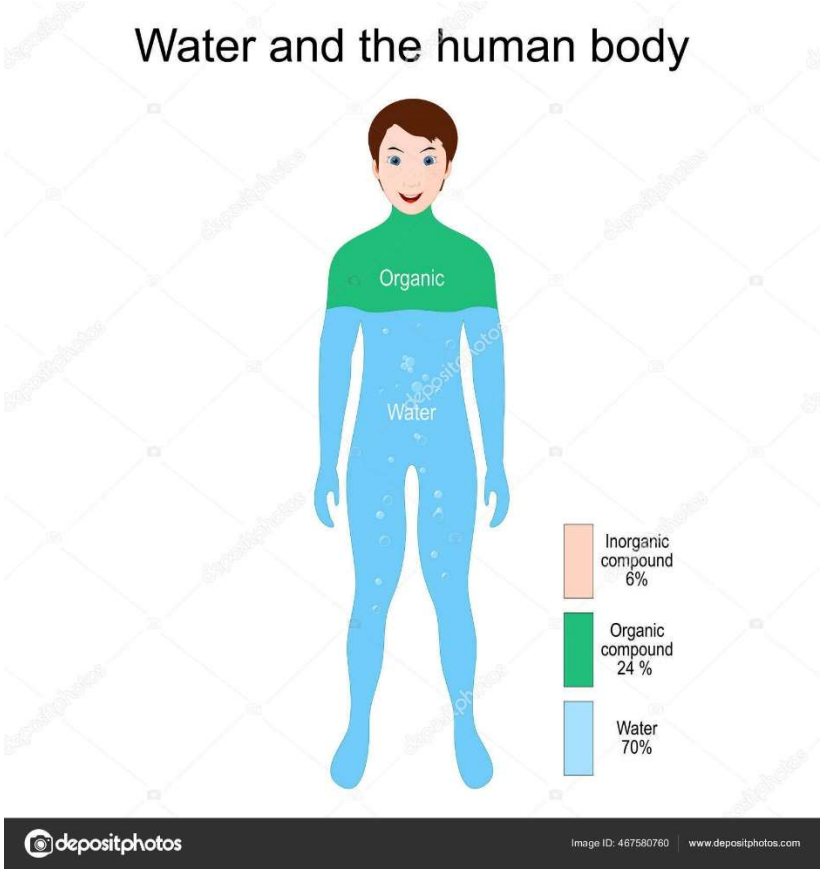
Water And Electrolytes Balance And Imbalance In Human Body

Diyah Candra Anita

BODY WATER

- Water is the chief constituent of human body.
- Water is the chief solvent of body.
- Water comprises 60-70% of total body weight
- Human body cannot exist without Water



Sources Of Body Water

ENDOGENOUS SOURCES

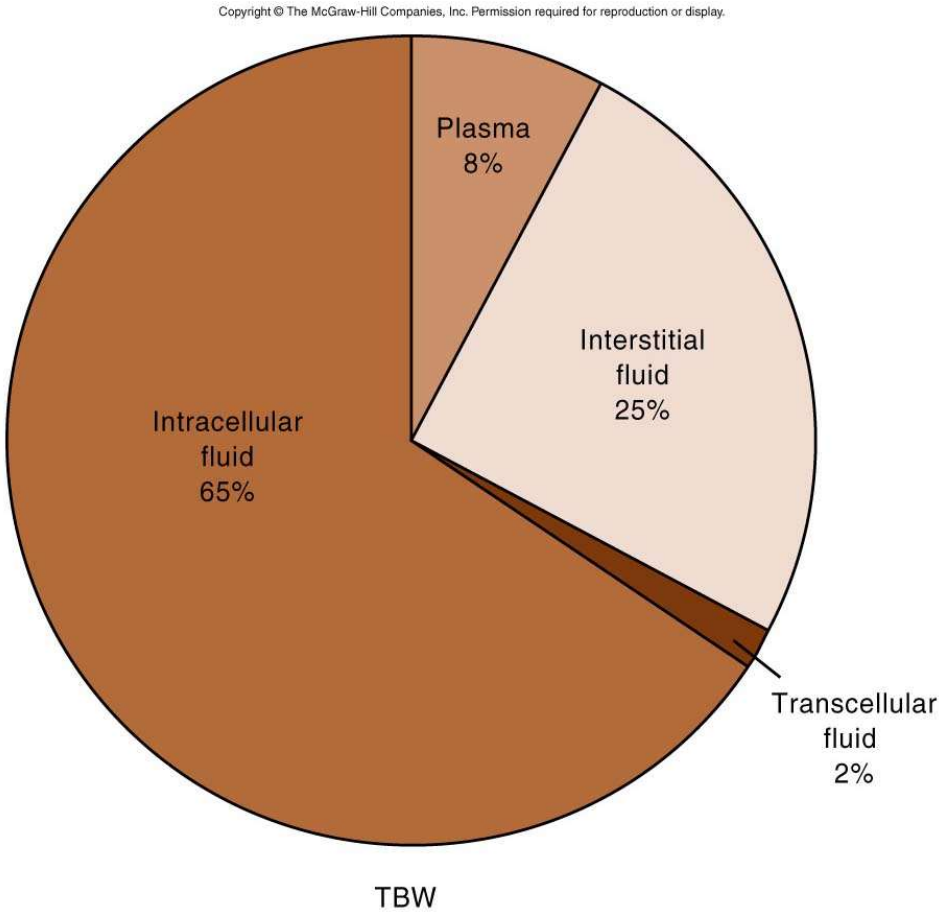
- Drinking Water, Beverages →1000-1500 ml
- Water from Cooked Foods
- Water intake through mouth is highly variable 1-5 Liters this depend on :
    - Social habits
    - Climatic condition

