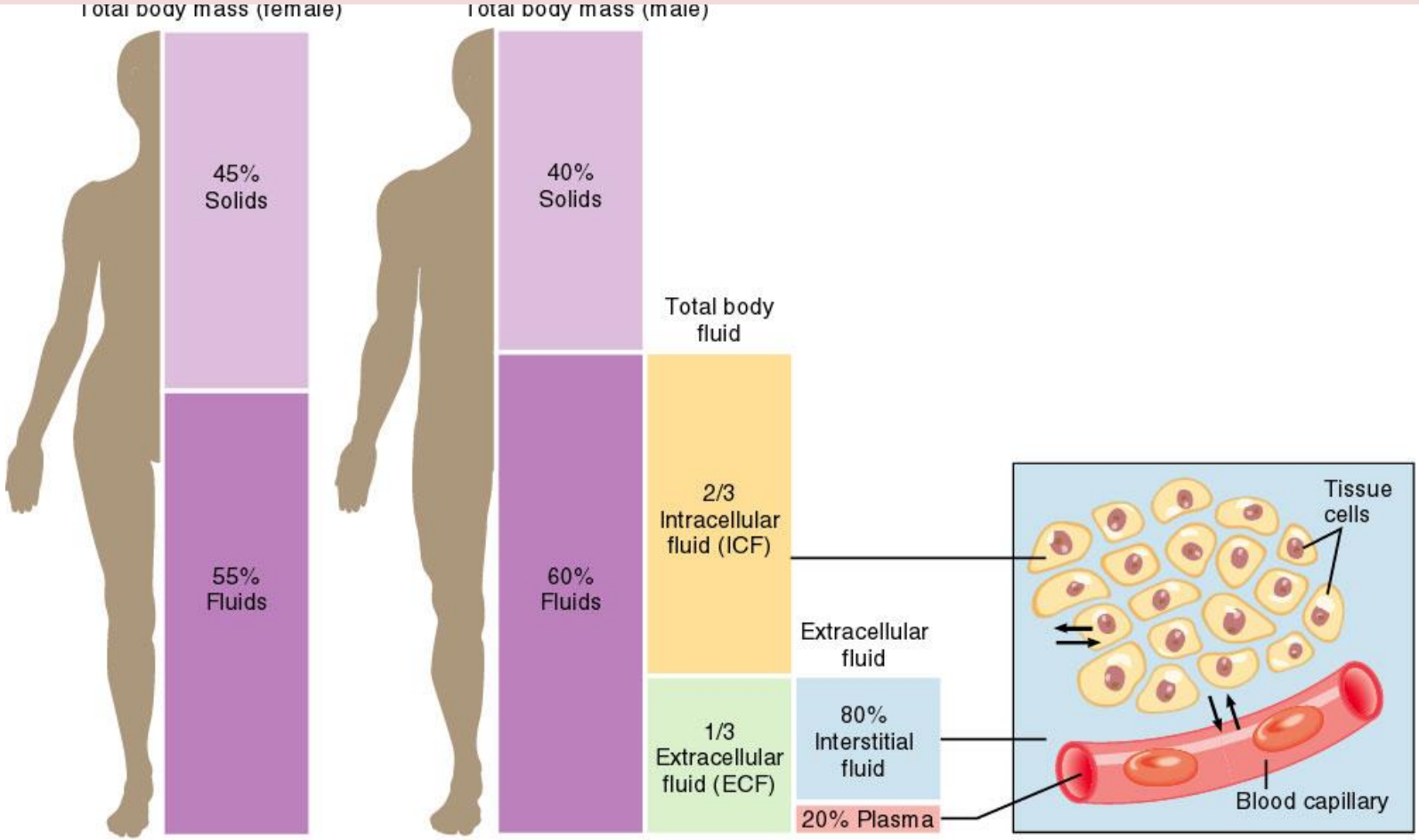
Body Fluids 1

Ref: Textbook of Medical Physiology Guyton and Hall, Jordan Ed.:305-321, 13th Edition 303-321, 12th Edition

Pages: 285-297

Fluid Compartments

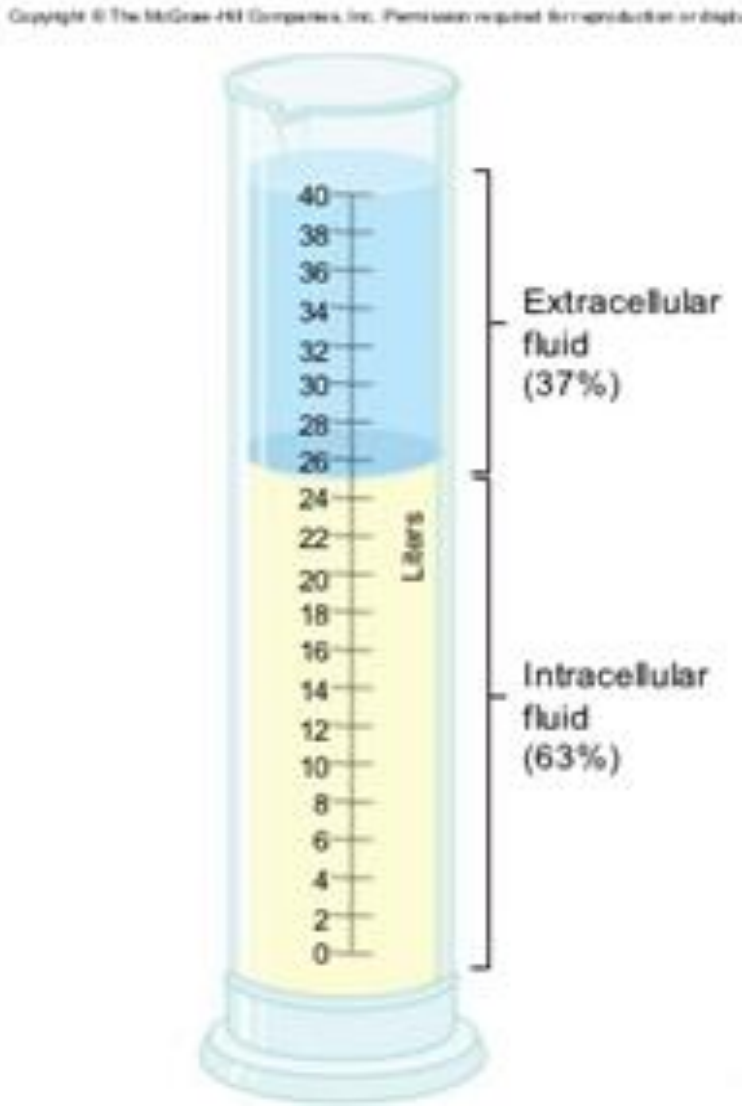


(a) Distribution of body solids and fluids in an average lean, adult female and male

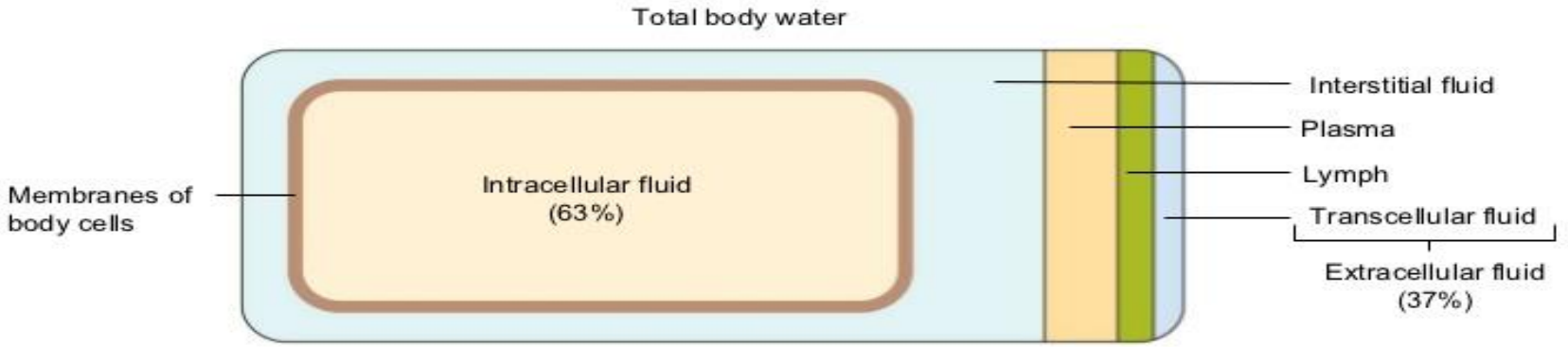
(b) Exchange of water among body fluid compartments

