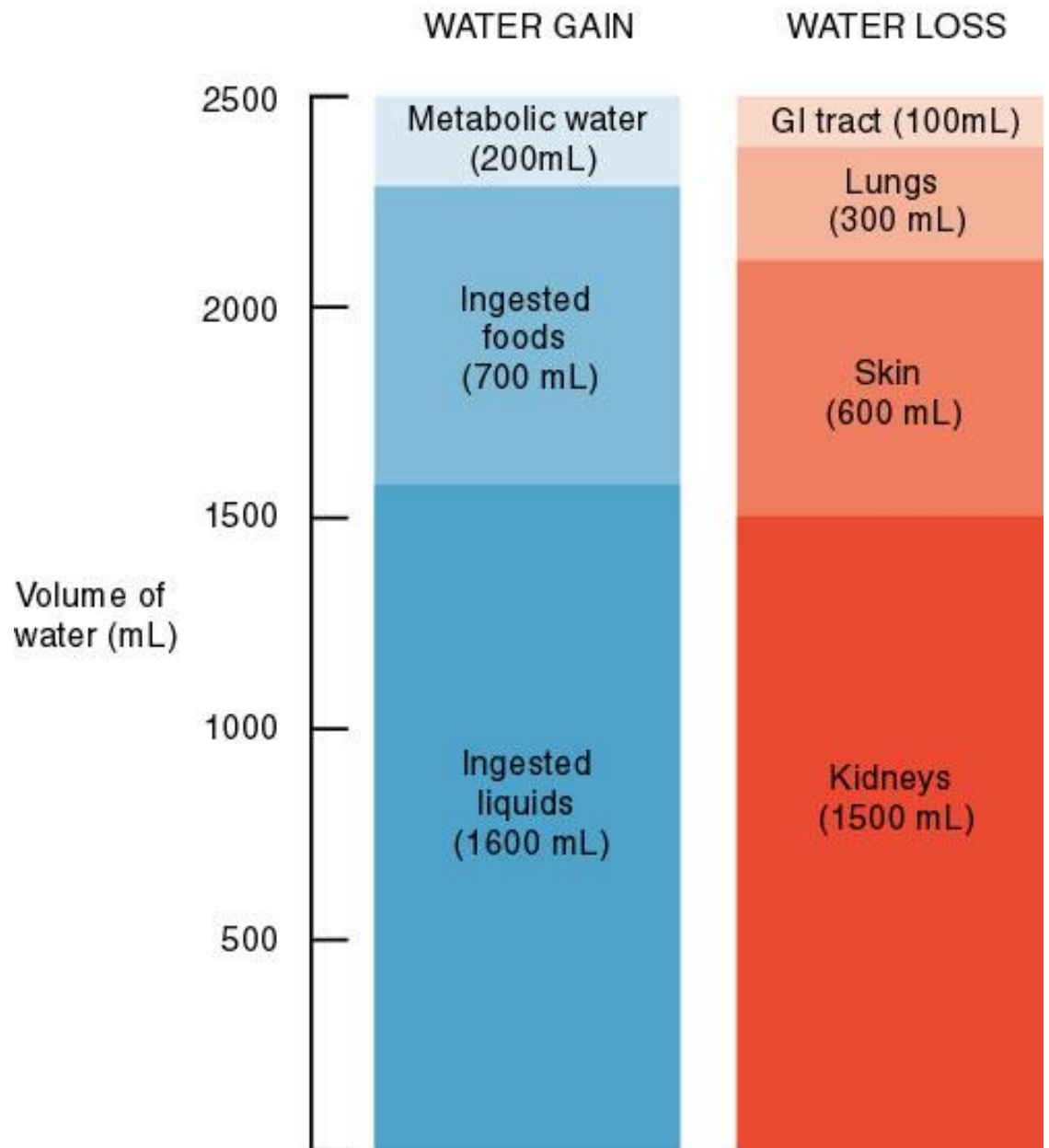
Water Inputs

- The volume of water gained each day varies among individuals averaging about 2,500 milliliters daily for an adult:

- 60% from drinking
- 30% from moist foods
- 10% as a bi-product of oxidative metabolism of nutrients called water of metabolism



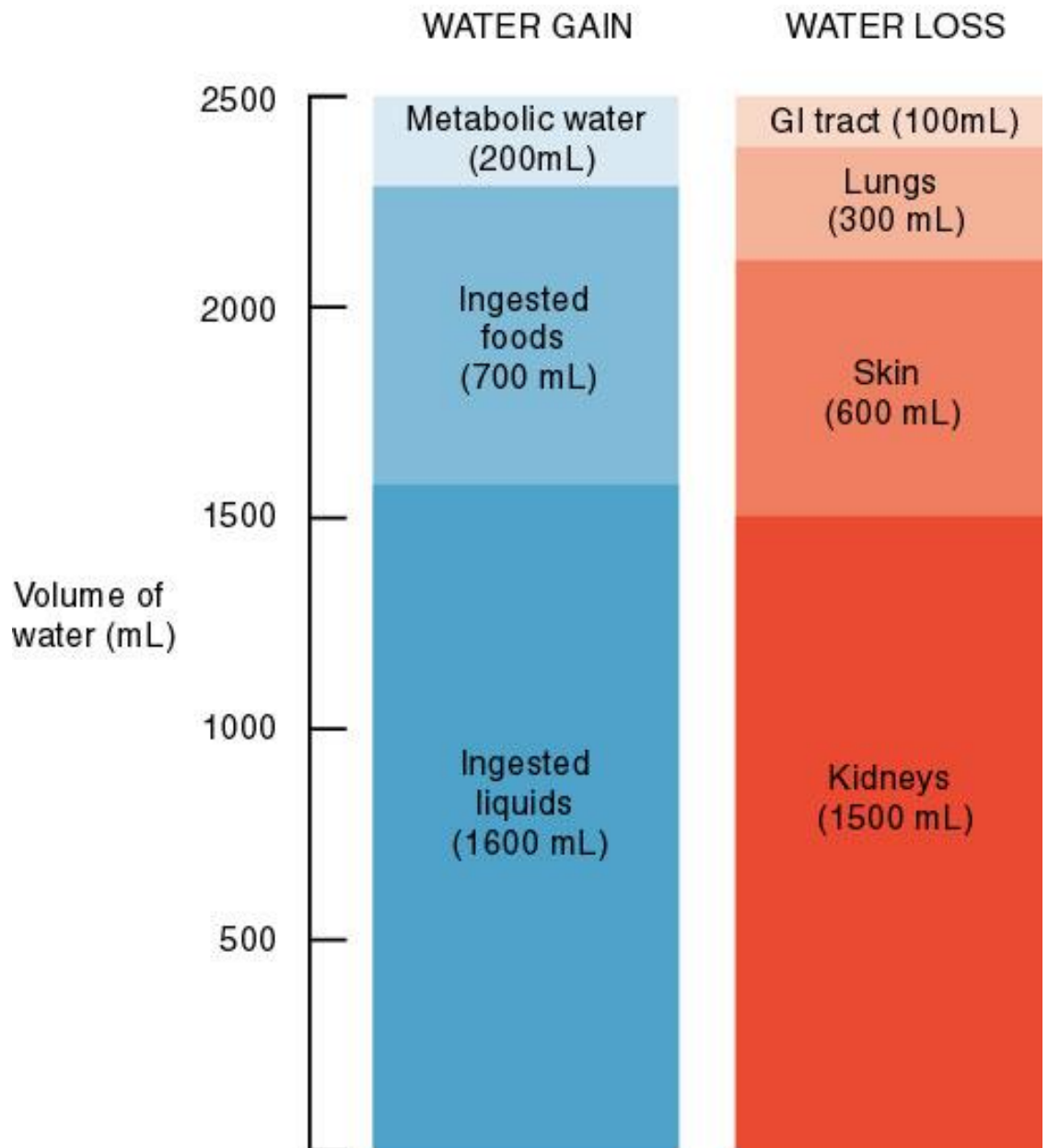
Water Balance



Water Output

- Water normally enters the body only through the mouth, but it can be lost by a variety of routes including:
 - Urine (60% loss)
 - Feces (6% loss)
 - Sweat (sensible perspiration) (6% loss)
 - Evaporation from the skin (insensible perspiration)
 - The lungs during breathing(Evaporation from the skin and the lungs is a 28% loss)

