
In The Name Of God

# C H A P T E R 2 5

## Regulation of Body Fluid Compartments: Extracellular and Intracellular Fluids; Edema

**هدف کلی جلسه:** آشنایی با تنظیم بخش های مایعات بدن، مایع خارج سلولی و داخل سلولی، ادم

**اهداف ویژه جلسه**
**در پایان دانشجو قادر باشد:**

- اجزای تشکیل دهنده مایع داخل سلولی و خارج سلولی را نام ببرد
- نحوه تعیین حجم هر کدام از بخش های مایعات بدن را توضیح دهد
- عوامل موثر بر جابجایی مایعات بدن را نام ببرد
- نحوه توزیع مایعات با اسمولاریته های مختلف در بدن پس از انفوزیون را شرح دهد
- نحوه تشکیل ادم را توضیح دهد
- فاکتورهای اطمینان در برابر ایجاد ادم را توضیح دهد

- **Fluid Intake and Output Are Balanced During Steady-State Conditions**

- **Daily Intake of Water** ▶

- **Daily Loss of Body Water**

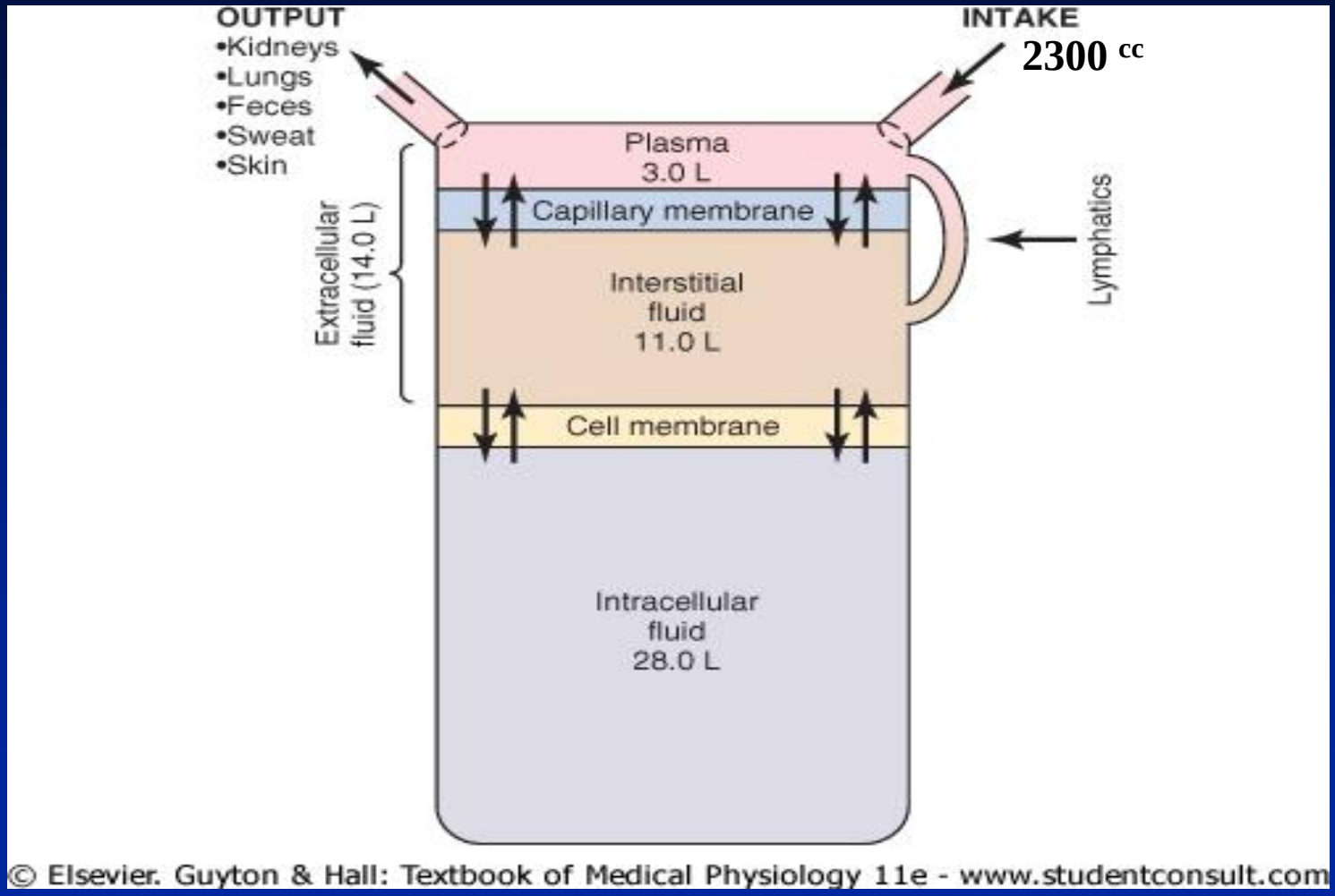
**-Insensible Water Loss (700 ml)**

**-Fluid Loss in Sweat (100 ml)**

**-Water Loss in Feces (100 ml)**

**-Water Loss by the Kidneys**

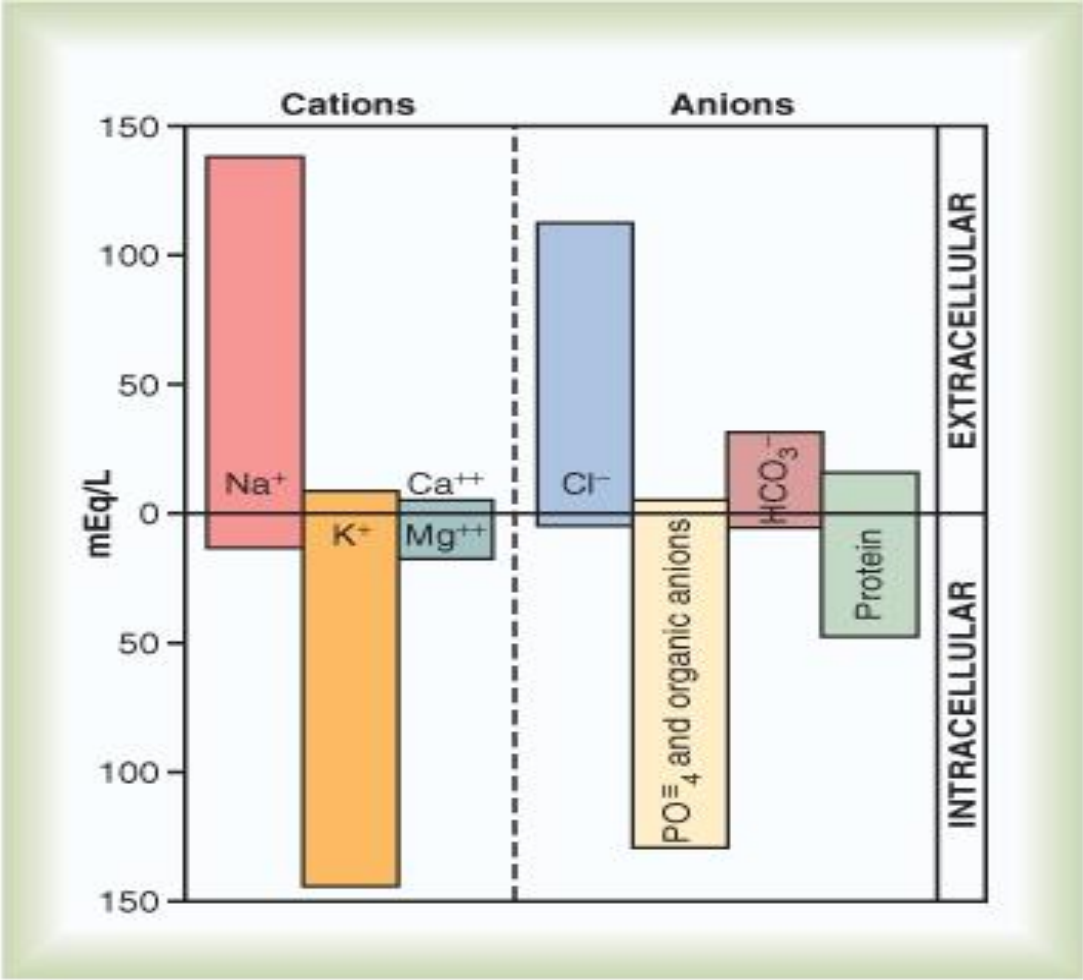
# The major body fluid compartments and body fluid regulation