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



Water Distribution



Water Distribution

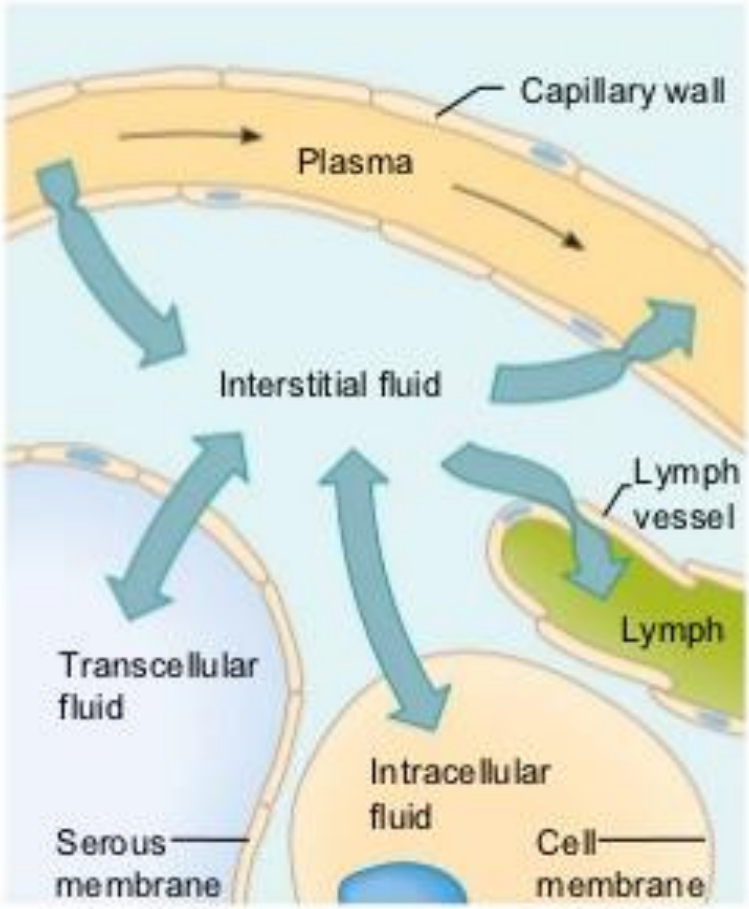
Transcellular Fluids

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

Movement of Fluids between Compartments

Major factors that regulate movements:

- Osmotic pressure
- Hydrostatic pressure



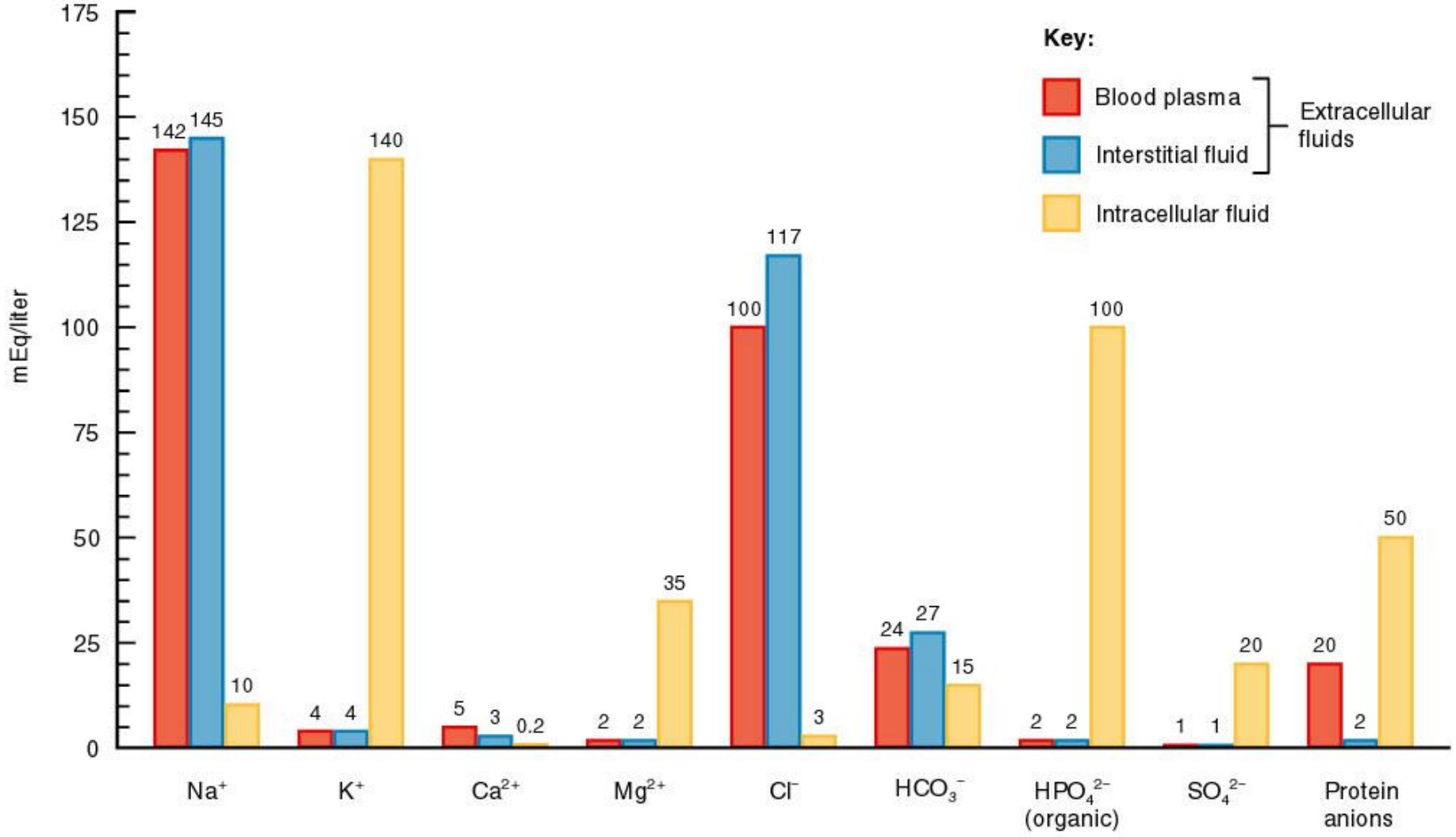
Fluid leaves plasma at arteriolar end of capillaries because outward force of hydrostatic pressure predominates