Water Balance



Water and Electrolytes Homeostasis

Systems involved in the regulation of fluids and electrolytes

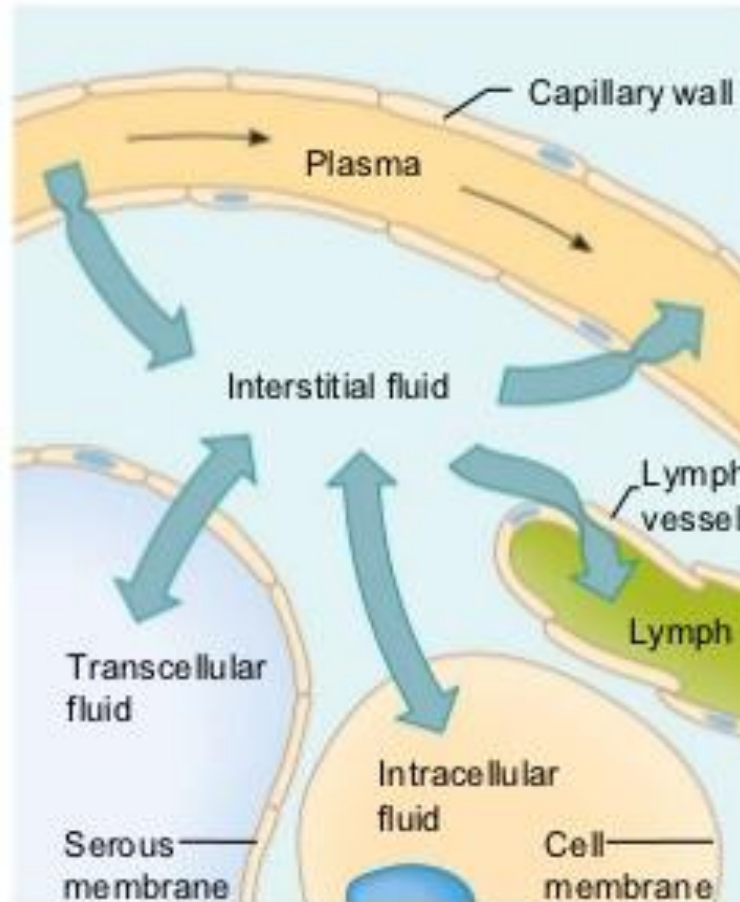
- Kidneys,
- Cardiovascular system,
- Endocrine (Pituitary, Parathyroids, Adrenal glands)
- Lungs

Movement of Fluids between Compartments

Major factors that regulate movements:

- Osmotic pressure
- Hydrostatic pressure

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Fluid leaves plasma at arteriolar end of capillaries because outward force of hydrostatic pressure predominates

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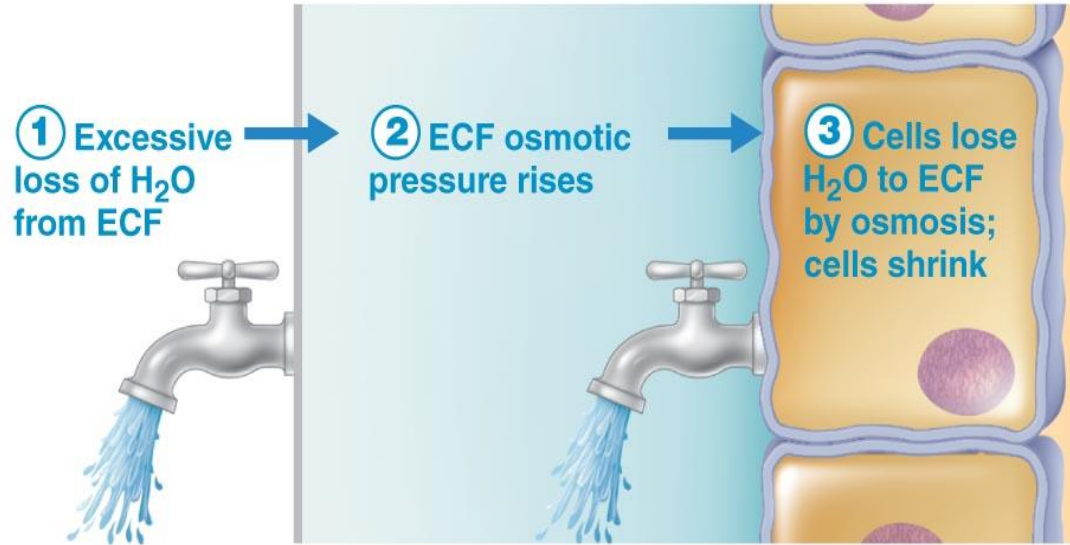
Interstitial fluid is in equilibrium with transcellular and intracellular fluids

Regulation of Na⁺ and Water

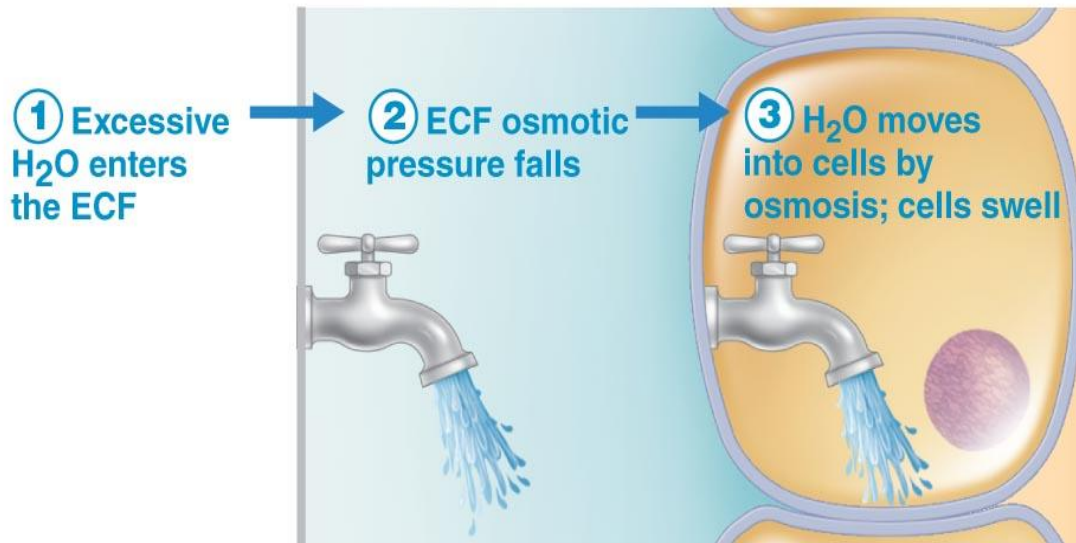
**Involves
regulation
of:**

- Osmolality
 - Volume of ECF
- different regulations
with many
overlapping
mechanisms.

Importance of Na⁺ and Water regulation

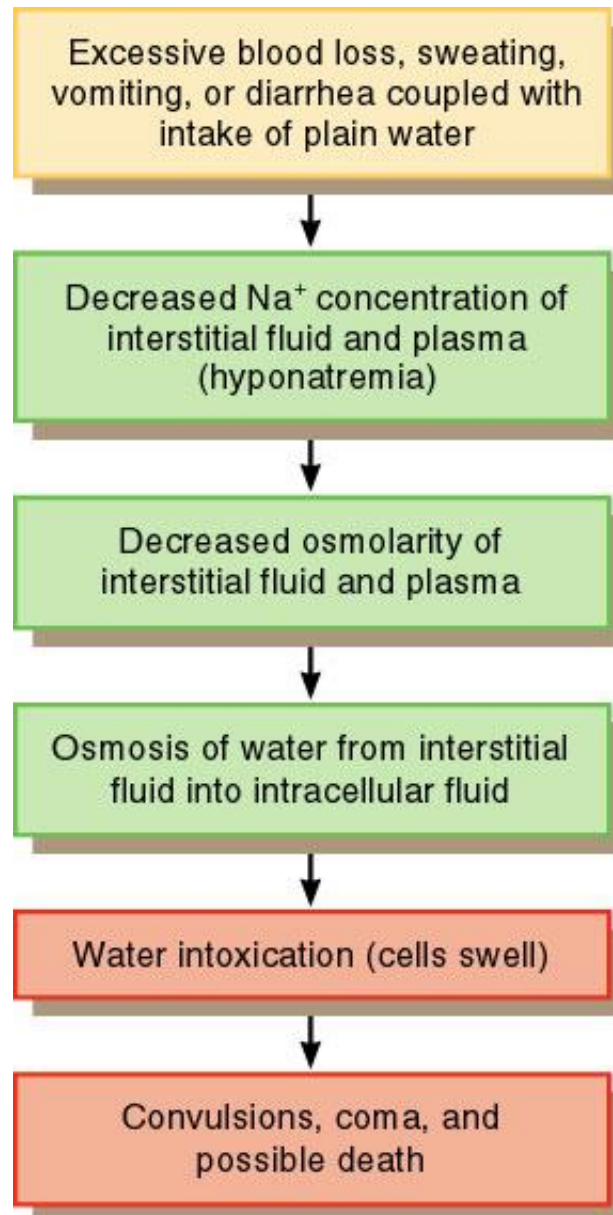


(a) Consequences of dehydration. If more water than solutes is lost, cells shrink.