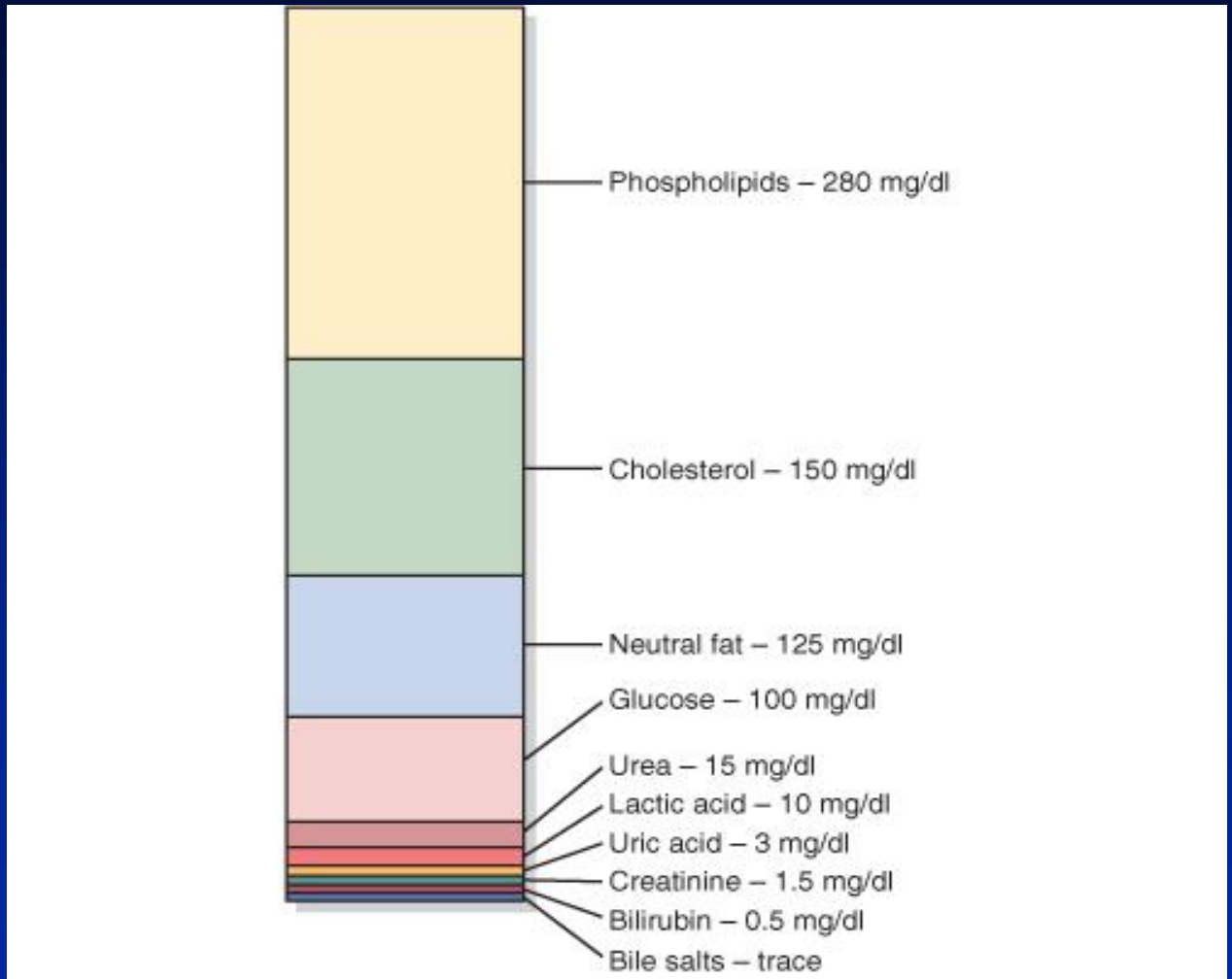
# Constituents of Extracellular and Intracellular Fluids

| | Plasma (mOsm/L $H_2O$) | Interstitial (mOsm/L $H_2O$) | Intracellular (mOsm/L $H_2O$) |
|---|---|---|---|
| $Na^+$ | 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 |
| $HPO_4^-$, $H_2PO_4^-$ | 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 |