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

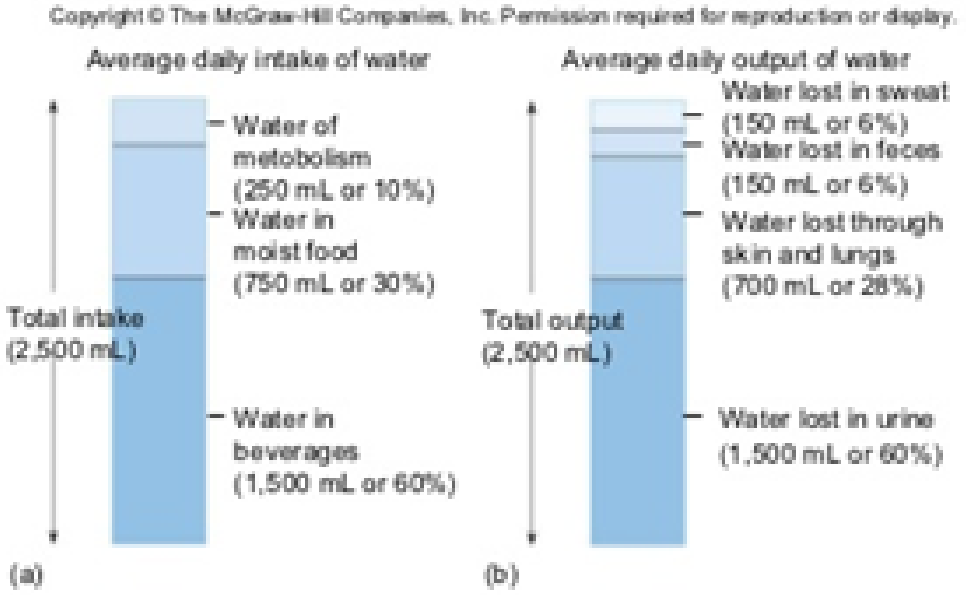
Composition of Body Fluids



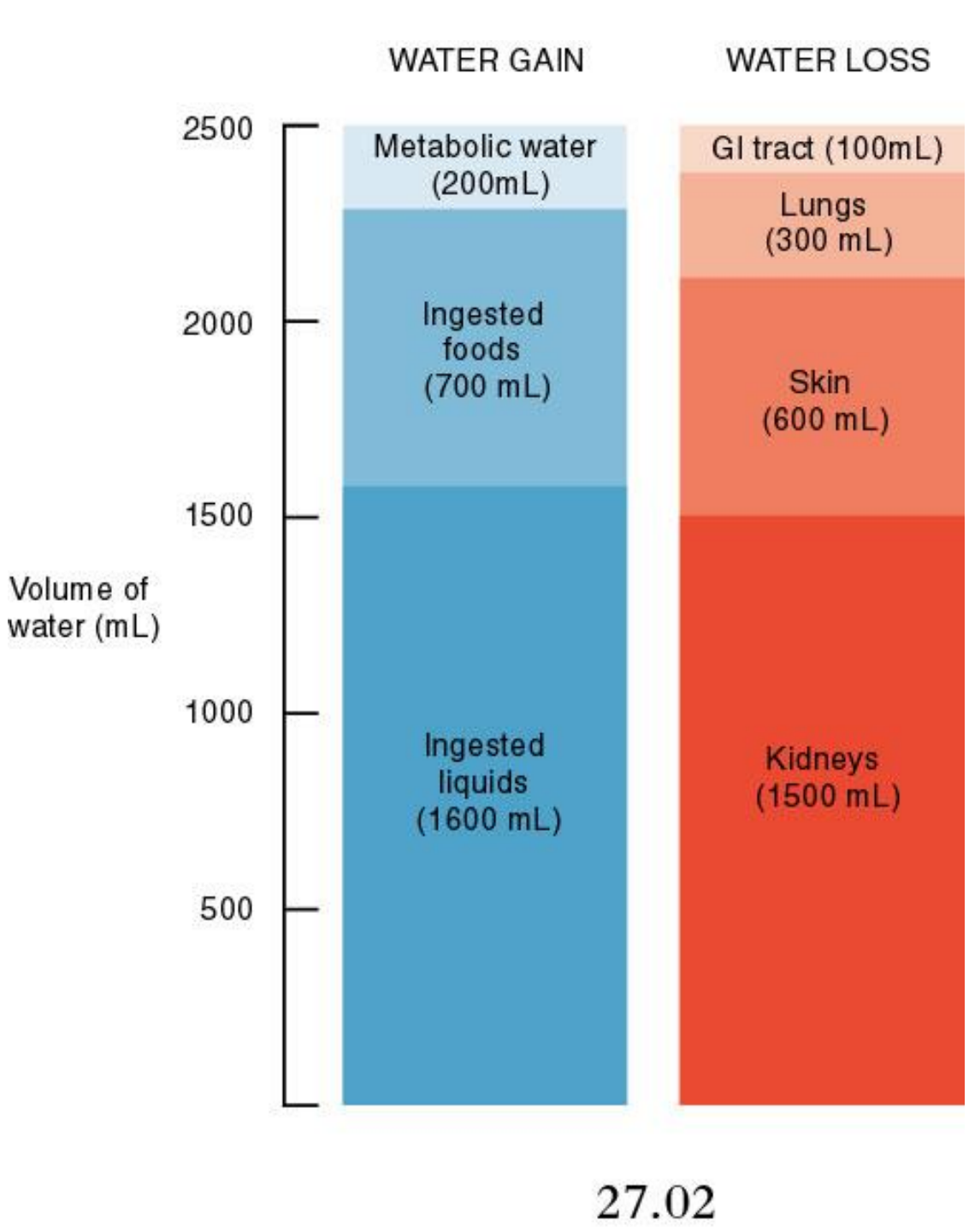
27.06

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

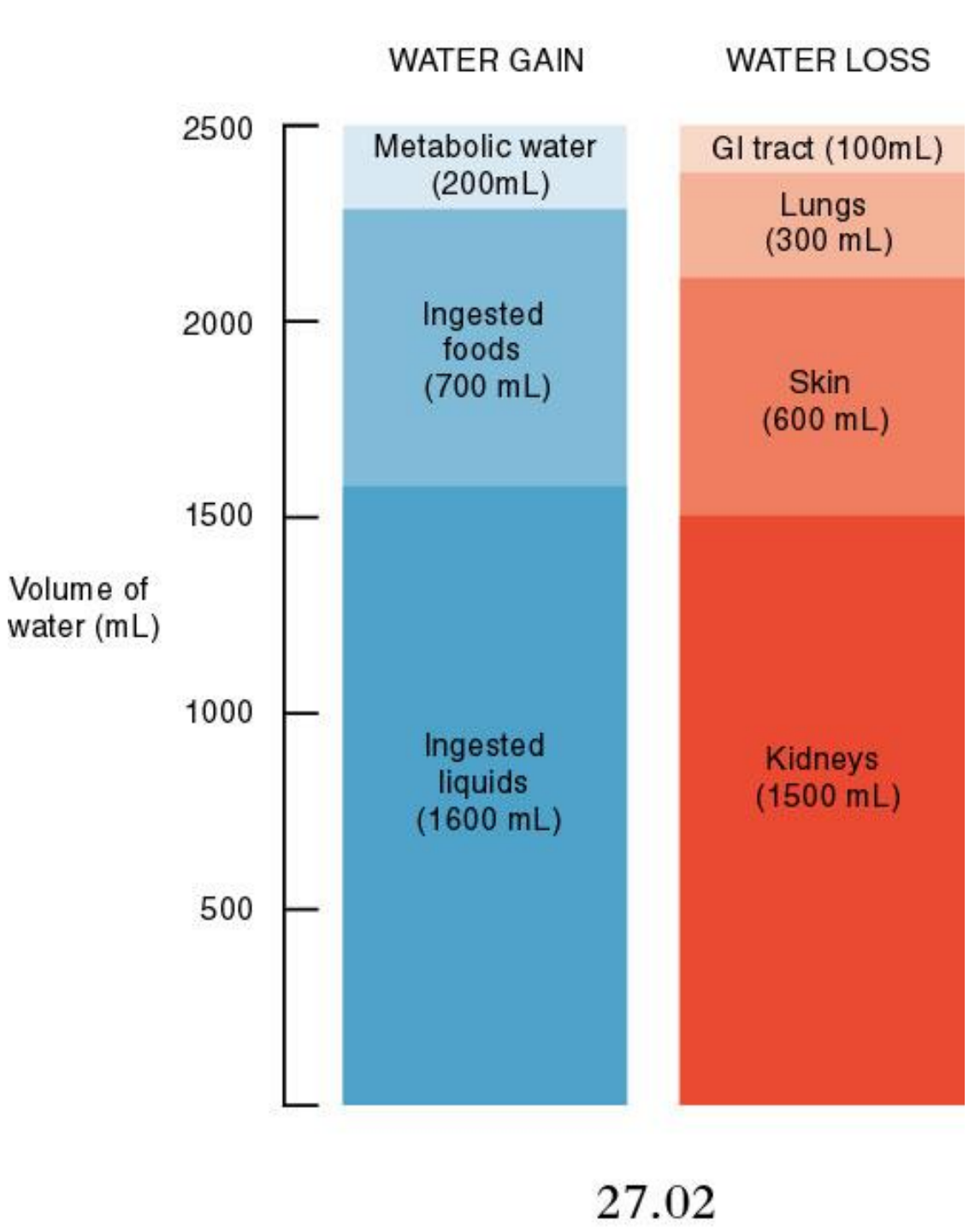


Water Output

- 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

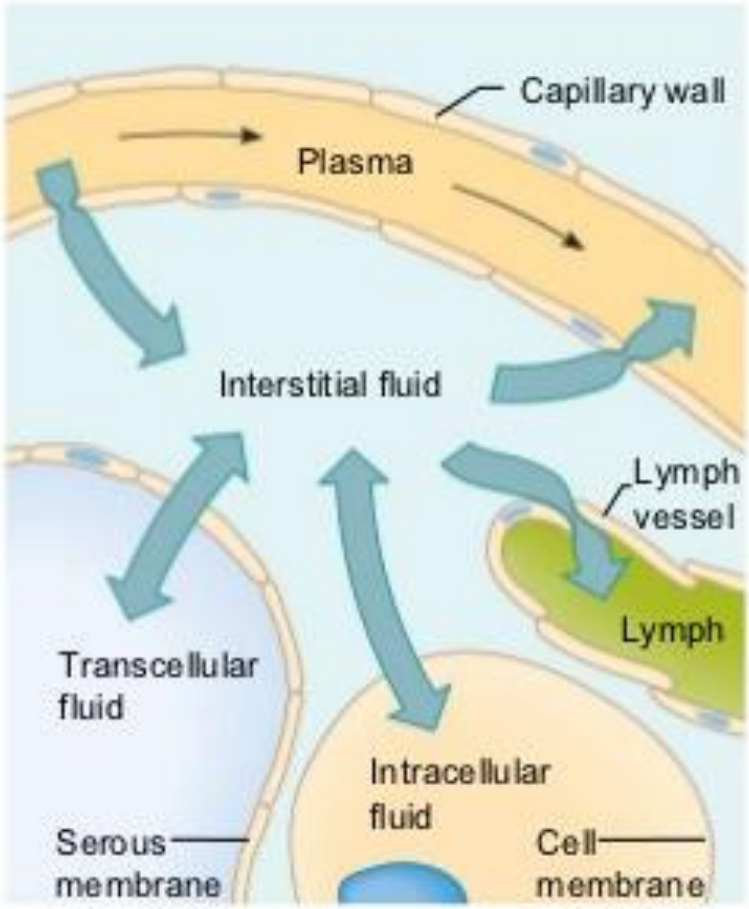
Systems involved in the regulation of fluids and electrolytes

- 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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Interstitial fluid is in equilibrium with transcellular and intracellular fluids

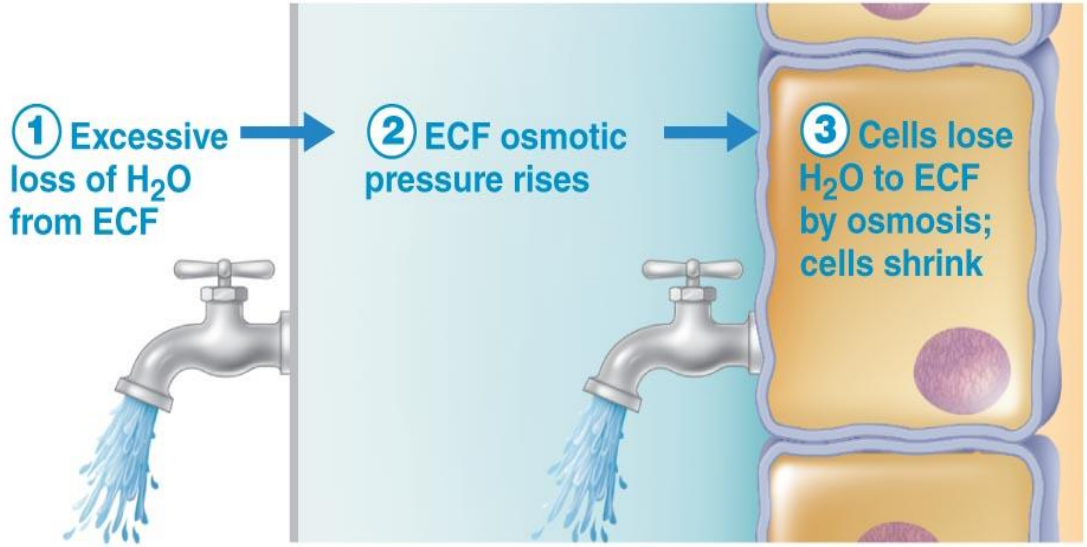
Regulation of Na+ and Water

Involves regulation of:

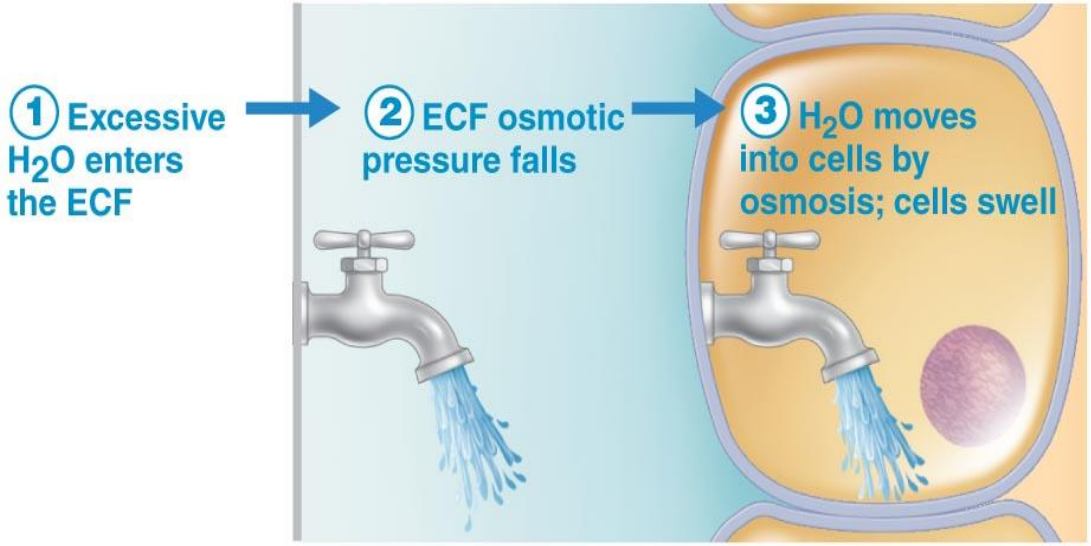
- Osmolality
- Volume of ECF

different regulations with many overlapping mechanisms.

Importance of Na+ and Water regulation

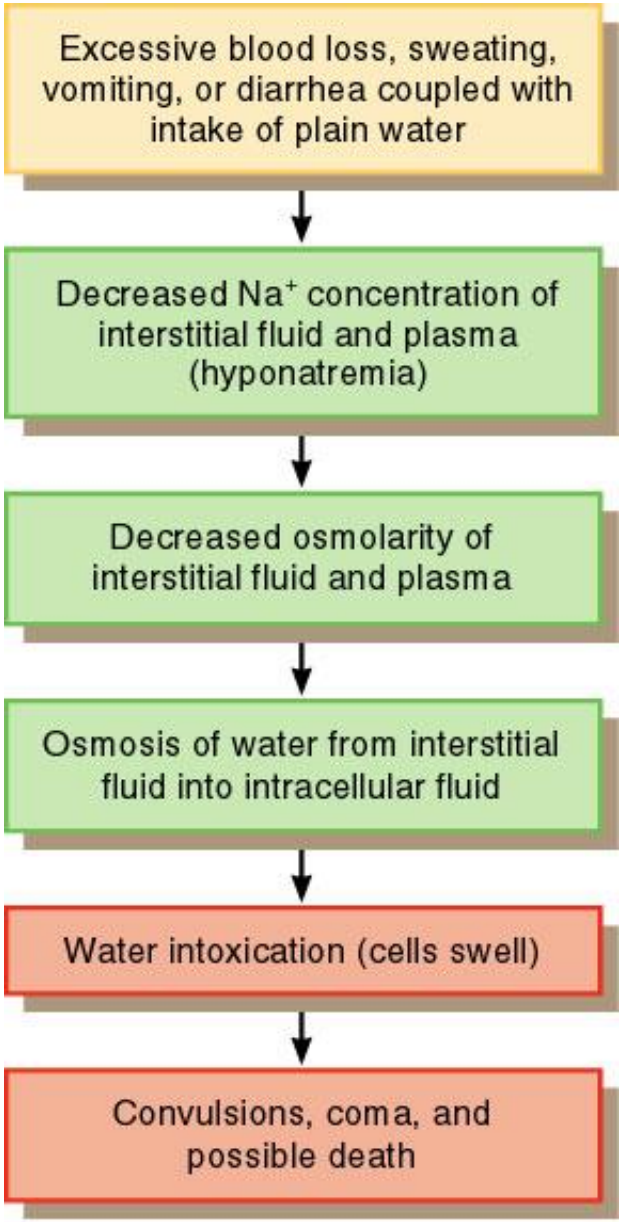


(a) Consequences of dehydration. If more water than solutes is lost, cells shrink.



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

Fig. 27.05



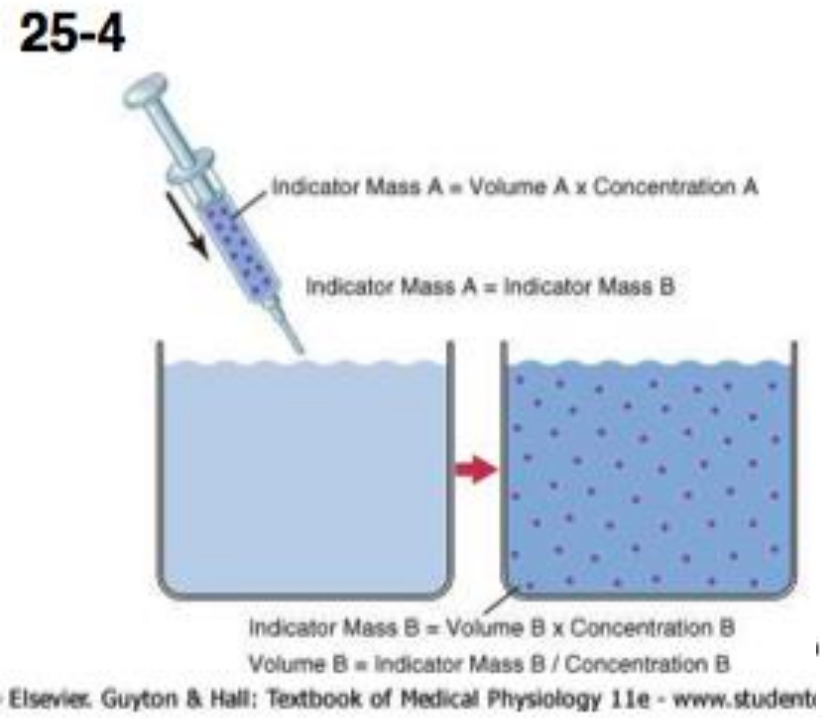
27.05

Measurements of Body Fluids

Measuring Body Fluids

Dilution Principle

Dilution method for calculating fluid volume



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

If 1ml 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 distribute 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 (^3H_2O, T_2O, Tritium) or heavy water (^2H_2O, 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

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

(Measured in 30-60 minutes)

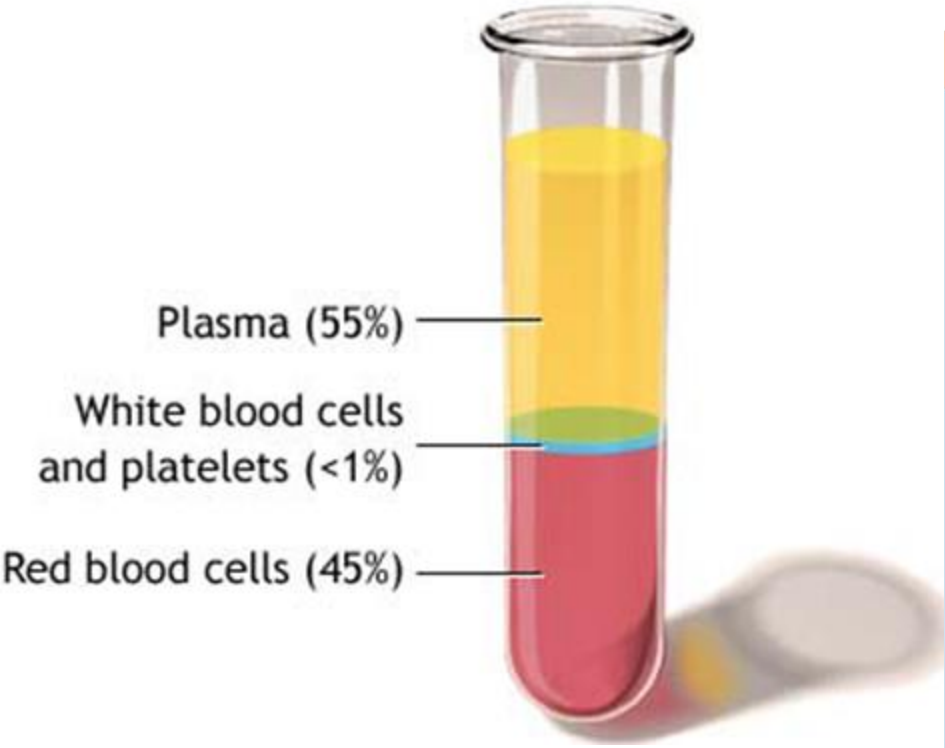
Calculation of ICF (Intra- Cellular Volume)