(b) Consequences of hypotonic hydration (water gain). If more water than solutes is gained, cells swell.

Fig. 27.05



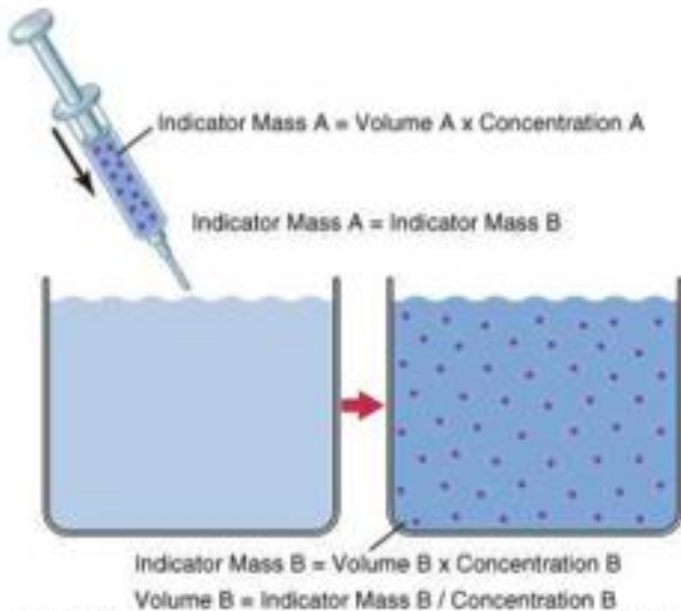
Measurements of Body Fluids

Measuring Body Fluids

Dilution Principle

Dilution method for calculating fluid volume

25-4



$$\text{Volume B} = \frac{\text{Volume A} \times \text{Concentration A}}{\text{Concentration B}}$$

If 1 ml of a 10mg/ml solution is injected into a fluid compartment, and the final concentration is 0.01mg/ml, the volume of the fluid compartment is,

$$\text{Volume B} = \frac{1 \text{ ml} \times 10 \text{ mg/ml}}{0.01 \text{ mg/ml}} = 1000 \text{ ml}$$

Properties of tracers used for calculation of volumes

- Properties of an Ideal Tracer The tracer should:
- be nontoxic
- be rapidly and evenly distributed throughout the nominated compartment not enter any other compartment.
- not be metabolized.
- not be excreted (or excretion is able to be corrected for) during the equilibration period
- be easy to measure
- not interfere with body fluid distribution

Measurement of Total Body Water

* Radioactive water ($^3\text{H}_2\text{O}$, T_2O , Tritium) or heavy water ($^2\text{H}_2\text{O}$, D_2O , Deuterium).

This will mix with the total body water in just a few hours and the dilution method for calculation can be used.

* Antipyrine

Measurement of ECF volumes

- $^{22}\text{Na}^+$, (Sodium Space)
- ^{125}I -iothalamate,
- Thiosulfate,
- Inulin (Inulin Space)

(Measured in 30-60 minutes)

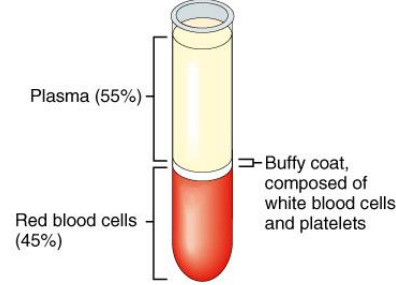
Calculation of ICF (Intra- Cellular Volume)

$$\text{ICF} = \text{Total Body water} - \text{ECF}$$

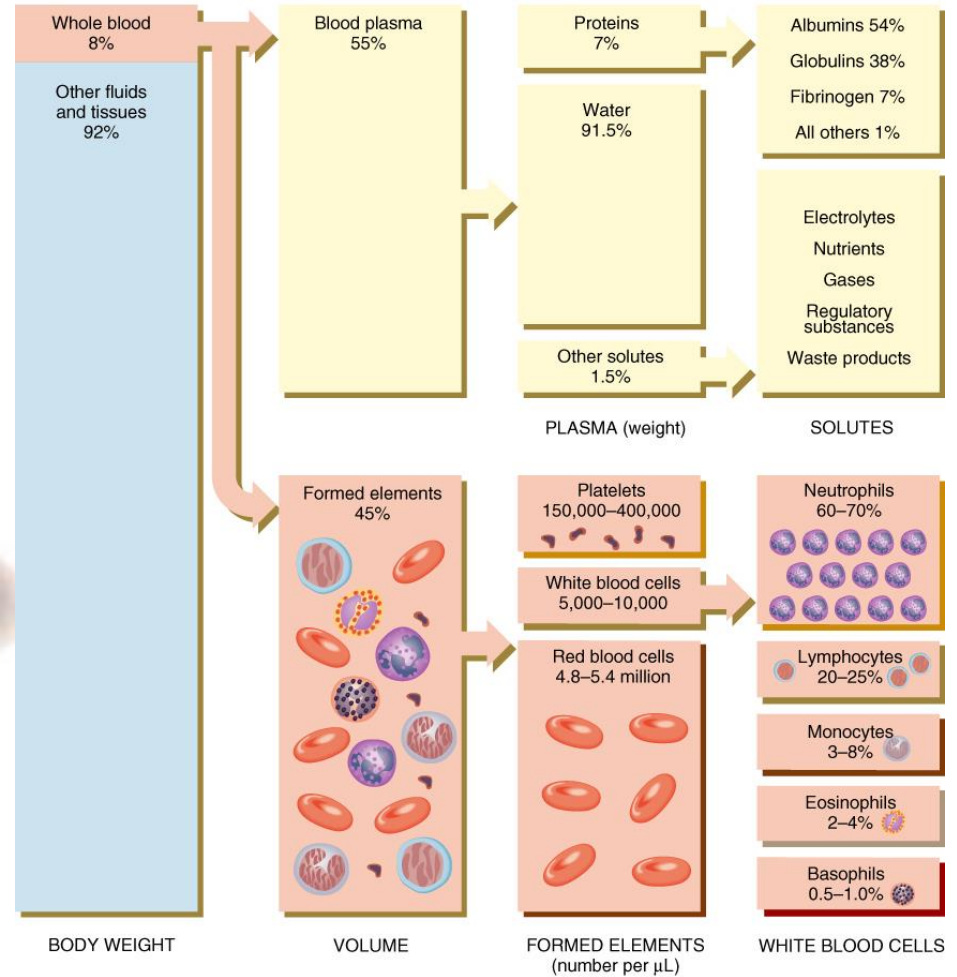
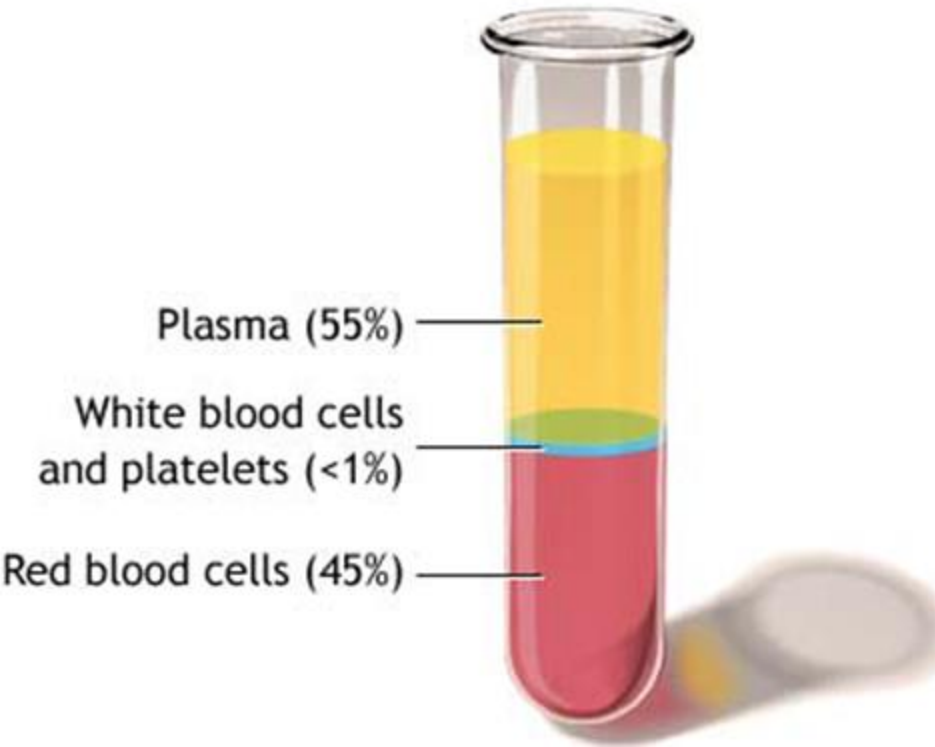
**Measurement
of Plasma
volumes**