# major cations and anions of the ICF and ECF

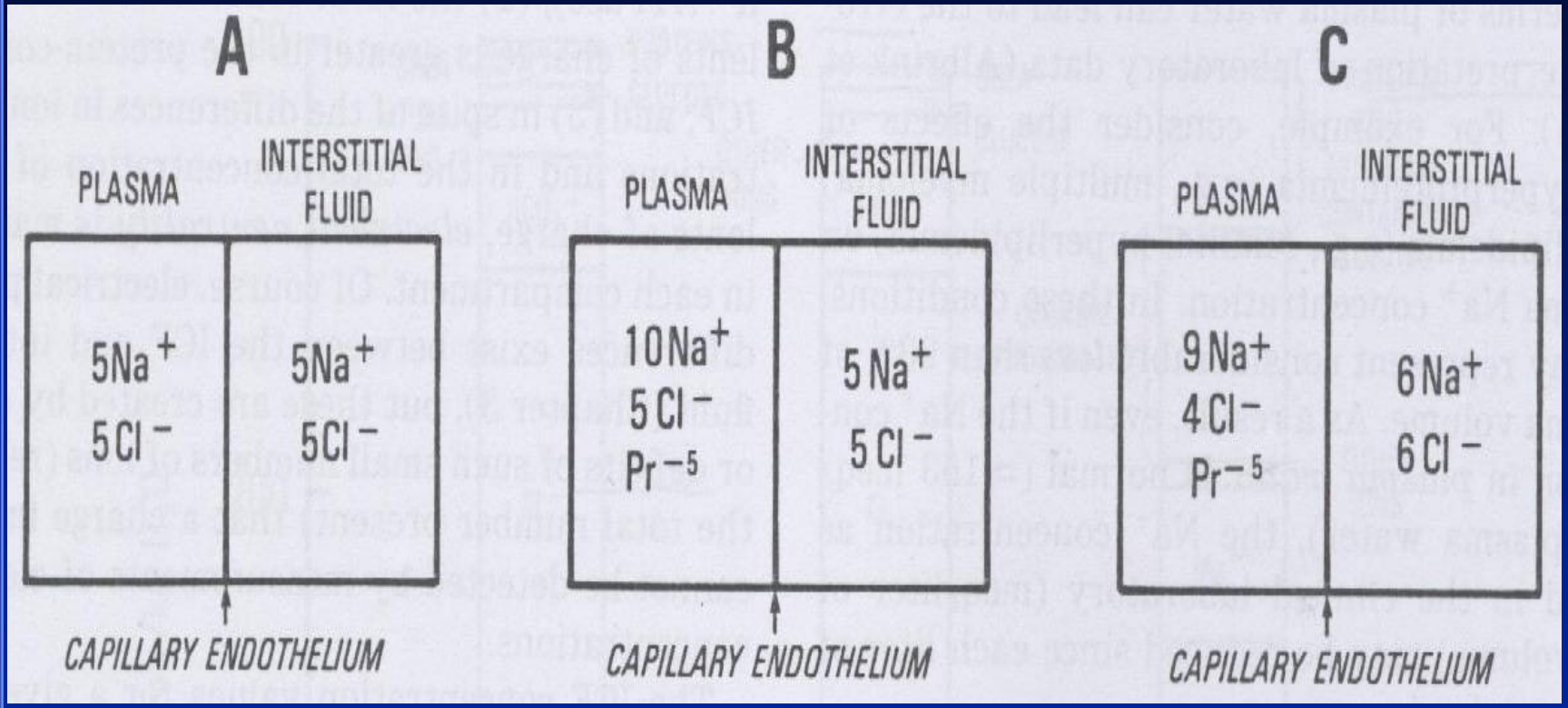


# Nonelectrolytes of the plasma



- **Ionic Composition of Plasma and Interstitial Fluid Is Similar**

# Gibbs-donan effect

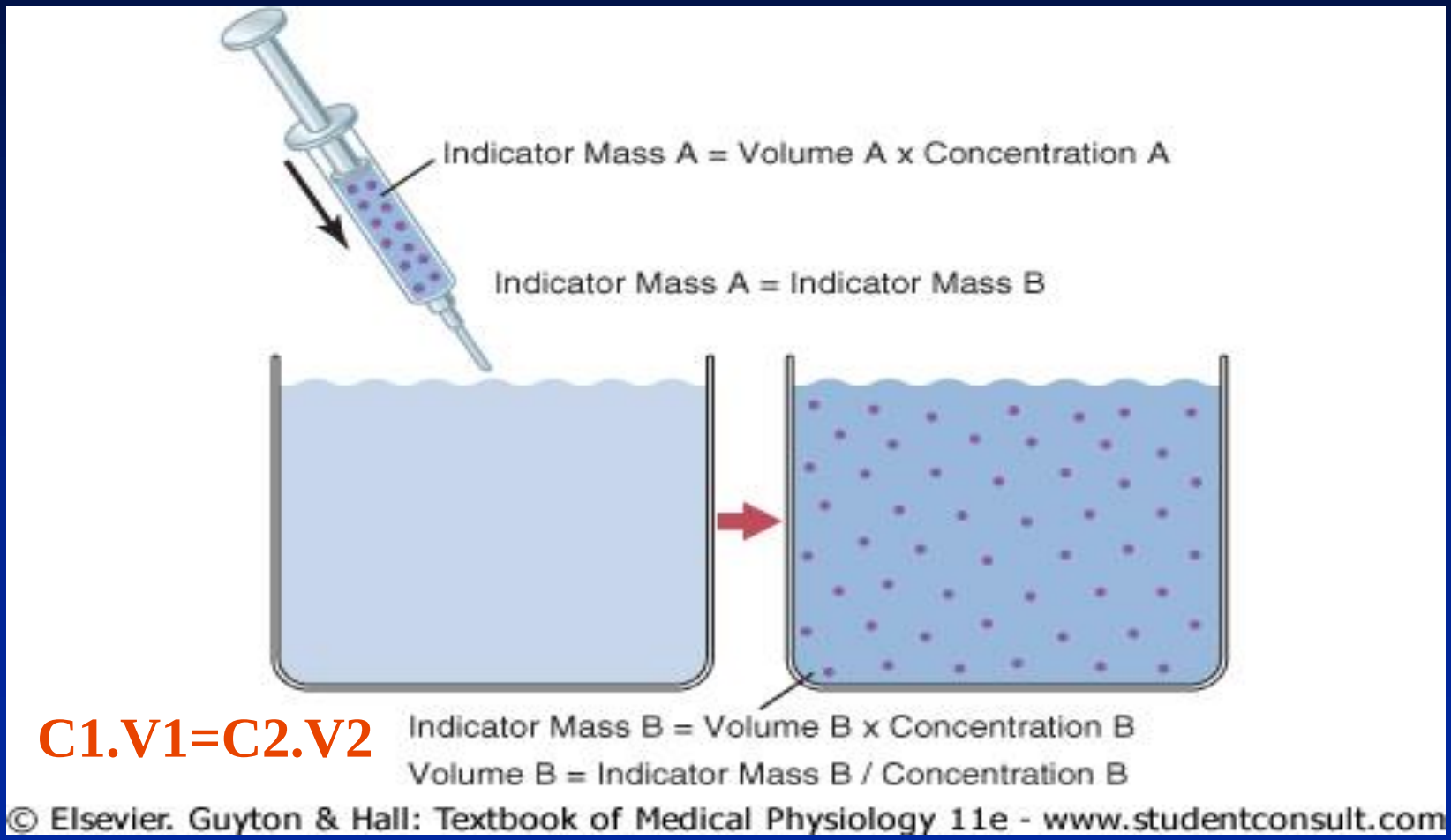



$[Na_x] \cdot [Cl_x] = [Na_y] \cdot [Cl_y]$

$(10-X)(5-X) = (5+X)(5+X)$

# Measurement of Fluid Volumes in the Different Body Fluid Compartments

## -The Indicator-Dilution Principle



# Determination of Volumes of Specific Body Fluid Compartments

- **Measurement of Total Body Water**

- Radioactive water (tritium, $^{3}H_2O$) or heavy water (deuterium, $^{2}H_2O$)

# Measurement of Body Fluid Volumes

| Volume | Indicators |
|---|---|
| Total body water | $^{3}H_2O$, $^{2}H_2O$, antipyrine |
| Extracellular fluid | $^{22}Na$, $^{125}I$-iothalamate, thiosulfate, inulin |
| Intracellular fluid | (Calculated as Total body water – Extracellular fluid volume) |
| Plasma volume | $^{125}I$-albumin, Evans blue dye (T-1824) |
| Blood volume | $^{51}Cr$-labeled red blood cells, or calculated as Blood volume = Plasma volume/ (1 – Hematocrit) |
| Interstitial fluid | (Calculated as Extracellular fluid volume – Plasma volume) |

- **Regulation of Fluid Exchange Between Extracellular and Intracellular Fluid**

- **Basic Principles of Osmosis and Osmotic Pressure**

**-Relation Between Moles and Osmoles**

**-Osmolality and Osmolarity**

## - Osmotic Pressure

## - Relation Between Osmotic Pressure and Osmolarity

$\pi = CRT$ (van't Hoff's law)

$\pi = 1\ \text{Osm/L} \times 62.26 \times 310 = 19300\ \text{mmHg}$

C: concentration of solutes in osmoles per liter

R: ideal gas constant

T: absolute temperature in degrees Kelvin (273° + centigrade°)