EXOGENOUS SOURCES

- Metabolic Water - 400 ml
- Produced during metabolism oxidation of food substances.

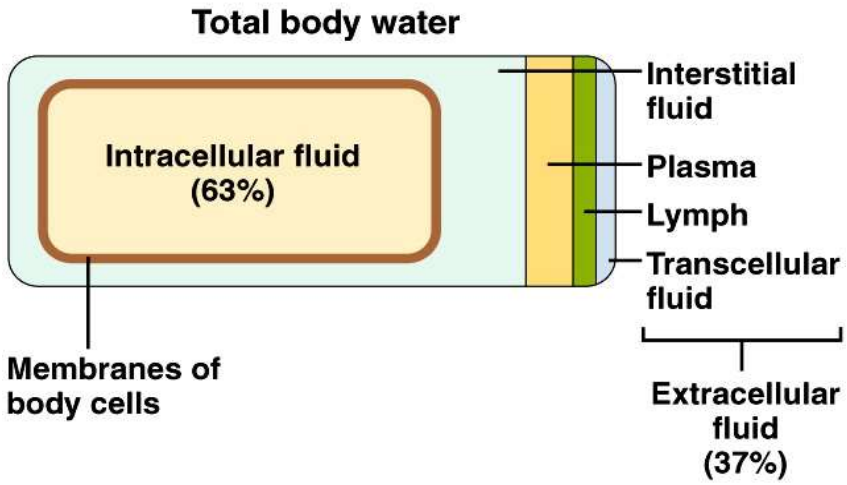
(At end of ETC Process)