**Measurement
of Total Blood
Volume**

Fig.19.01



(a) Appearance of centrifuged blood



(b) Components of blood

Plasma Composition

- **Water:** > 90%
- **Small molecule:** 2%, it is electrolytes, nutriment, metabolic products, hormone, enzymes, etc.
- **Protein:** 60-80 g/L, plasma protein include albumin (40-50 g/L)(54%), globulins (20-30 g/L, α_1 -, α_2 , β -, γ -) (38%) and fibrinogen (7%). Most of albumin and globulin made from liver.

Measurement of Plasma volumes

- * ^{125}I -Albumin (RISA),
- * Evans Blue (Dye (T1824))

Measurement of Total Blood Volume

- * ^{51}Cr -labeled Red Blood Cells
- * **Calculated As =**
Plasma Volume
1-Hematocrit

Body Fluids

Ref: Textbook of Medical Physiology
Guyton and Hall, 13th Ed: pp: 305-321
12th Ed.: pp: 285-297

Regulation of Fluid volumes and osmolality

Regulation of Na⁺ and Water

Involves regulation of:

- Osmolality
- Volume of ECF

different regulations with many overlapping mechanisms.

Regulation of Na⁺ and Water

Involves regulation of:

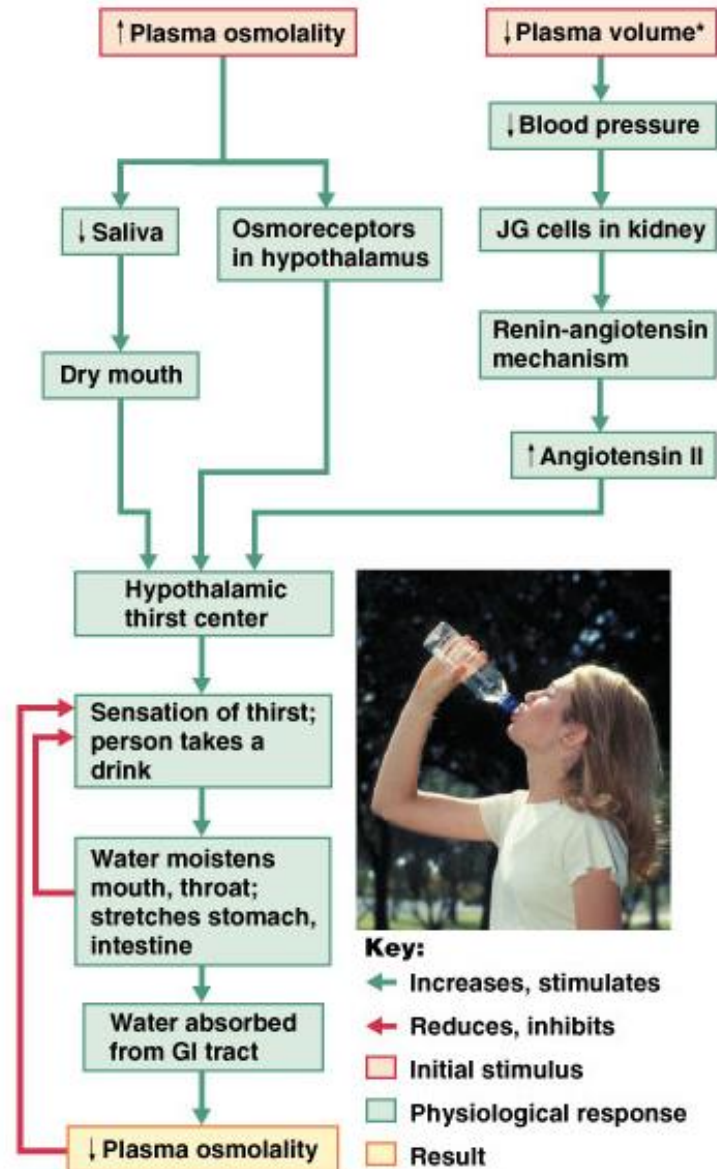
- Osmolality:

Osmoregulation

- Increased **osmolality** → thirst (**Increase** ↑ **water intake**).
- Increased **osmolality** → stimulates release of ADH --> acts on renal collecting ducts → increased water reabsorption (**Decrease** ↓ **water output**)
- **Volume of ECF**

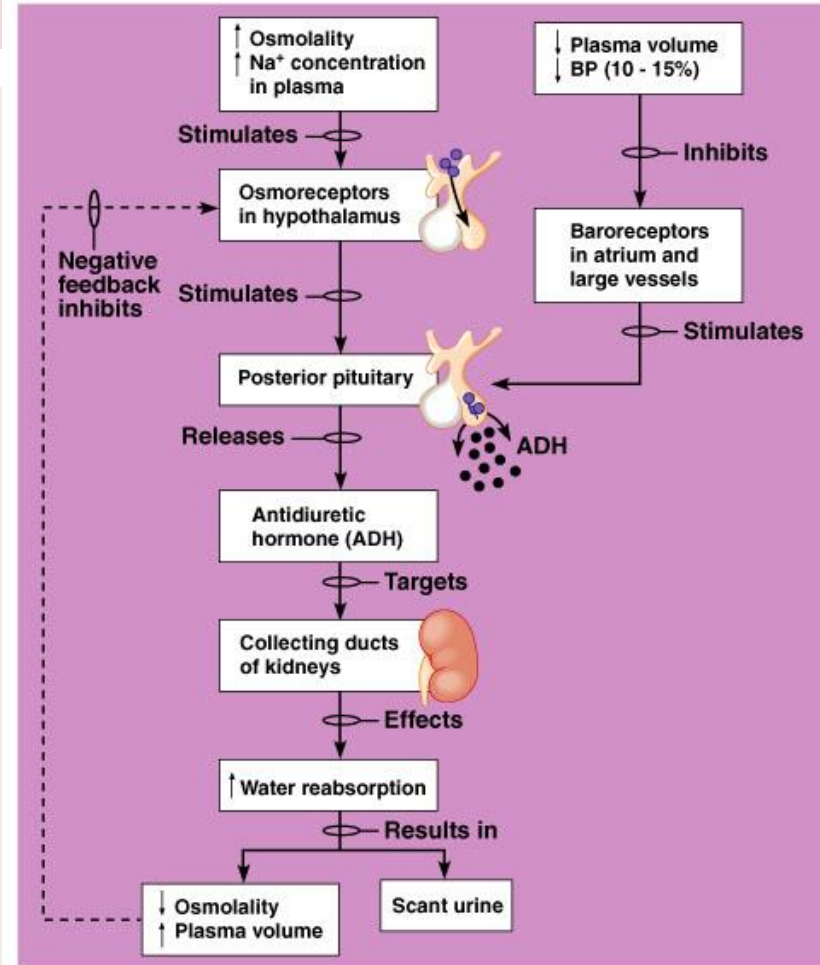
Body Water

- **Regulation of intake**
 - Regulated by hypothalamic “thirst center”
 - “Thirst center” responds to osmoreceptor impulses, angiotensin II



Body Water

- **Regulation of output**
 - Regulated by hypothalamus
 - ADH release from posterior pituitary