## - Calculation of the Osmolarity and Osmotic Pressure of a Solution

- **Osmolarity of the Body Fluids**

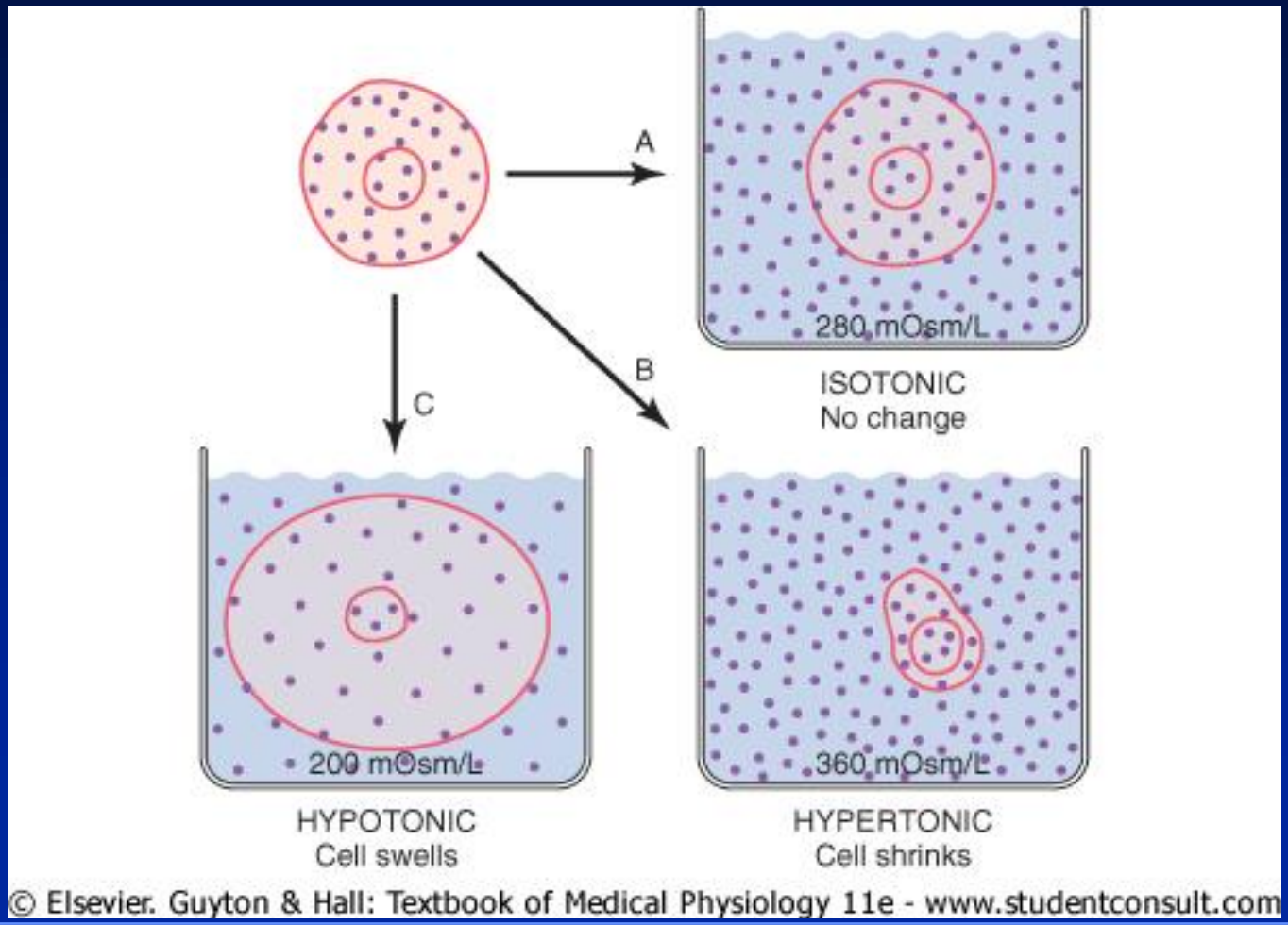
**- Corrected Osmolar Activity of the Body Fluids**

**- Total Osmotic Pressure Exerted by the Body Fluids**

- **Osmotic Equilibrium Is Maintained Between Intracellular and Extracellular Fluids**