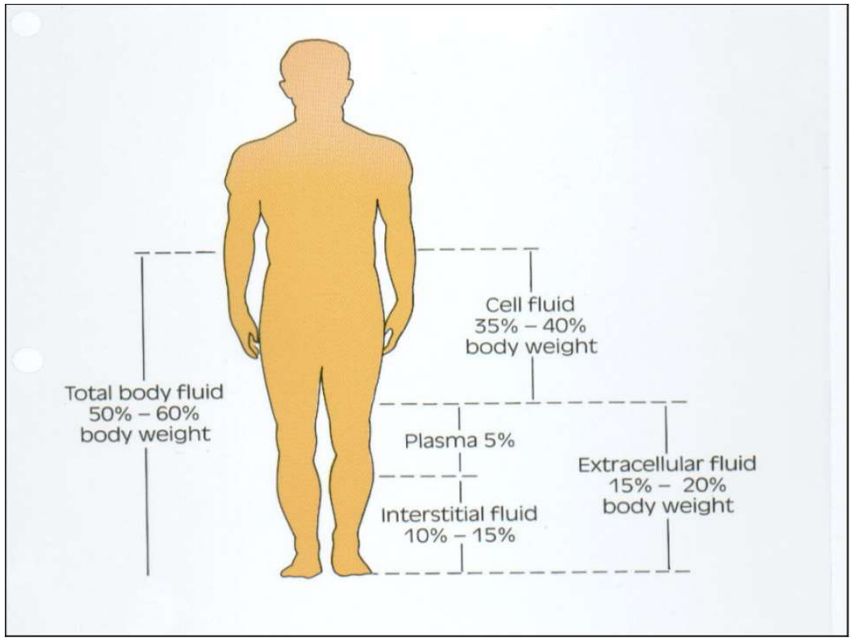
Distribution Of Body Water

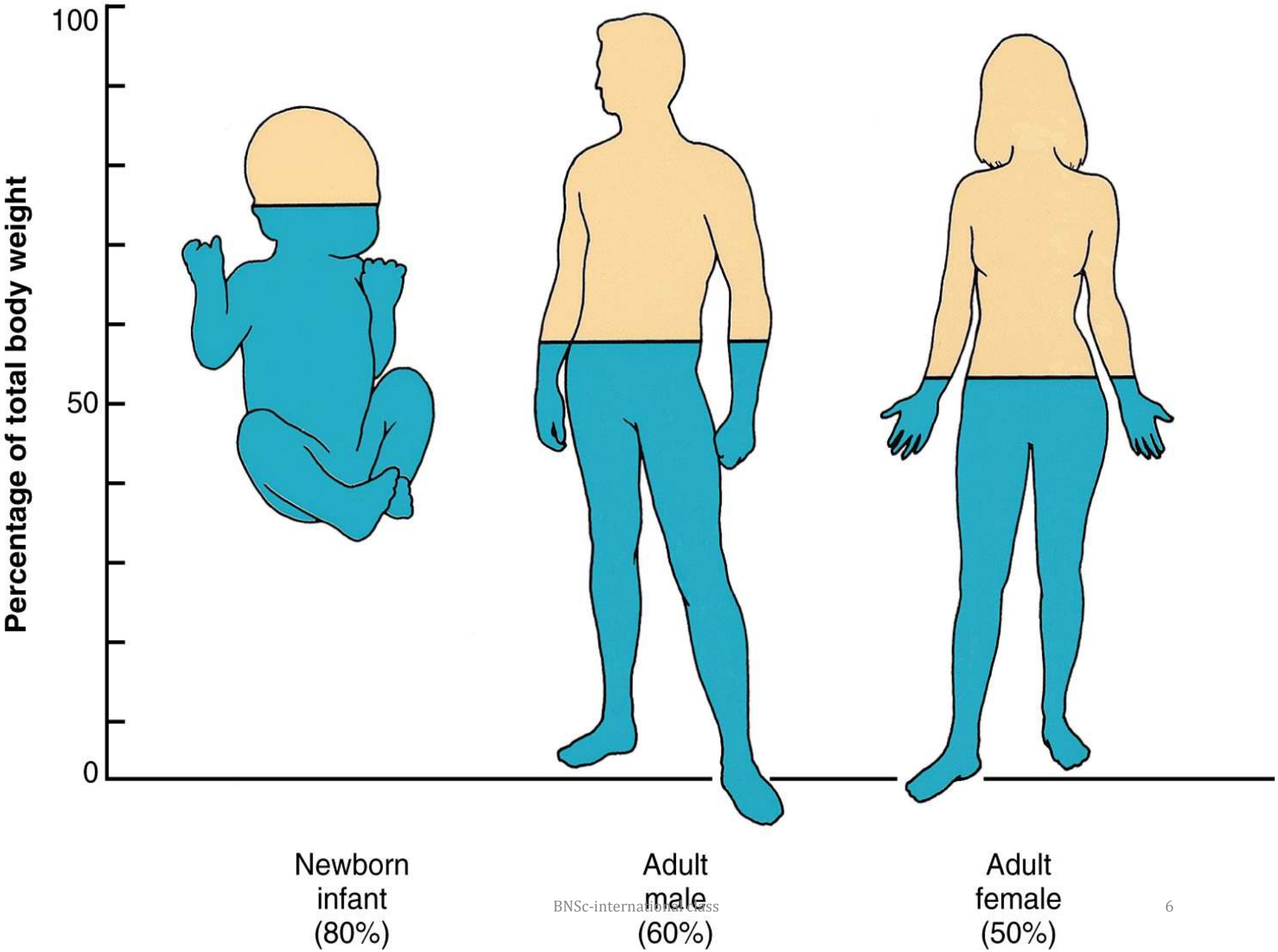


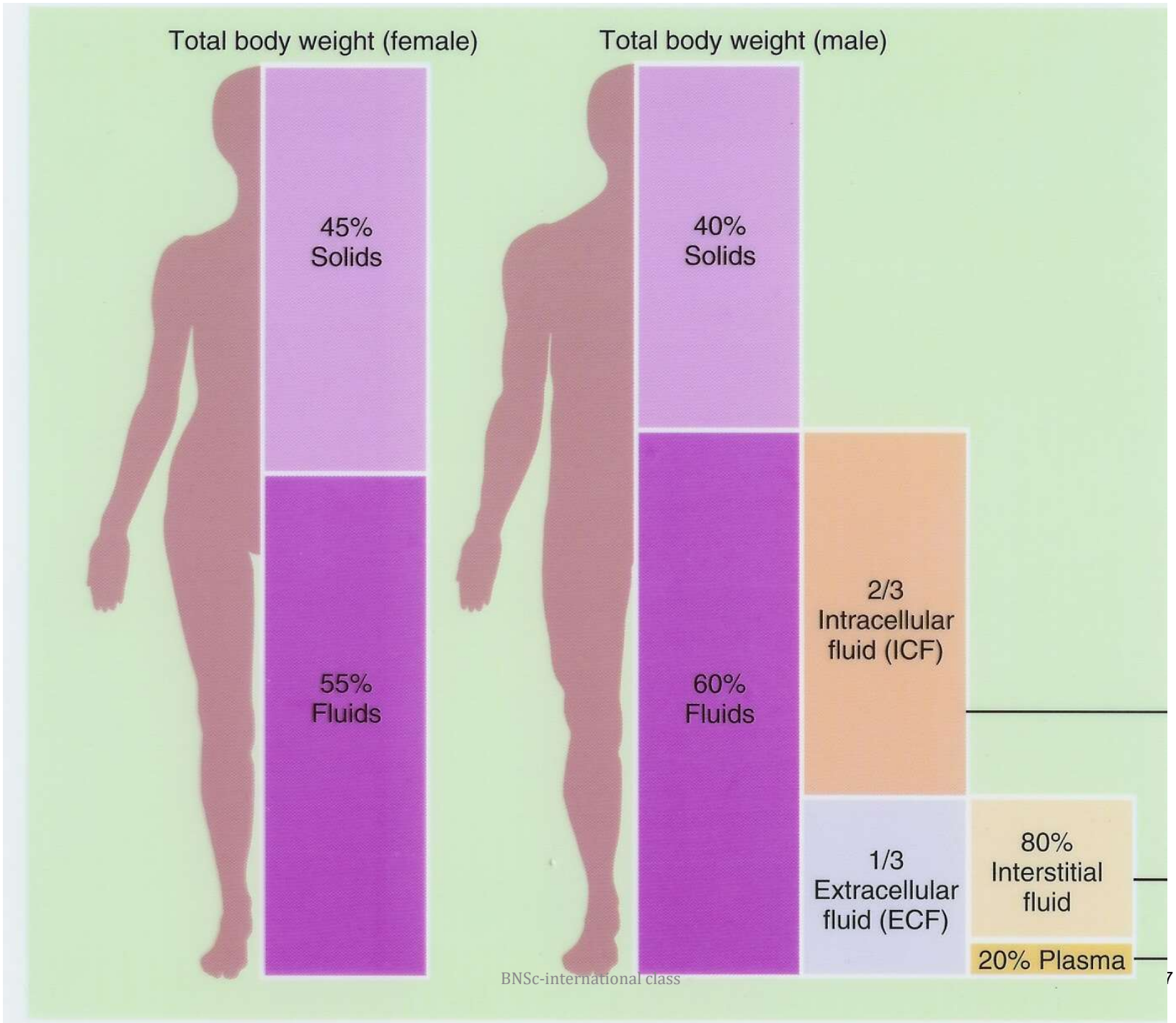
In an adult of 70 kg body

- Total Body Water : 60-70% /36-49 Lt
- Intracellular Fluid : 65% - 35 L
- Extracellular Fluid : 35% - 14 L
  - Interstitial Tissue Fluid : 25% - 11L
  - Plasma /Intra Vascular Fluid : 8% - 3L
  - Transcellular Fluid : 2%






Percentage of total body weight
100
50
0
Newborn infant (80%)
Adult male (60%)
Adult female (50%)


Total body weight (female)
45%
Solids
55%
Fluids
Total body weight (male)
40%
Solids
60%
Fluids
2/3
Intracellular
fluid (ICF)
1/3
Extracellular
fluid (ECF)
80%
Interstitial
fluid
20% Plasma

Question

- Body water content in percentage of a body weight is lowest in :

  (A)Well built man

  (B) Fat woman

  (C)Well nourished child

  (D) Fat man

Functions Of Body Water

- Involved in Biochemical reactions
  - Water act as reactant in many hydration
  - Hydrolytic reactions of metabolic pathways.
- Transporting media of body:
  - Transportation of nutrients and waste metabolites through aqueous media of blood and tissue floods.
- Regulates body temperature
- Water transports Hormones, Enzymes, blood platelets, and red and white blood cells
- Water act as a solvent for Electrolytes and Non electrolytes
- Water Facilitates Digestion and promoting Elimination of ingested food
- Water serve as a tissue Lubricant