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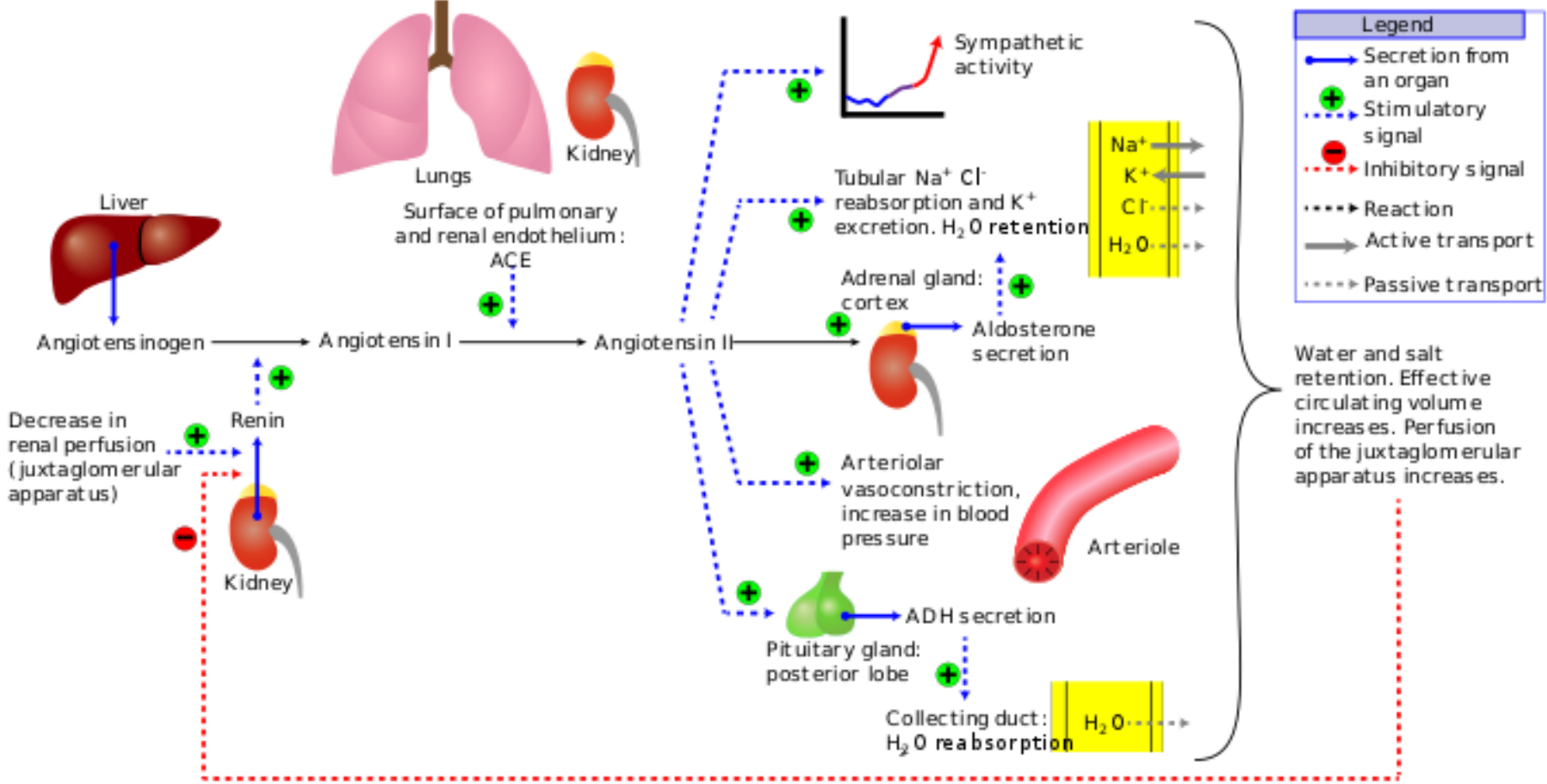
Regulation of Na⁺ and Water

Involves regulation of:

- **Osmolality:**
- **Volume of ECF:**
 - **Depends on Na⁺ excretion in urine.**
 - **Controlled by renin-angiotensin aldosterone system**

Reduced Volume → Juxtaglomerular Cells
(Kidney) release Renin → Angiotensinogen
→ Angiotensin I → Angiotensin II (Lung) →
Aldosterone

Renin-angiotensin-aldosterone system



Decrease in renal perfusion (juxtaglomerular apparatus)

Renin
Kidney

Angiotensin I

Angiotensin II

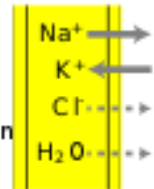
Sympathetic activity

Lungs
Surface of pulmonary and renal endothelium: ACE

Tubular Na^+ Cl^- reabsorption and K^+ excretion. H_2O retention

Adrenal gland: cortex
Aldosterone secretion

Arteriolar vasoconstriction, increase in blood pressure

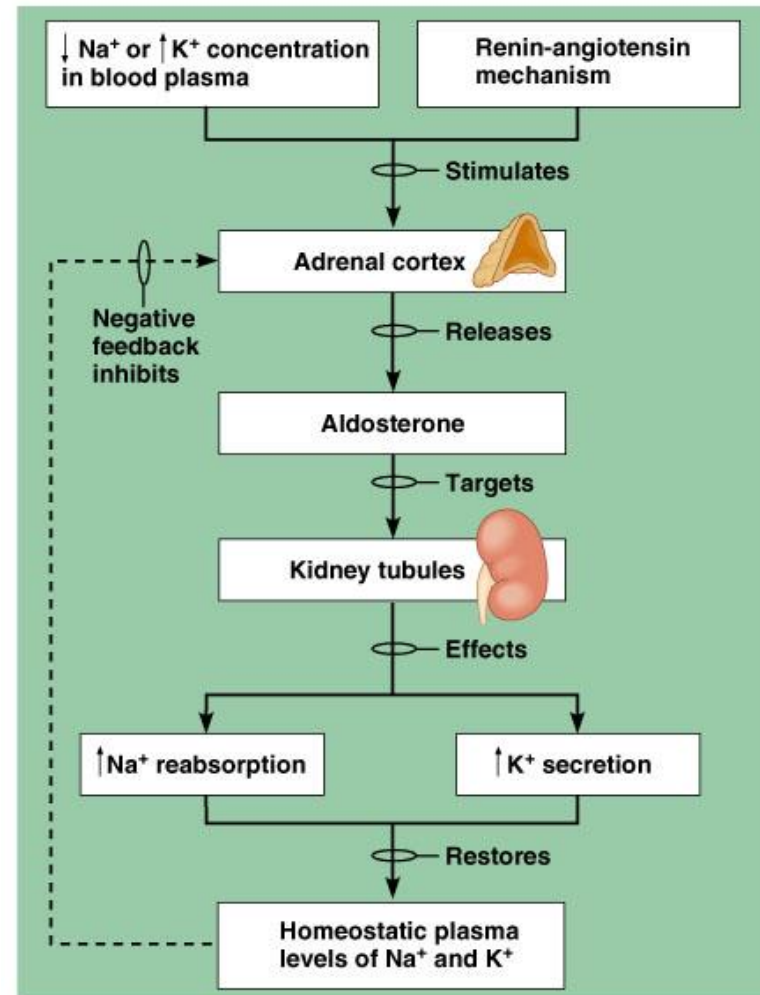


Pituitary gland: posterior lobe
ADH secretion

Collecting duct: H_2O reabsorption

Body Water

- **Regulation of output**
 - Regulated by renin-angiotensin mechanism
 - Angiotensin II stimulates aldosterone secretion