**-Isotonic, Hypotonic, and Hypertonic Fluids**

# Effects of isotonic (*A*), hypertonic (*B*), and hypotonic (*C*) solutions on cell volume

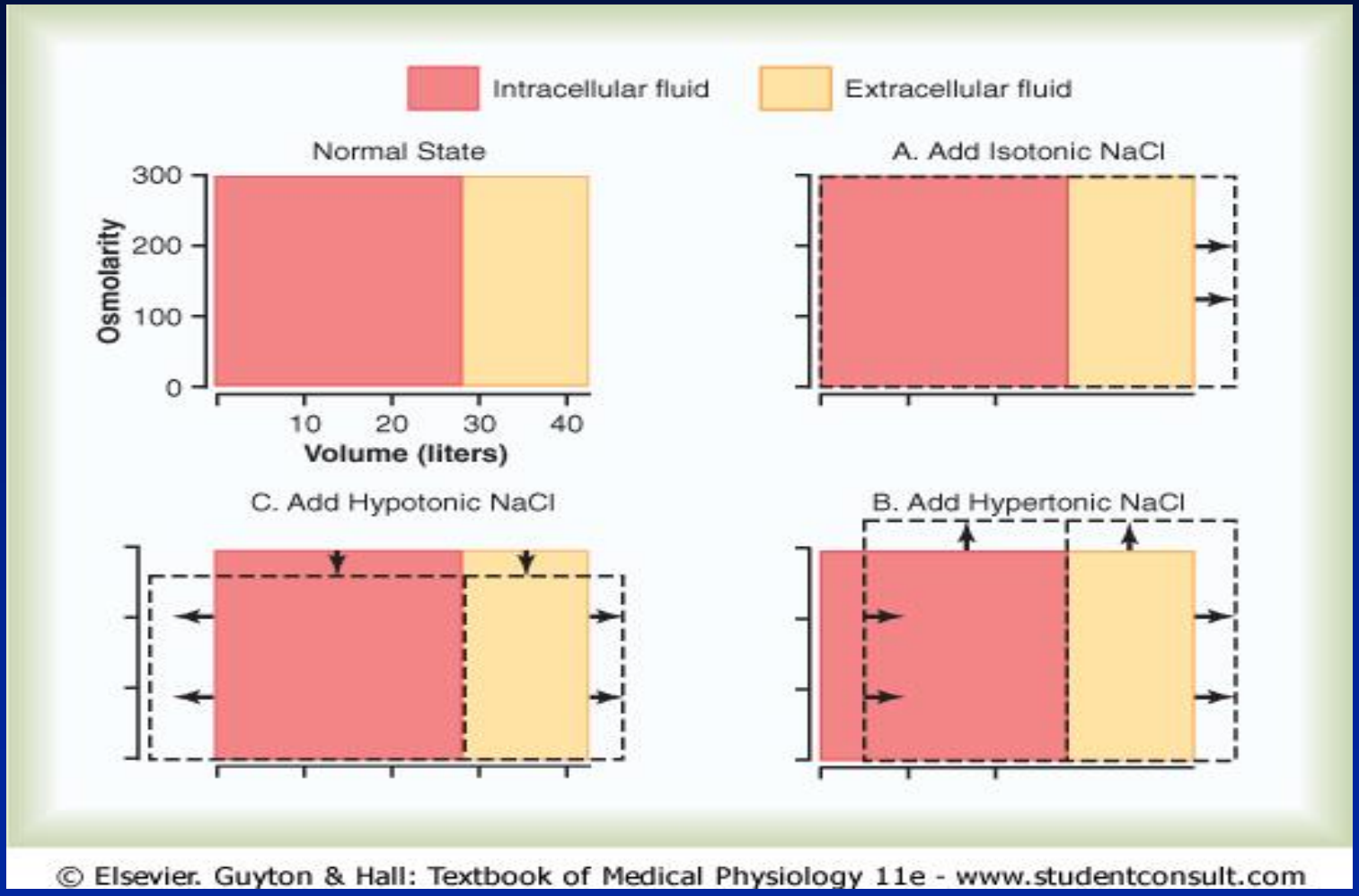


- **Isosmotic, Hyperosmotic, and Hypo-osmotic Fluids**

- **Osmotic Equilibrium Between Intracellular and Extracellular Fluids Is Rapidly Attained**

**- Effect of Adding Saline Solution to the Extracellular Fluid**

# Effect of adding different solutions to ECF after osmotic equilibrium



# Calculation of Fluid Shifts and Osmolarities After Infusion of Hypertonic Saline

**Step 1. Initial Conditions**

| | Volume (Liters) | Concentration (mOsm/L) | Total (mOsm) |
|---|---|---|---|
| Extracellular fluid | 14 | 280 | 3,920 |
| Intracellular fluid | 28 | 280 | 7,840 |
| Total body fluid | 42 | 280 | 11,760 |

**Step 2. Instantaneous Effect of Adding 2 Liters of 3.0 Per Cent Sodium Chloride**

| | Volume (Liters) | Concentration (mOsm/L) | Total (mOsm) |
|---|---|---|---|
| Extracellular fluid | 16 | 373 | 5,971 |
| Intracellular fluid | 28 | 280 | 7,840 |
| Total body fluid | 44 | No equilibrium | 13,811 |

**Step 3. Effect of Adding 2 Liters of 3.0 Per Cent Sodium Chloride After Osmotic Equilibrium**

| | Volume (Liters) | Concentration (mOsm/L) | Total (mOsm) |
|---|---|---|---|
| Extracellular fluid | 19.02 | 313.9 | 5,971 |
| Intracellular fluid | 24.98 | 313.9 | 7,840 |
| Total body fluid | 44.0 | 313.9 | 13,811 |

- **Glucose and Other Solutions Administered for Nutritive Purposes**

- **Clinical Abnormalities of Fluid Volume Regulation: Hyponatremia and Hypernatremia**