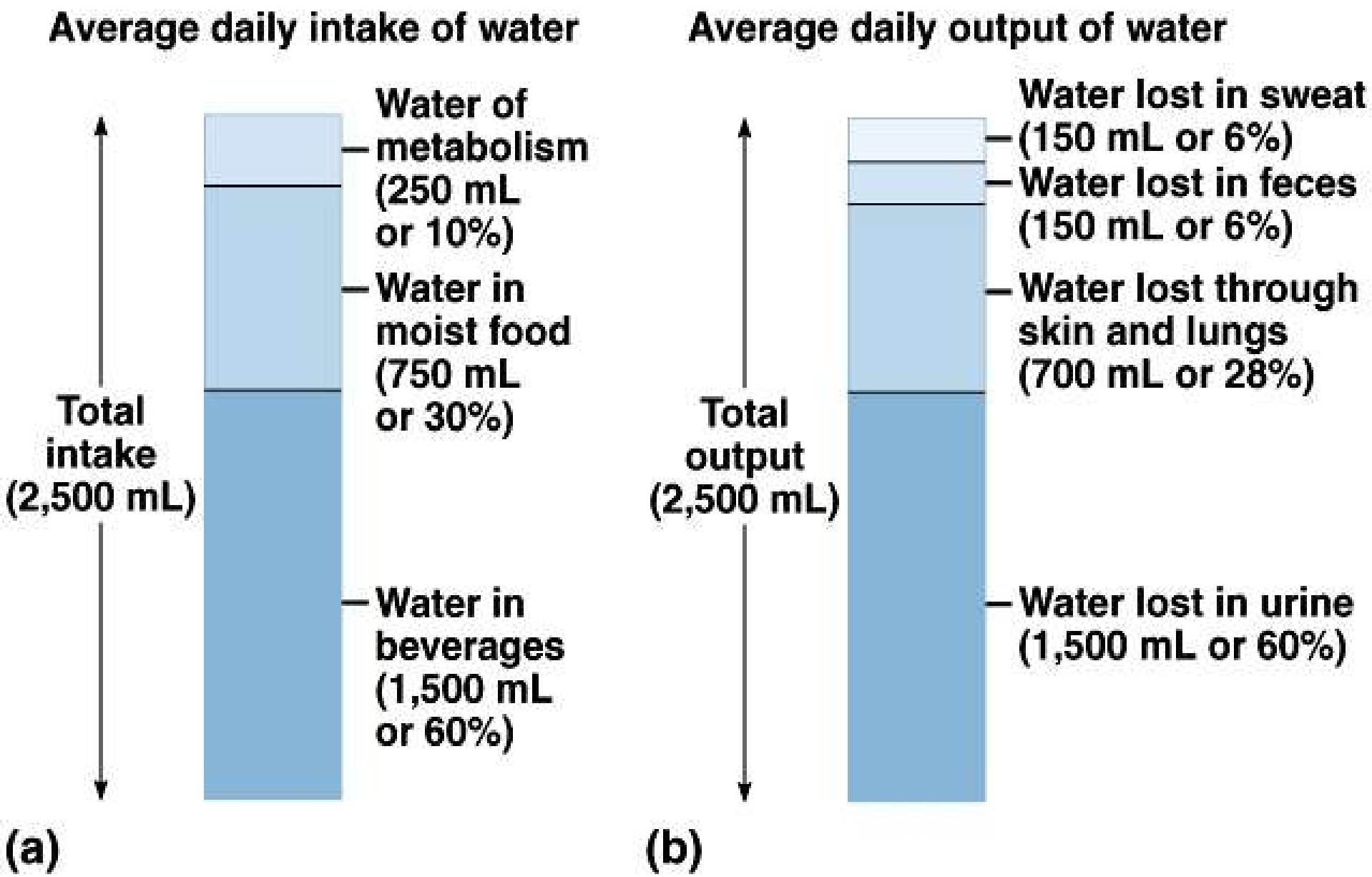
Body Water Input and Output

Body Water Input

- Body can gain water by
  - **Ingestion** of liquids and moist foods (**2300mL/day**)
  - **Metabolic** synthesis of water during cellular respiration **(200mL/day)**

Body Water Output

- Body losses water through:
  - Kidneys (1500mL/day)
  - Evaporation from Skin (600mL/day)
  - Exhalation from Lungs (300mL/day)
  - Feces (100mL/day)