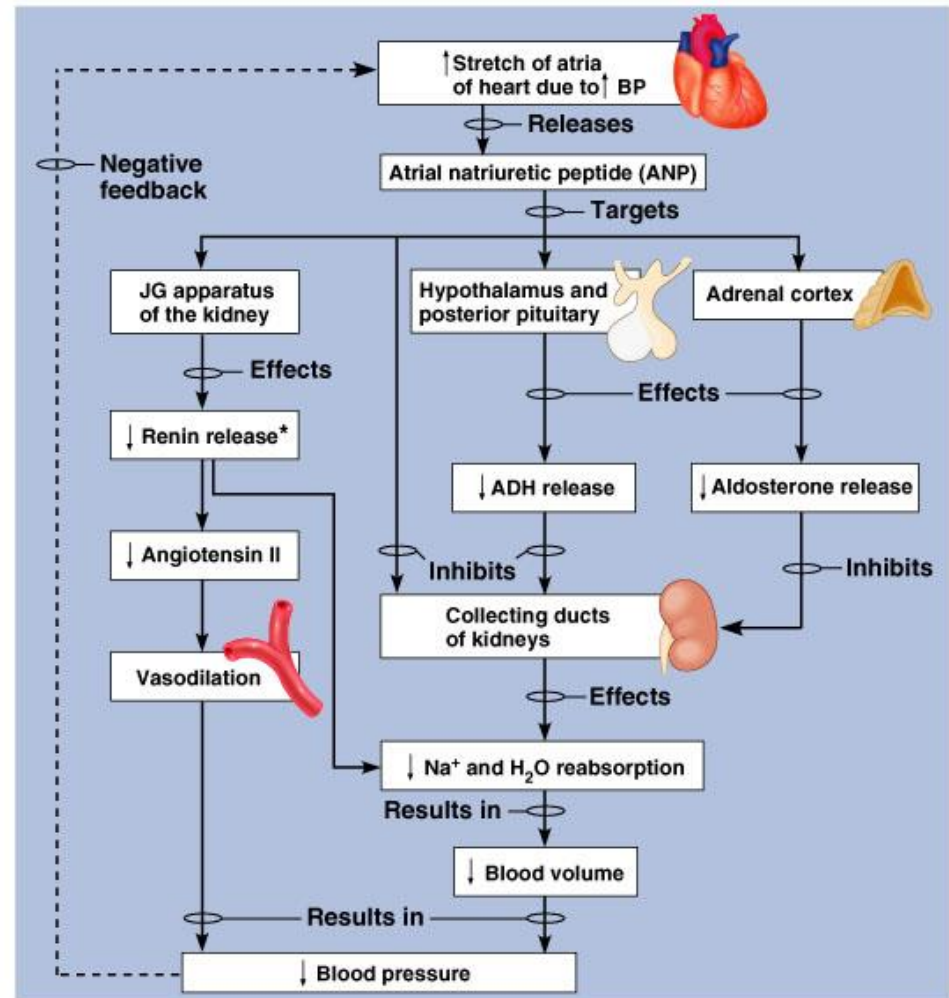


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Body Water

- **Regulation of output**
 - Regulated by atrial natriuretic peptide (ANP)

Effects: reduces BP, Salts and water by effects over vessels, decrease Angiotensin II, and Aldosterone secretions



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Disorders of Volumes

–Hypovolemia

Results by excessive loss of fluids

–Hypervolemia

Results by excessive intake or administration of fluids

Disorders of Osmolality

–Hyponatremia

Results by excessive loss of Na^+ or administration of hypotonic fluids.

–Hypernatremia

Results by excessive intake of Na^+ or administration of hypertonic fluids

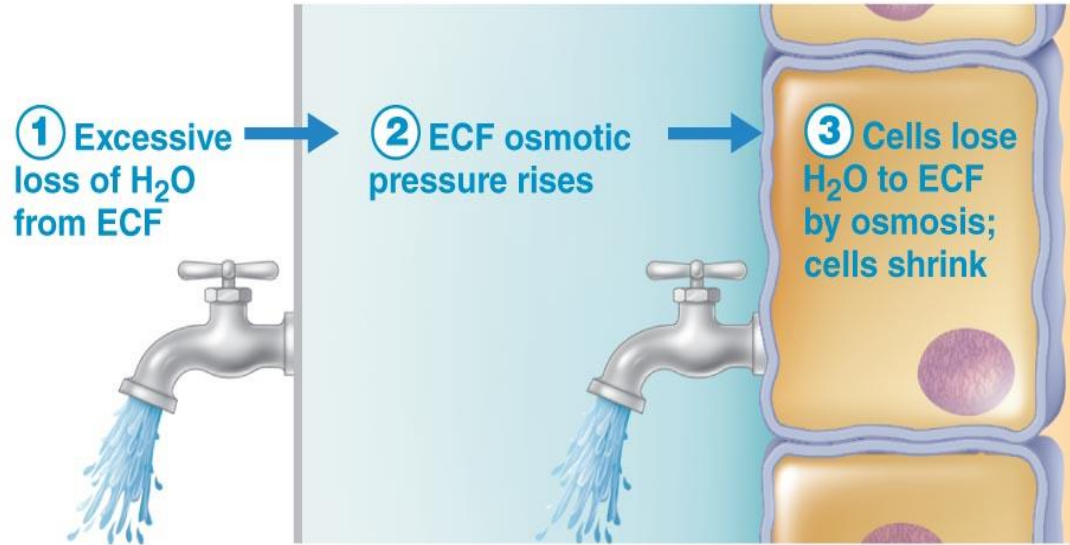
Disorders of Volumes

–Hypovolemia

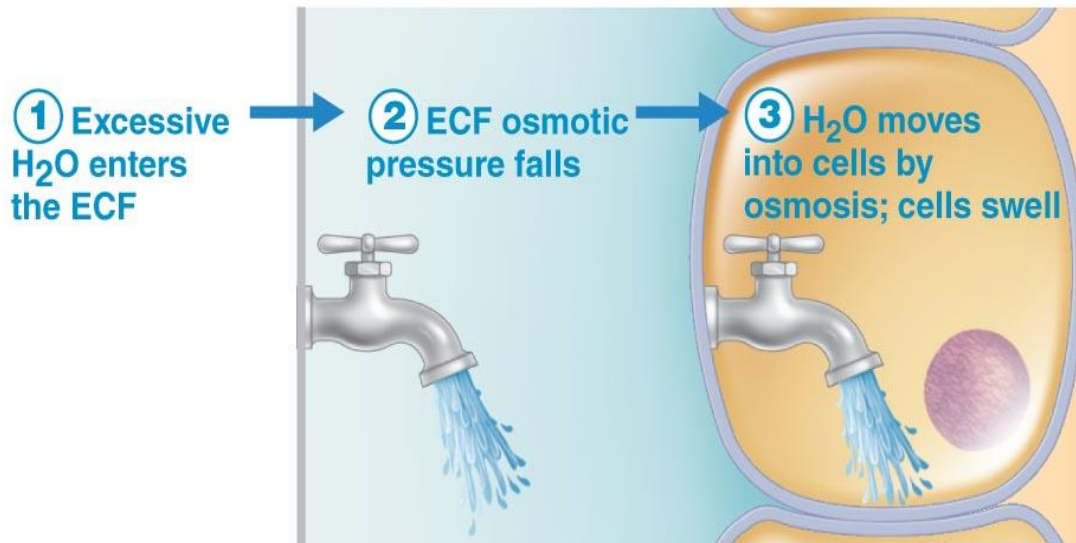
Results by excessive loss of fluids

–Hypervolemia

Results by excessive intake or administration of fluids



(a) Consequences of dehydration. If more water than solutes is lost, cells shrink.



(b) Consequences of hypotonic hydration (water gain). If more water than solutes is gained, cells swell.