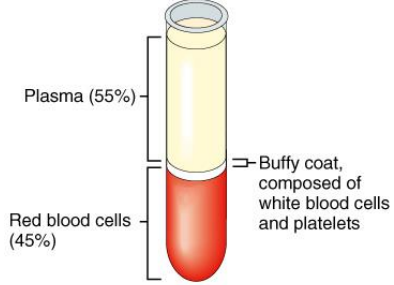
ICF= Total Body water - ECF

Measurement of Plasma volumes

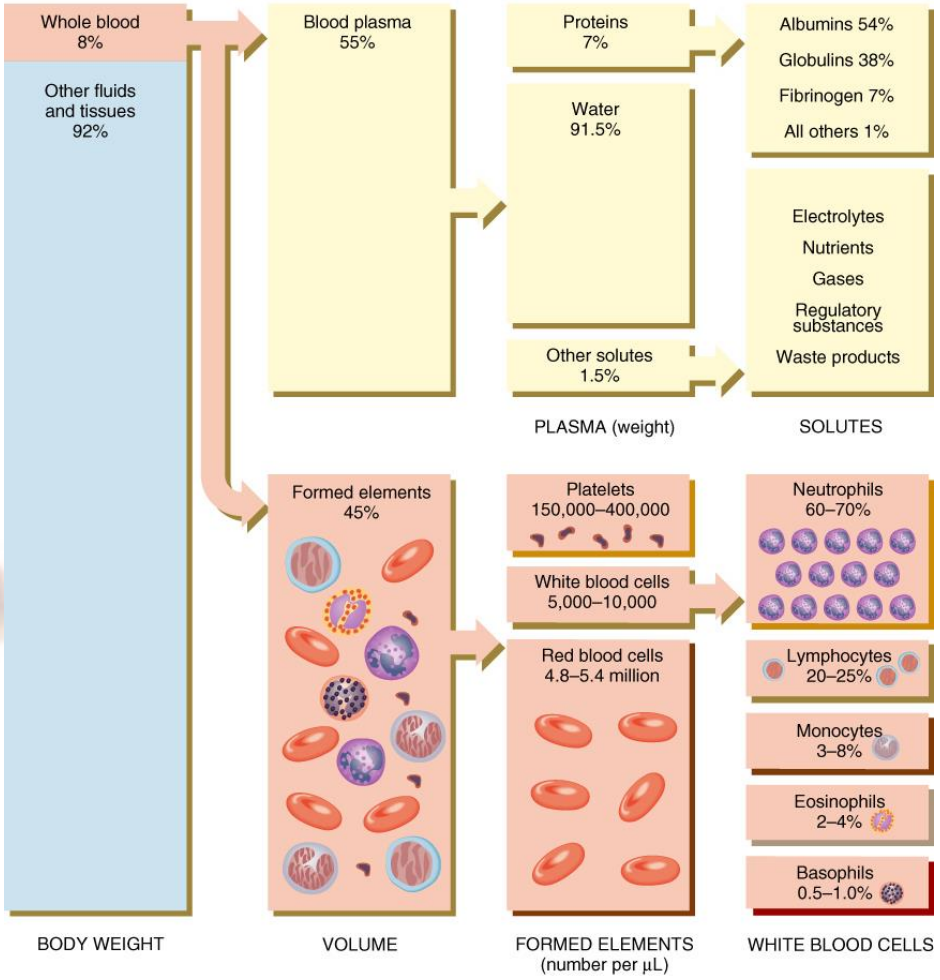
Measurement of Total Blood Volume

Fig.19.01





(a) Appearance of centrifuged blood



(b) Components of blood

19.01

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 = $\frac{\text{Plasma Volume}}{\text{1-Hematocrit}}$

Body Fluids 2

Ref: Textbook of Medical Physiology
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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

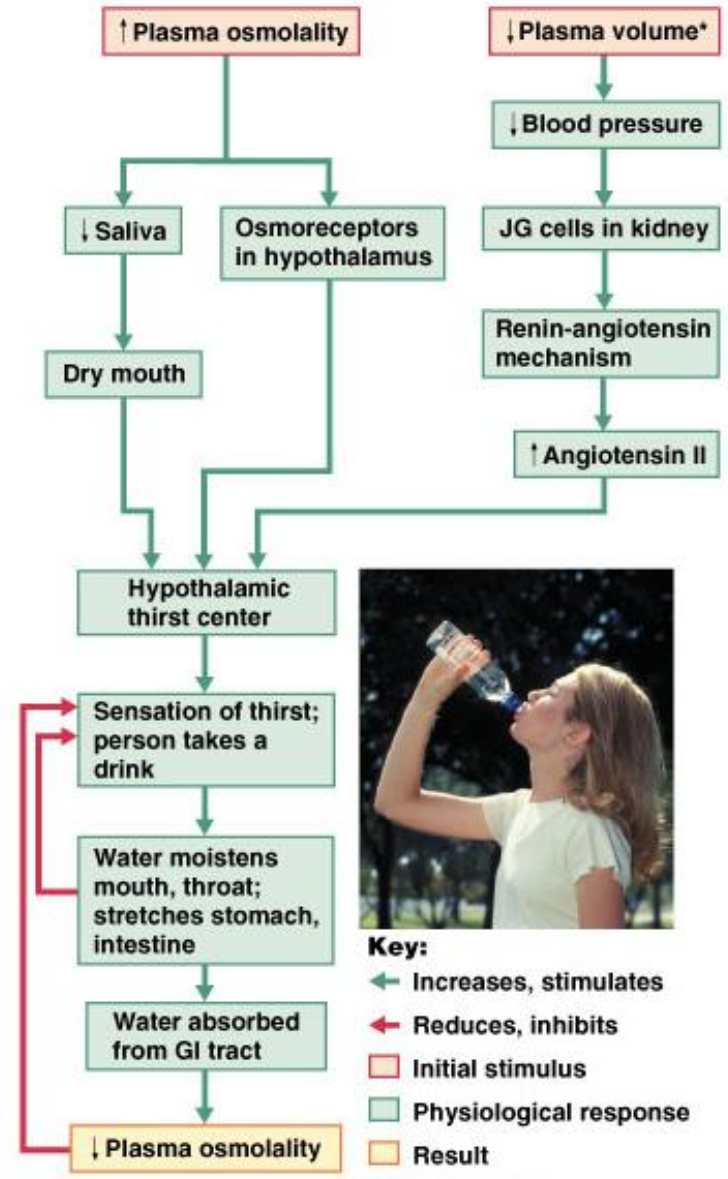
- Increased osmolality → thirst (Increase water intake).

- Increased osmolality → stimulates release of ADH --> acts on renal collecting ducts → increased water reabsorption (Decrease water output)

- **Volume of ECF**

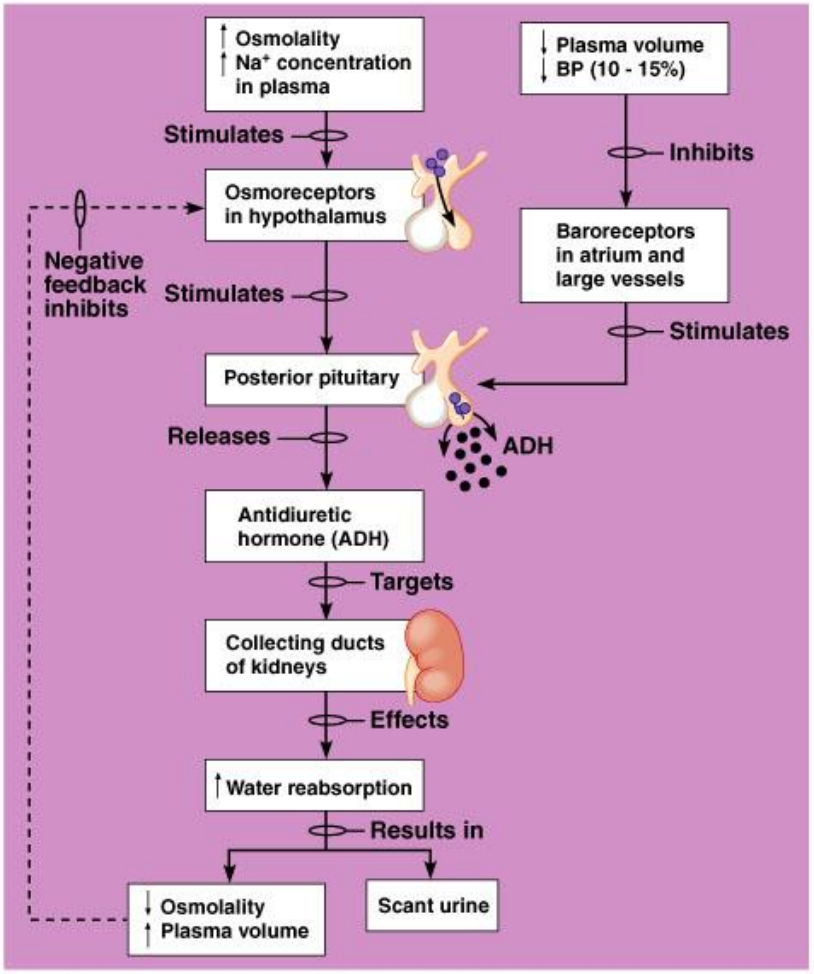
Body Water

- **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



Regulation of Na+ and Water

Involves regulation of:

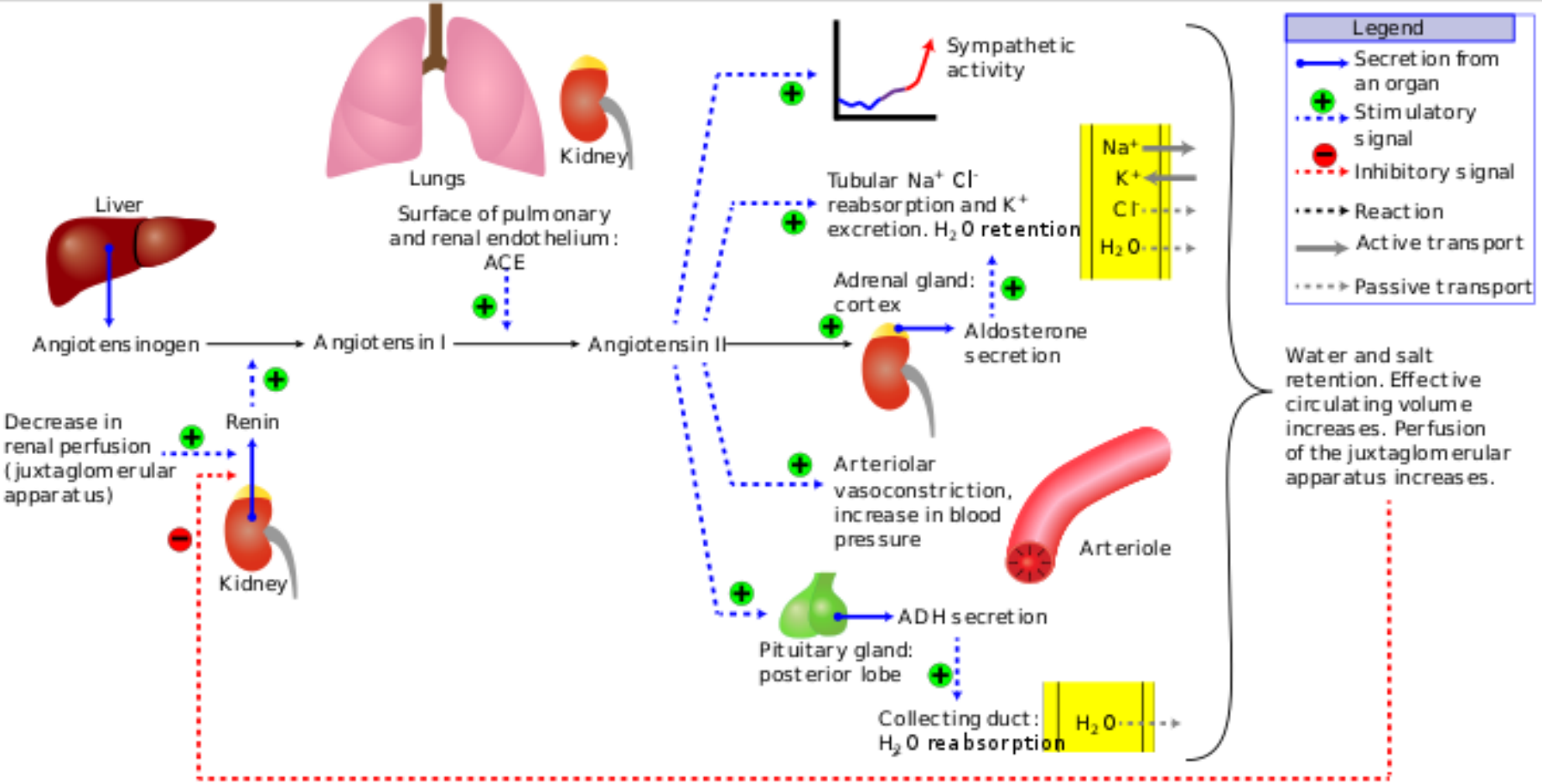
- **Osmolality:**
- **Volume of ECF:**

  - Depends on Na+ excretion in urine.

  - Controlled by renin-angiotensin aldosterone system

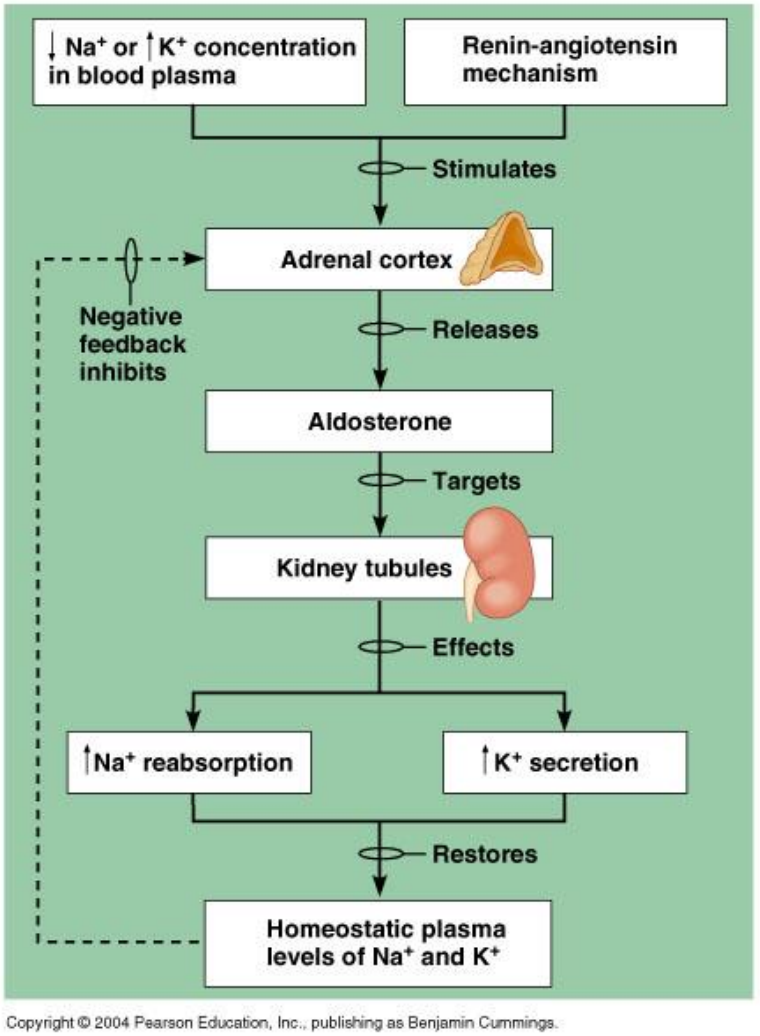
Reduced Volume → Juxtaglomerular Cells (Kidney) release Renin → Angiotensinogen →Angiotensin I →Angiotensin II (Lung) → Aldosterone

Renin-angiotensin-aldosterone system



Body Water

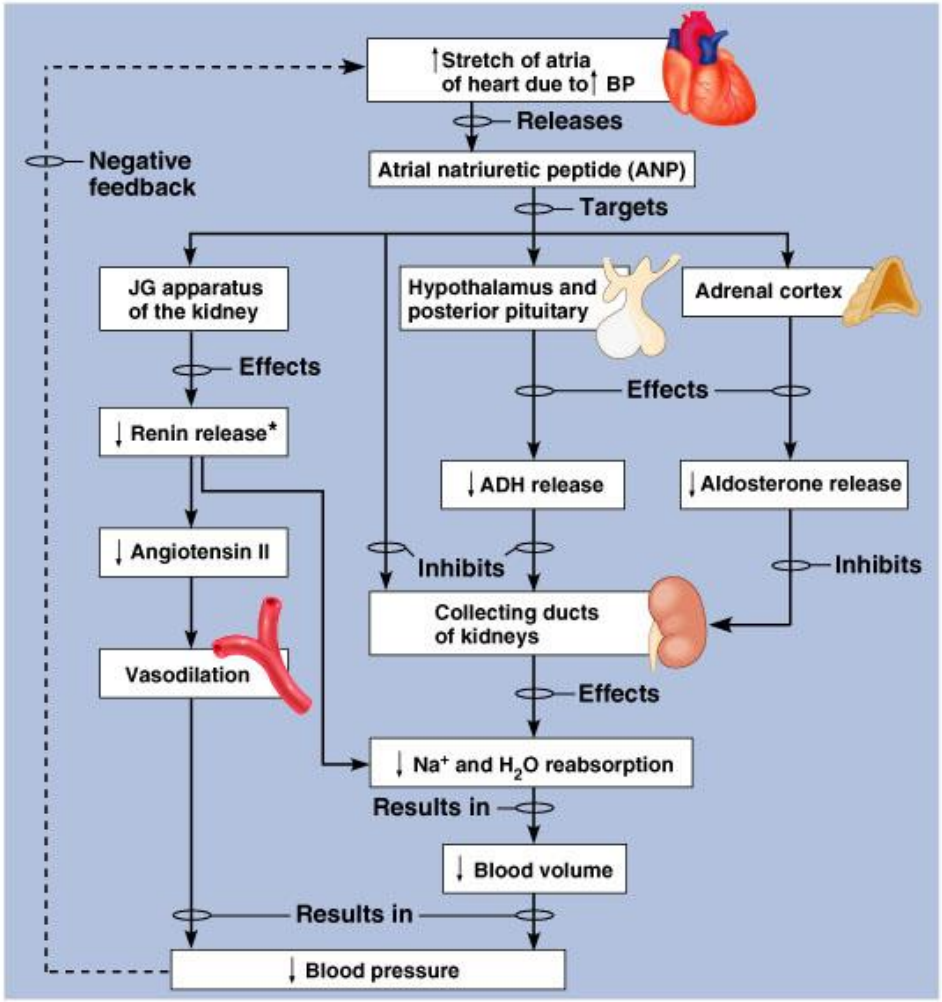
- **Regulation of output**
  - Regulated by renin-angiotensin mechanism
    - Angiotensin II stimulates aldosterone secretion