Average daily intake of water
Water of metabolism (250 mL or 10%)
Water in moist food (750 mL or 30%)
Total intake (2,500 mL)
Water in beverages (1,500 mL or 60%)
(a)
Average daily output of water
Water lost in sweat (150 mL or 6%)
Water lost in feces (150 mL or 6%)
Water lost through skin and lungs (700 mL or 28%)
Total output (2,500 mL)
Water lost in urine (1,500 mL or 60%)
(b)

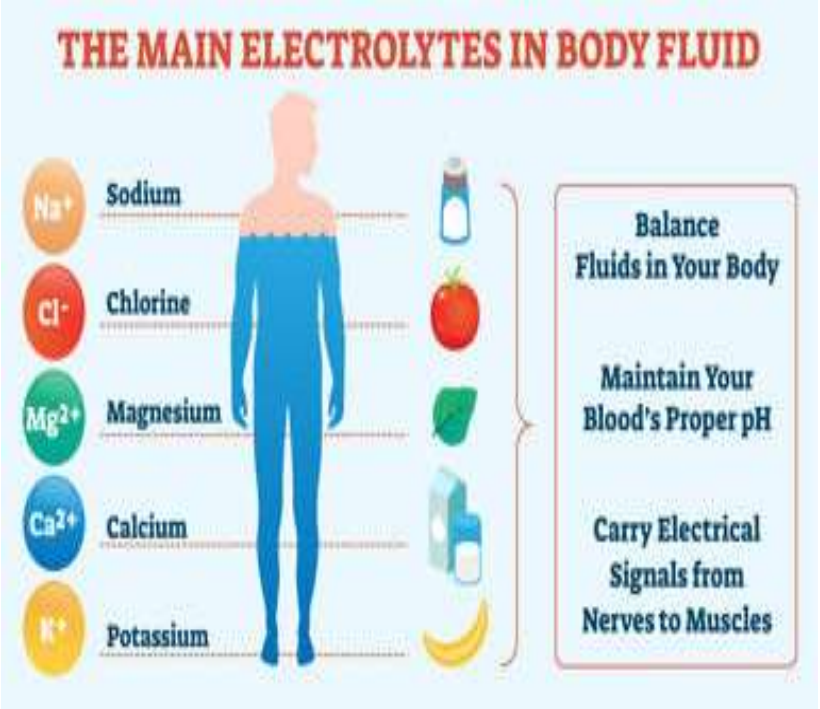
BODY ELECTROLYTES

What Are Electrolytes?

- Substance when dissolved in solution **dissociates into ions**
- These ions are able to **carry an electrical current**
- **An Electrolyte** is a substance
- Which **develops an electrical charge when dissolved in water**

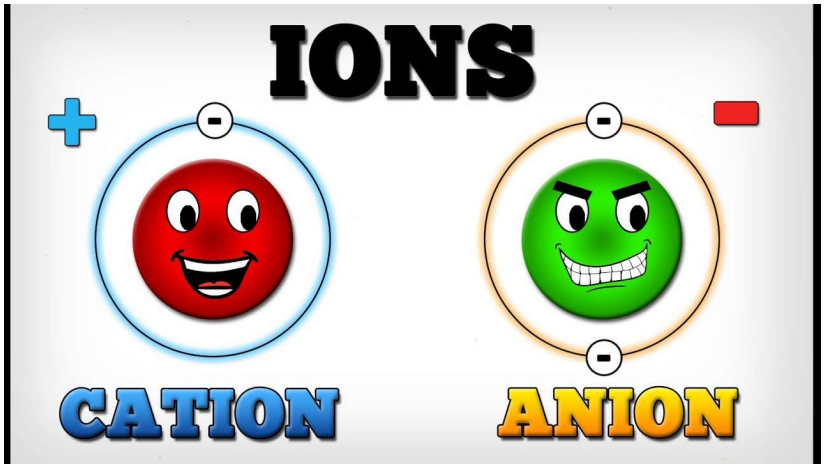
Body Electrolytes

- Salts like **NaCl** and **KCl** in aqueous solutions gets dissociated to
- **Charged ions Na^+ and Cl^- called as Electrolytes.**
- The **concentration of these Electrolytes is expressed** as **mEq/L.**



Types Of Electrolytes

- **CATION -** Positively charged Electrolyte
- **ANION -** Negatively charged Electrolyte
- **Water molecules completely surround these dissociated ions**
- These **prevents union of Cations and Anions.**