Disorders of Volumes


–Hypovolemia

Results by excessive loss of fluids

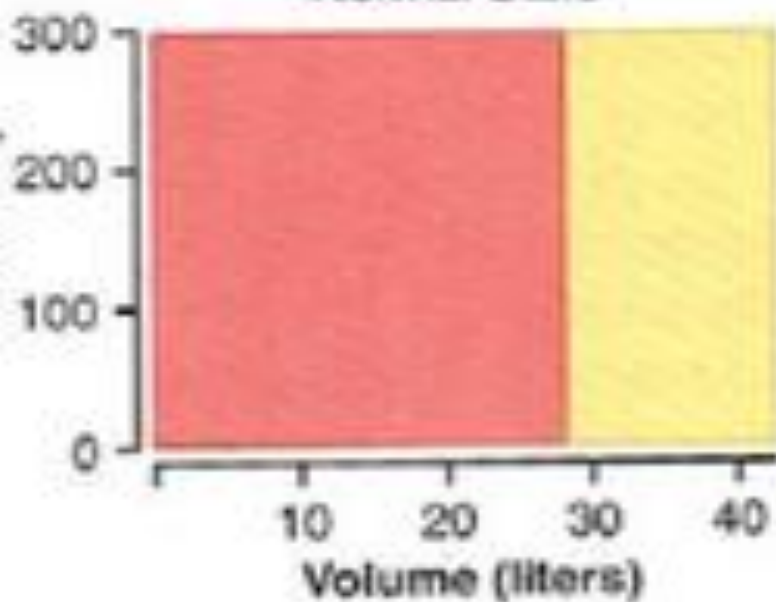
–Hypervolemia

Results by excessive intake or administration of fluids

 Intracellular fluid

 Extracellular fluid

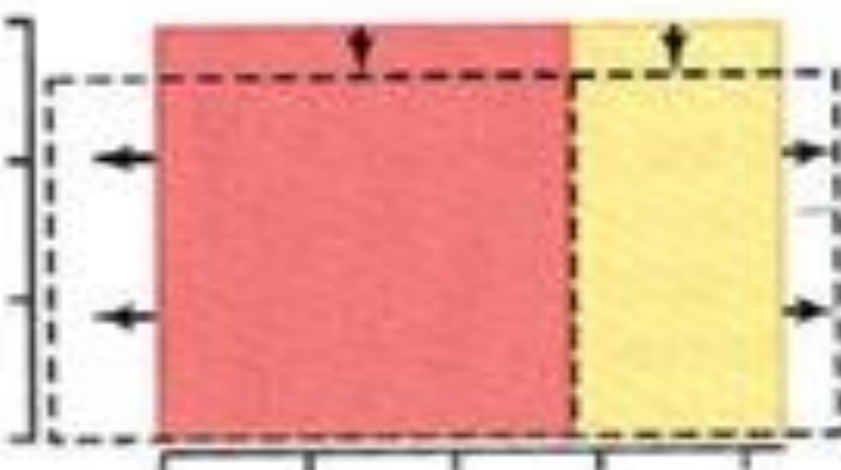
Normal State



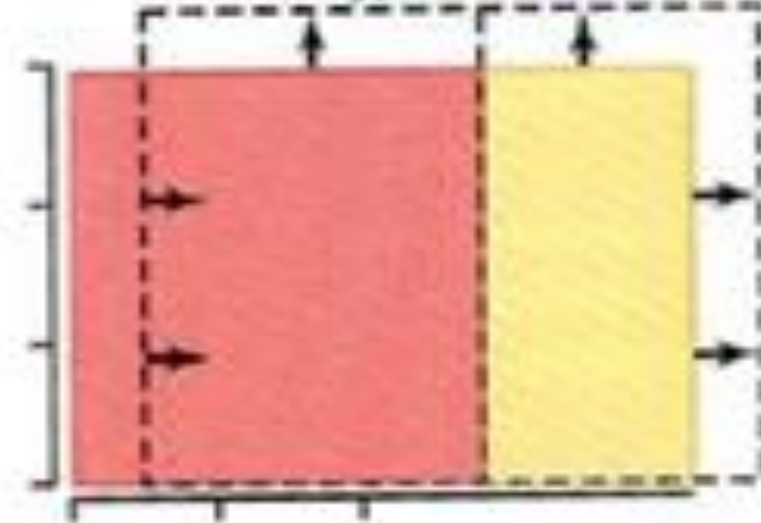
A. Add Isotonic NaCl



C. Add Hypotonic NaCl



B. Add Hypertonic NaCl



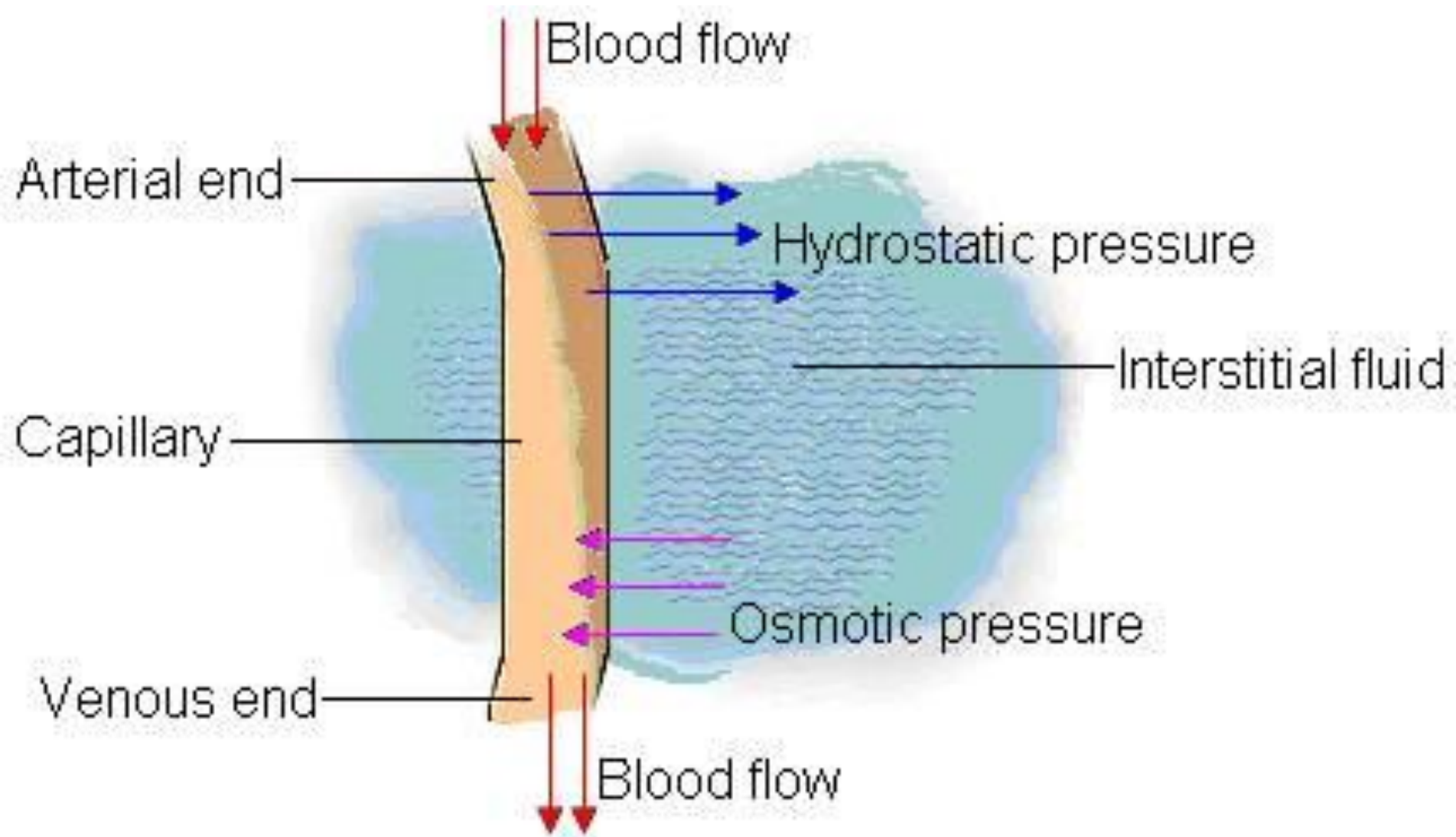
Disorders of Volumes and Osmolality

- Hyponatremia with dehydration**
- Hyponatremia with overhydration**
- Hypernatremia with dehydration**
- Hypernatremia with overhydration**

Oedema

- **Caused by increasing capillary filtration:**

- - Increased capillary hydrostatic pressure:
- - Decreased oncotic pressure
- - Increase capillary permeability
- - Decreased lymph drainage



Oedema

- **Caused by increasing capillary filtration:**
 - **Increased capillary hydrostatic pressure:**
 - Kidney causes: more retention of water and salts (Renal failure)
 - Excess of Mineralocorticoids (aldosterone)
 - **High venous pressure:**

Heart failure, decrease of Venous return (obstruction, decreased venous pump activity)
 - **Decreased arteriolar resistance**

Oedema

- **Caused by increasing capillary filtration:**
 - **Increased capillary hydrostatic pressure:**
 - **High venous pressure:**
 - **Decreased arteriolar resistance**
(Excessive body heat, Insufficiency of sympathetic nervous system, Vasodilators)

Oedema

- **Decreased Oncotic pressure**
 - **Increased loss of proteins**
 - From Kidney in nephrotic syndrome
 - from skin in burns and severe wounds
 - **Decreased production of proteins:**
 - Liver diseases
 - Decreased intake of proteins in malnutrition

Oedema

- **Increase capillary permeability**
 - During immune reactions by release of histamine
 - Toxins,
 - Infections
 - Vitamin C deficiency
 - Ischemia
 - Burns

Oedema

- **Decreased lymph drainage:**
 - Cancer
 - Infections
 - Surgery
 - Absence or abnormality of lymphatic vessels