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



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

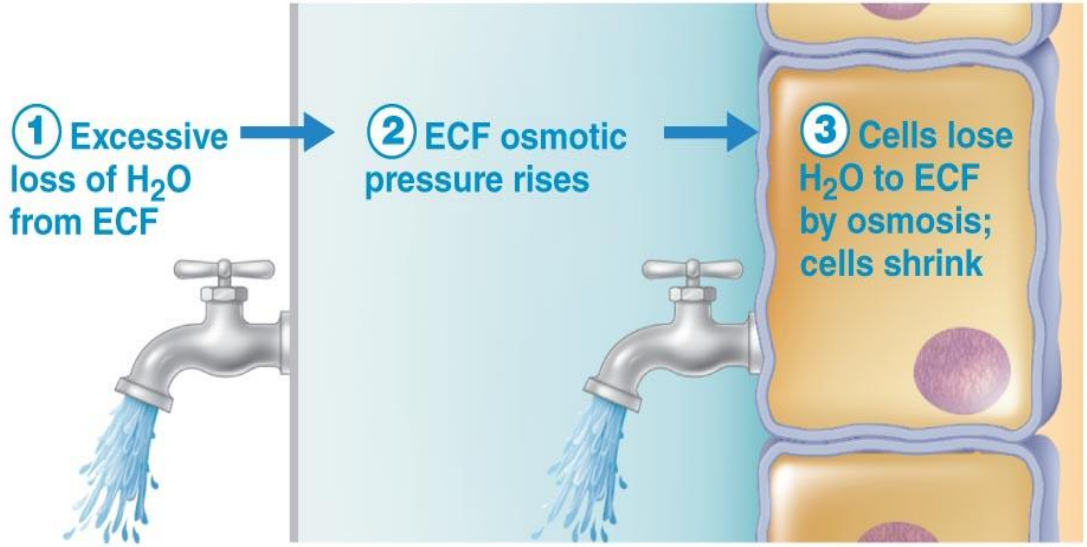
Disorders of Volumes

- **Hypovolemia**

  Results by excessive loss of fluids

- Hypervolemia

  Results by excessive intake or administration of fluids



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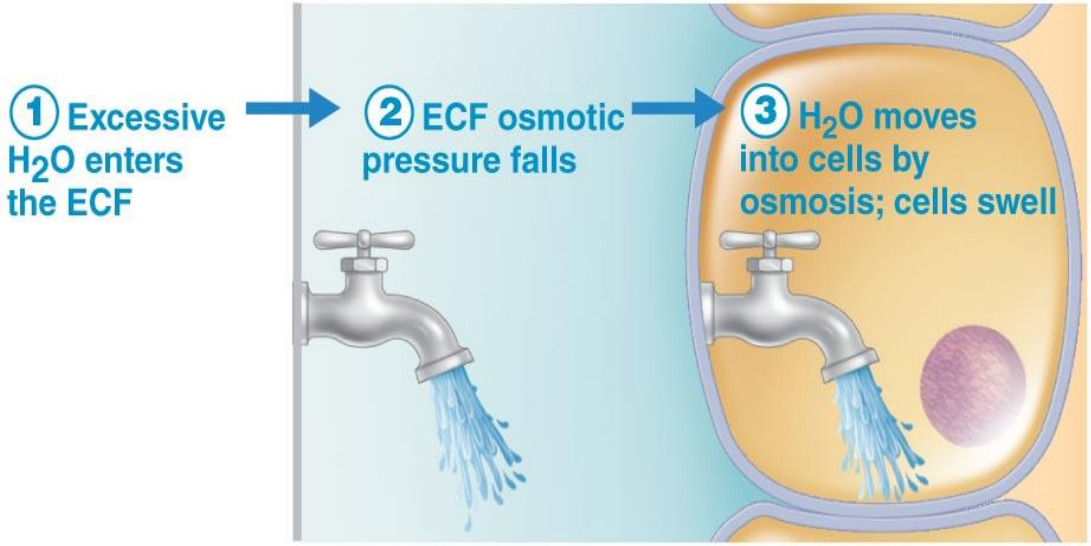

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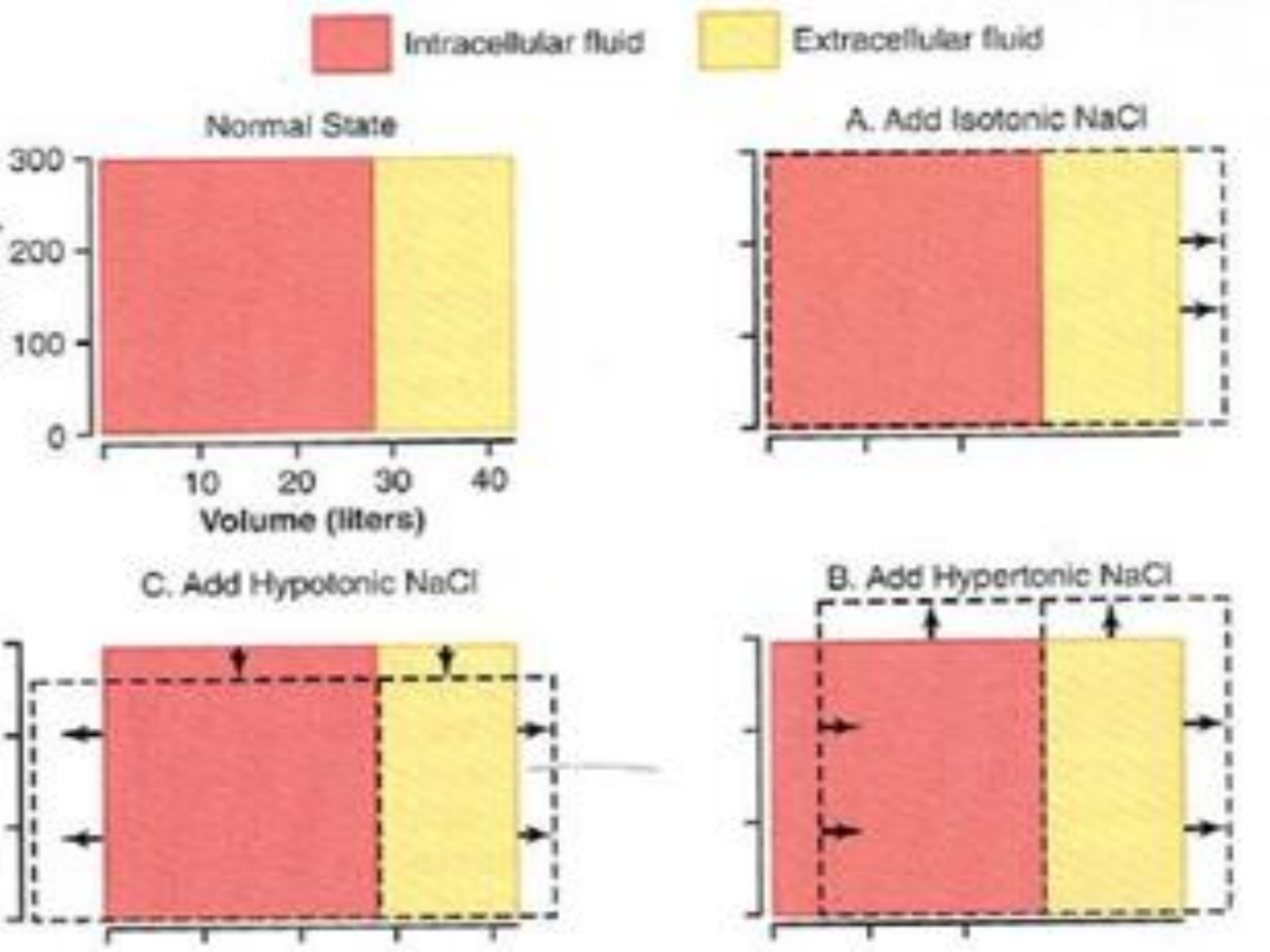
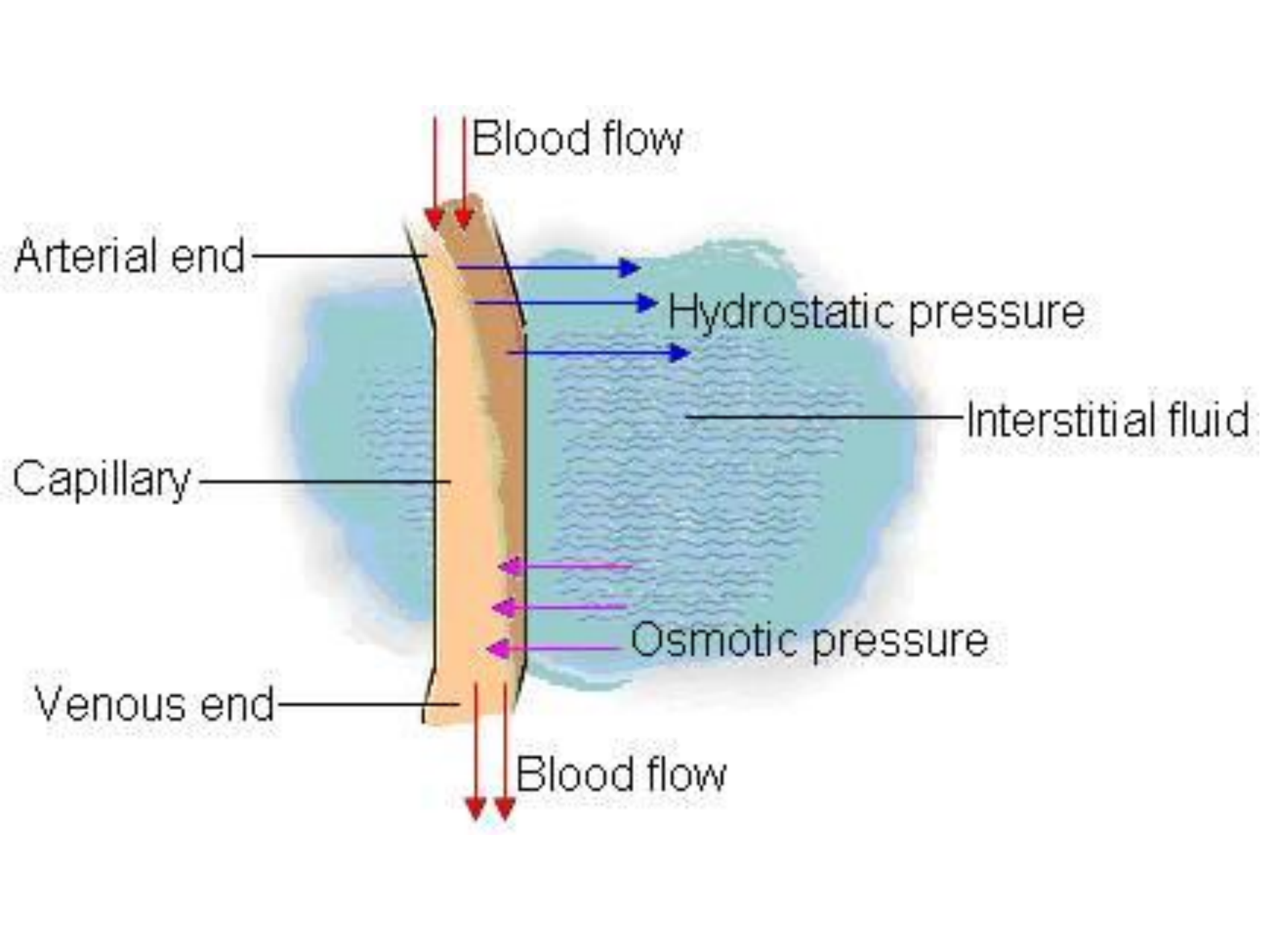