Electrolytes In Body Fluid Compartments

INTRACELLULAR Electrolytes	EXTRACELLULAR Electrolytes
POTASSIUM	SODIUM
MAGNESIUM	CHLORIDE
PHOSPHOROUS	BICARBONATE

To Maintain Electrical Neutrality In Each Fluid Compartments

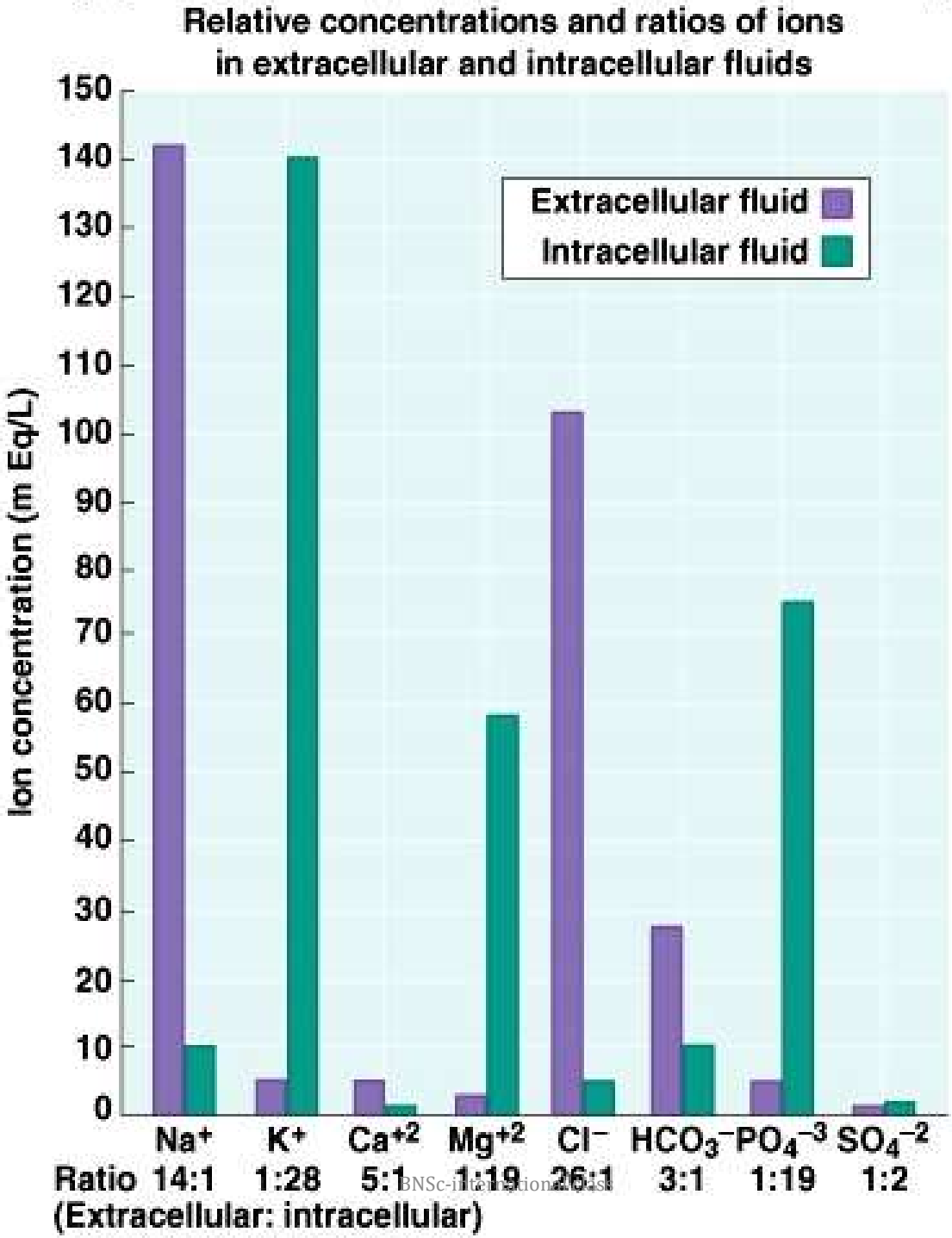
Number Cations
=
Number Anions

ECF Cations	ECF Anions
Na^+ (140 mEq/L)	Cl^- (103 mEq/L)
K^+	$HCO3^-$
Ca^+	$HPO4^{--}$
Mg^+	$SO4^{--}$
Total Cations 155 mEq/L	**Total Anions 155 mEq/L**

Predominant Cations and Anions of ECF:
Na^+ and Cl^- respectively.