**-Causes of Hyponatremia: Excess Water or Loss of Sodium**

**-Causes of Hypernatremia: Water Loss or Excess Sodium**

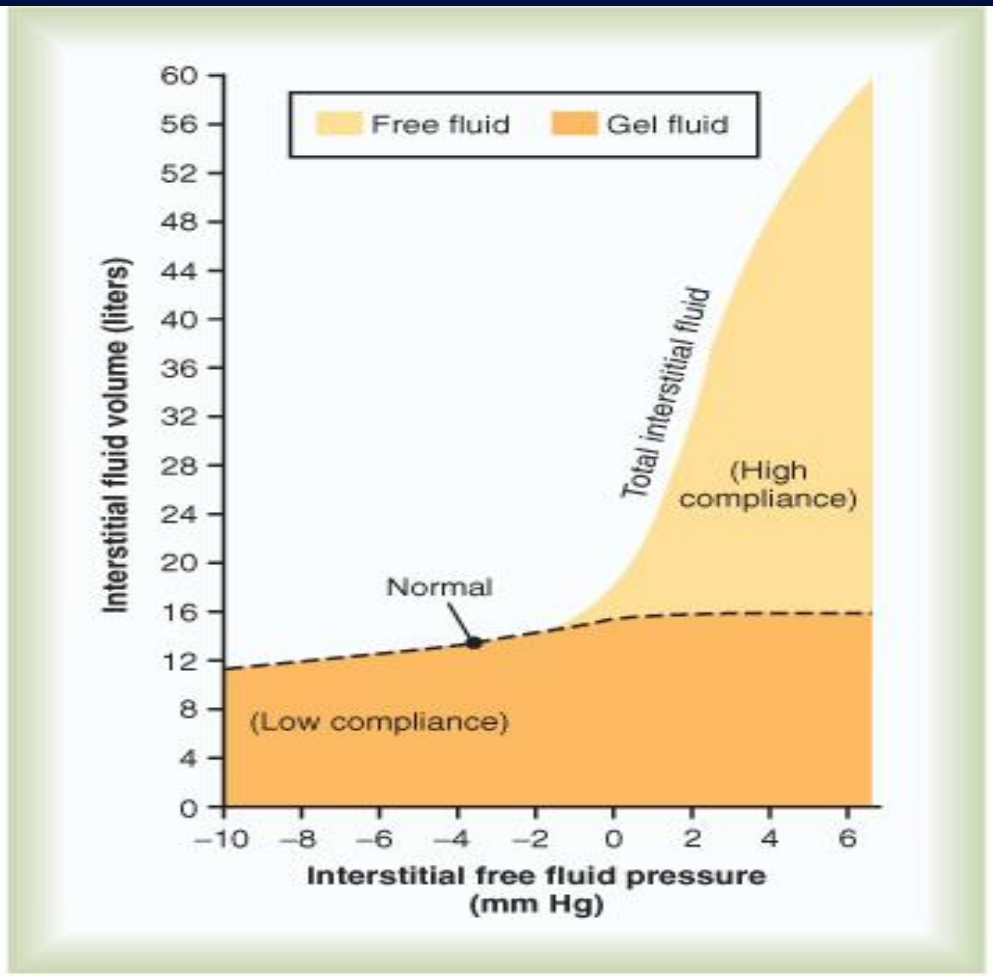
# Edema: Excess Fluid in the Tissues

- Intracellular Edema
- Extracellular Edema
- Factors That Can Increase Capillary Filtration
- Lymphatic Blockage Causes Edema

- **Edema Caused by Heart Failure**
- **Edema Caused by Decreased Kidney Excretion of Salt and Water**
- **Edema Caused by Decreased Plasma Proteins**

- **Safety Factor Caused by Low Compliance of the Interstitium in the Negative Pressure Range**

# Relationship between ISF pressure and its volume



- **Importance of Interstitial Gel in Preventing Fluid Accumulation in the Interstitium**
- **Importance of the Proteoglycan Filaments as a "Spacer" for the Cells and in Preventing Rapid Flow of Fluid in the Tissues**
- **Increased Lymph Flow as a Safety Factor Against Edema**
- **"Washdown" of the Interstitial Fluid Protein as a Safety Factor Against Edema**

- **Safety factors against edema**

1- Low compliance of intrestitume in negative pressure (3 mmHg)

2- increasing of lymph flow up to 10-50 times (7 mmHg)

3- wash out of proteins (7 mmHg)

# Fluids in the "Potential Spaces" of the Body

- Fluid Is Exchanged Between the Capillaries and the Potential Spaces
- Lymphatic Vessels Drain Protein from the Potential Spaces
- Edema Fluid in the Potential Spaces Is Called "Effusion"

# Thanks for your attention

Table 25-1 Daily Intake and Output of Water (ml/day)

| Intake or Output | Normal | Prolonged Heavy Exercise |
|---|---|---|
| **Intake** | | |
| Fluids ingested | 2100 | ? |
| From metabolism | 200 | 200 |
| Total intake | 2300 | ? |
| **Output** | | |
| Insensible: skin | 350 | 350 |
| Insensible: lungs | 350 | 650 |
| Sweat | 100 | 5000 |
| Feces | 100 | 100 |
| Urine | 1400 | 500 |
| Total output | 2300 | 6600 |