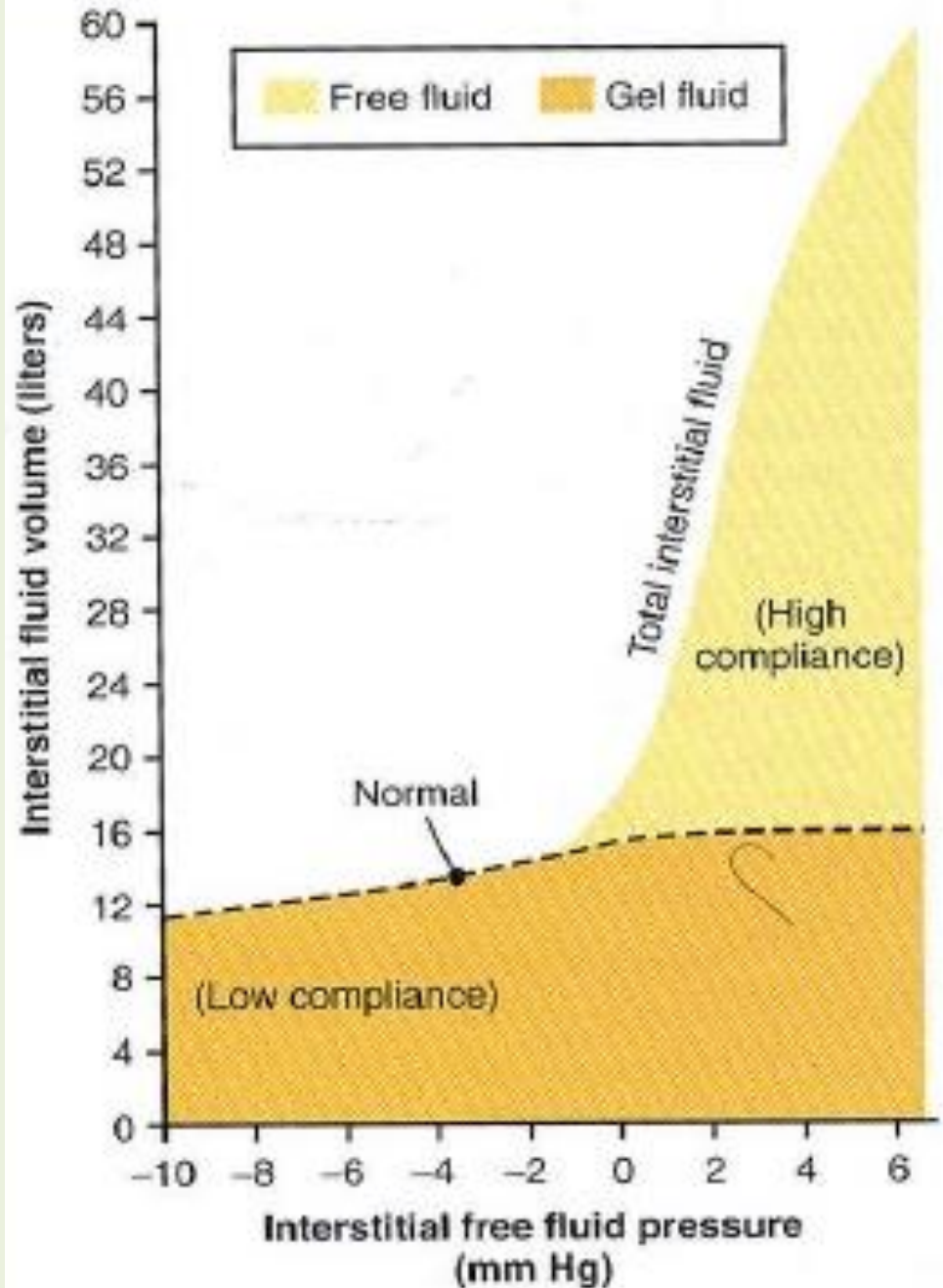
Safety factors for preventing oedema

- **Low tissue compliance**
- Increased lymph flow
- Increased protein wash-down from interstitial fluids

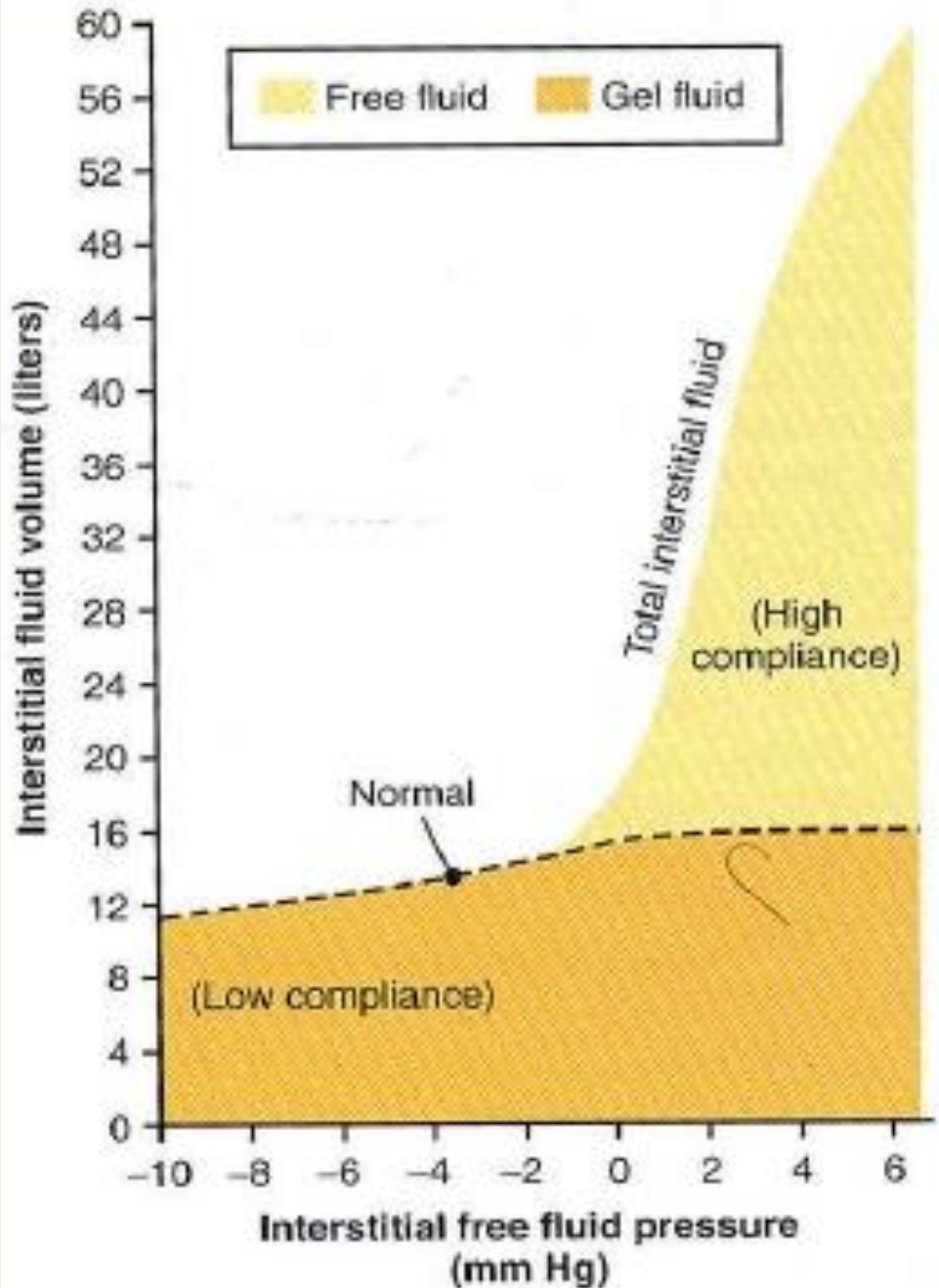
In negative
pressure ranges

LOW compliance

by presence of
gel fluids results
in relative increase
in hydrostatic
pressure to small
changes in
volume →
prevents capillary
filtration



In positive
pressure ranges
HIGH compliance
by accumulation
of **free fluids**
results in smaller
increase in
hydrostatic pressure
to high changes
in volume →
Pitting oedema



Safety factors for preventing oedema

- Low tissue compliance
- **Increased lymph flow**
- Increased protein wash-down from interstitial fluids

Increased
lymph flow
as safety factor

- **Lymph flow can increase up to 10-50 folds**
- **Carry away large amounts of fluids** → prevents interstitial pressure from rising into **POSITIVE** ranges

Safety factors for preventing oedema

- Low tissue compliance
- Increased lymph flow
- **Increased protein wash-down from interstitial fluids**

Increased lymph flow
→ increased Protein washout from interstitial fluids

- **Increased Lymph flow**
 - **Carry away large amounts of proteins** (Protein washed out from interstitial fluids) → decrease Colloid osmotic pressure in interstitial fluid → Lowering net filtration forces → **Prevents accumulation of fluids**

GOOD LUCK

E-mail: malessa@ju.edu.jo