Intracellular fluid
Extracellular fluid
Normal State
300
200
100
0
10
20
30
40
Volume (liters)
A. Add Isotonic NaCl
C. Add Hypotonic NaCl
B. Add Hypertonic NaCl

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


Blood flow
Arterial end
Hydrostatic pressure
Interstitial fluid
Capillary
Osmotic pressure
Venous end
Blood flow

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

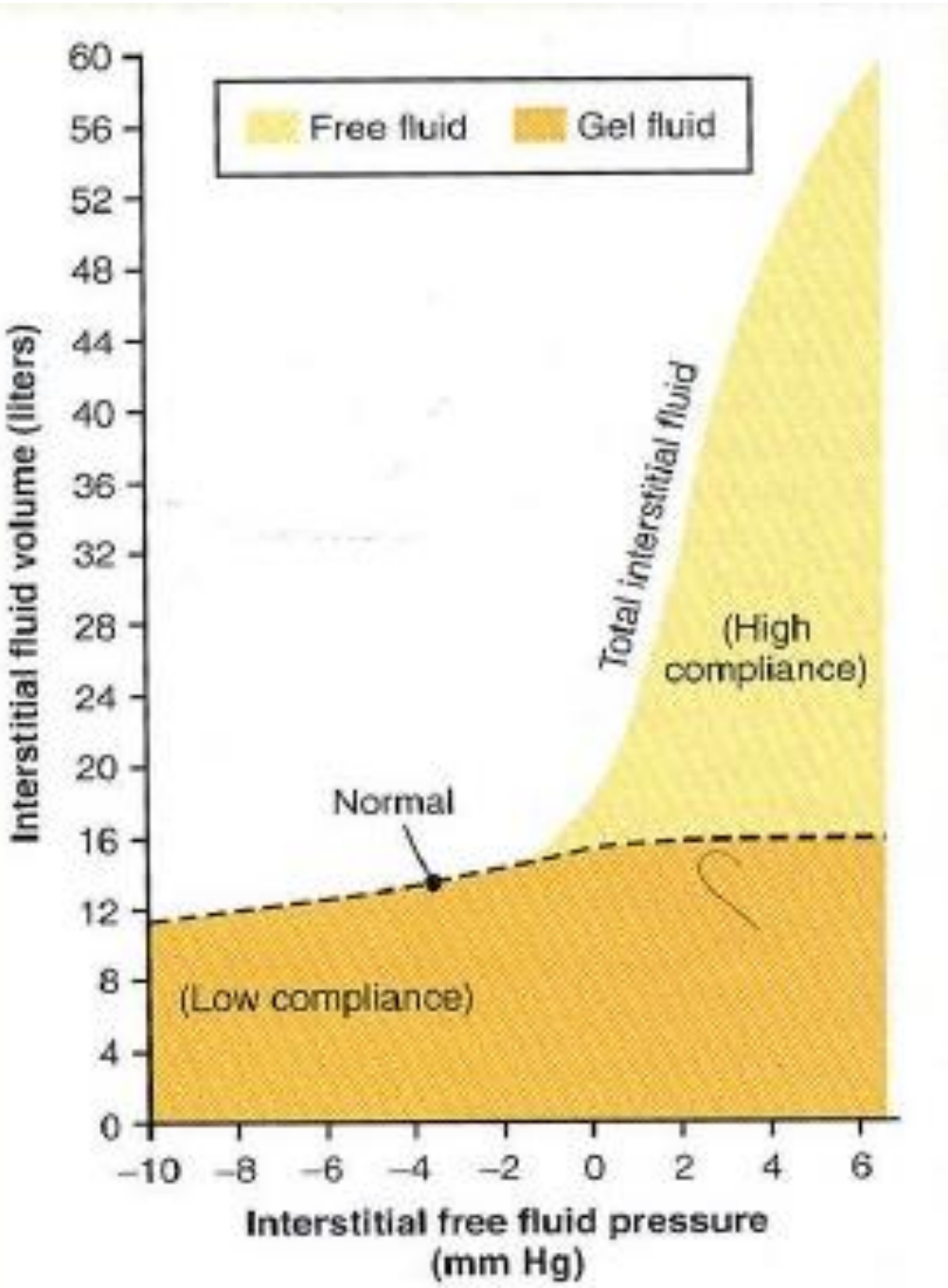
Safety factors for preventing oedema

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

In negative pressure ranges

LOW compliance

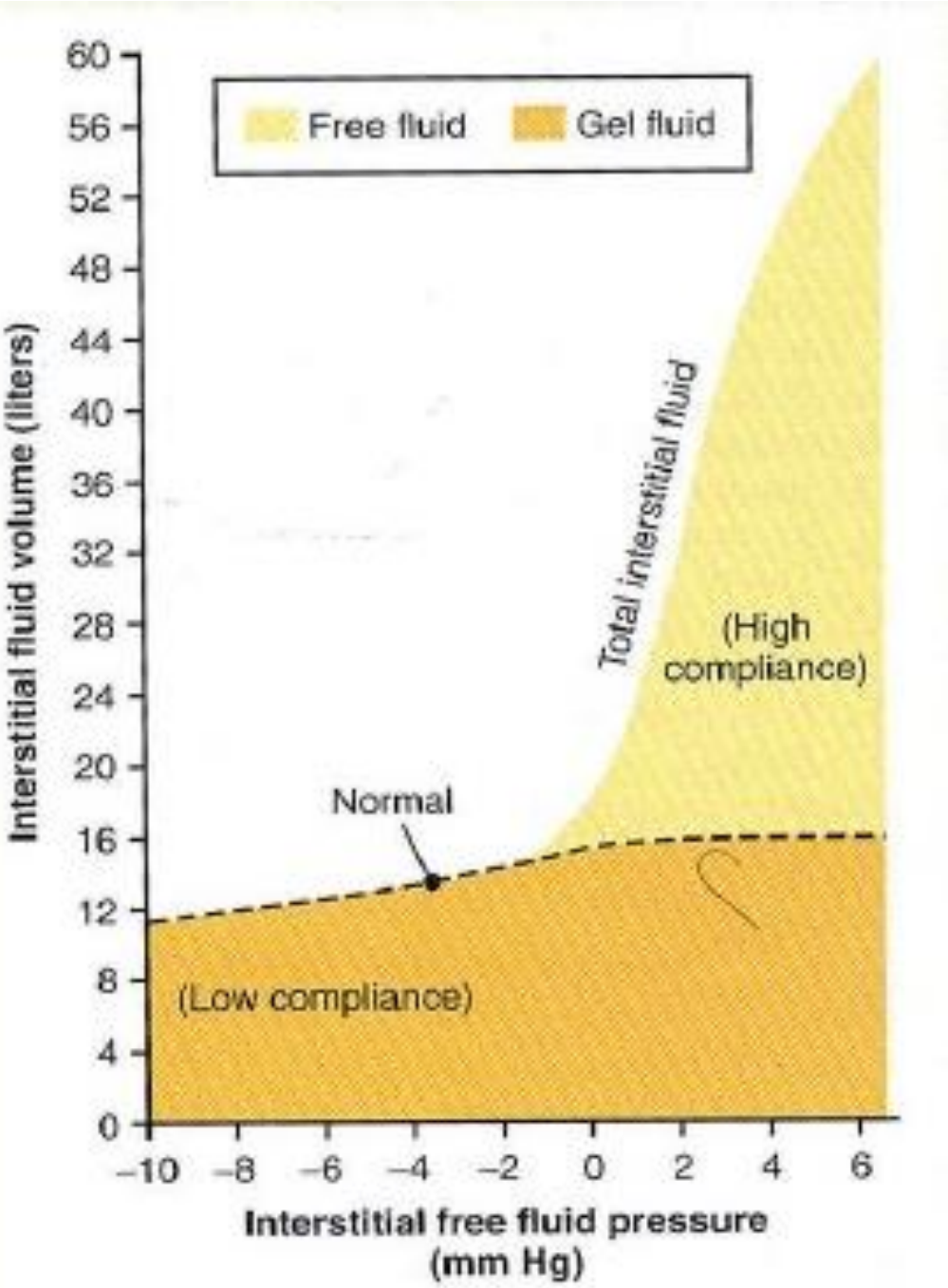
by presence of gel fluids results in relative increase in hydrostatic pressure to small changes in volume → prevents capillary filtration



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