ICF Cations	ICF Anions
Na^+	Cl^-
K^+ (150 mEq/L)	$HCO3^-$
Ca^+	$HPO4^{--}$ (140 mEq/L)
Mg^+	$SO4^{--}$
Total Cations 195 mEq/L	**Total Anions 195 mEq/L**

Thus the predominant Cations and Anions of ICF
K^+ and $HPO4^{--}$ respectively.


Relative concentrations and ratios of ions
in extracellular and intracellular fluids
Ion concentration (m Eq/L)
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
Extracellular fluid
Intracellular fluid
Na+
K+
Ca+2
Mg+2
Cl−
HCO3−
PO4−3
SO4−2
Ratio 14:1 1:28 5:1 1:19 26:1 3:1 1:19 1:2
(Extracellular: intracellular)

Electrolyte and protein anion concentrations

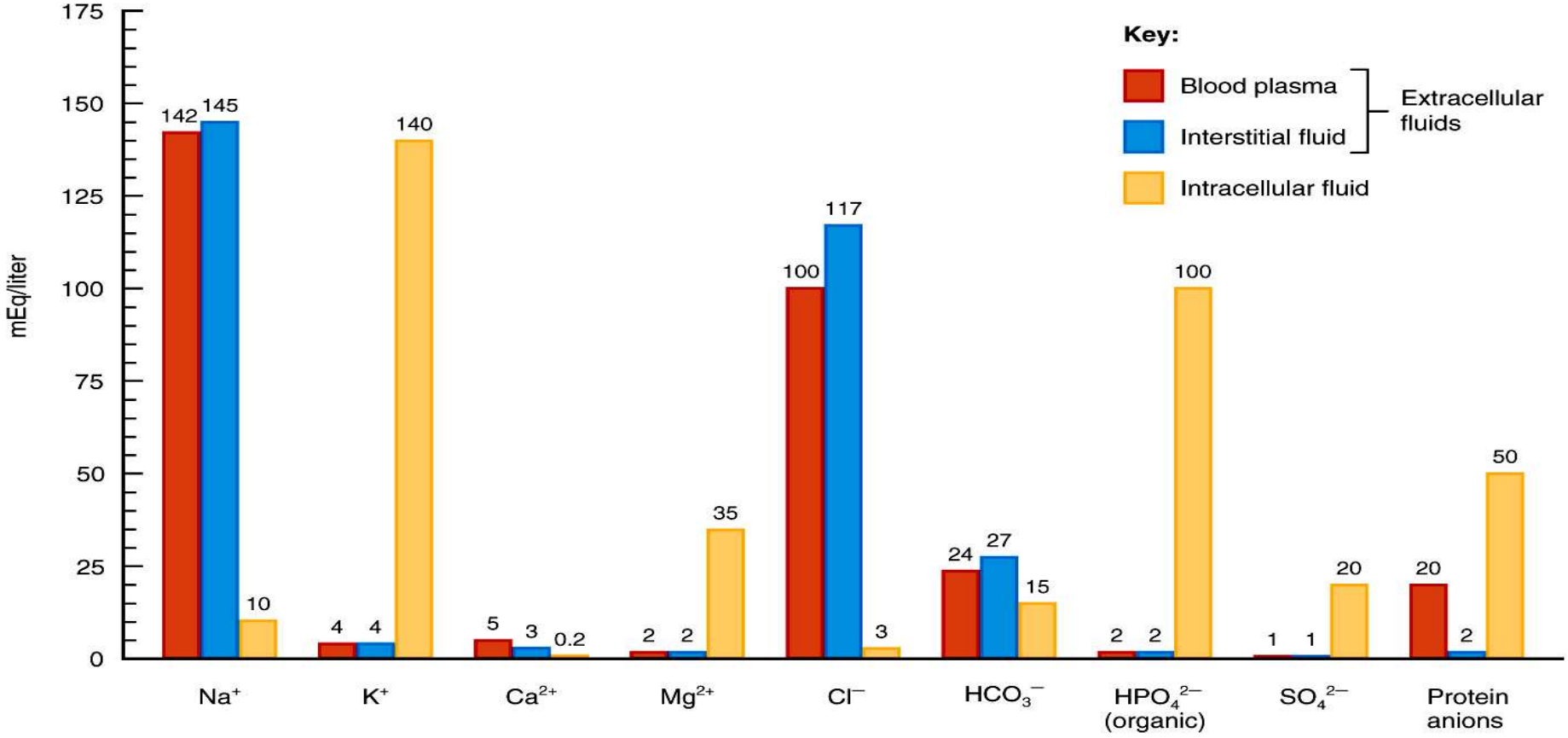
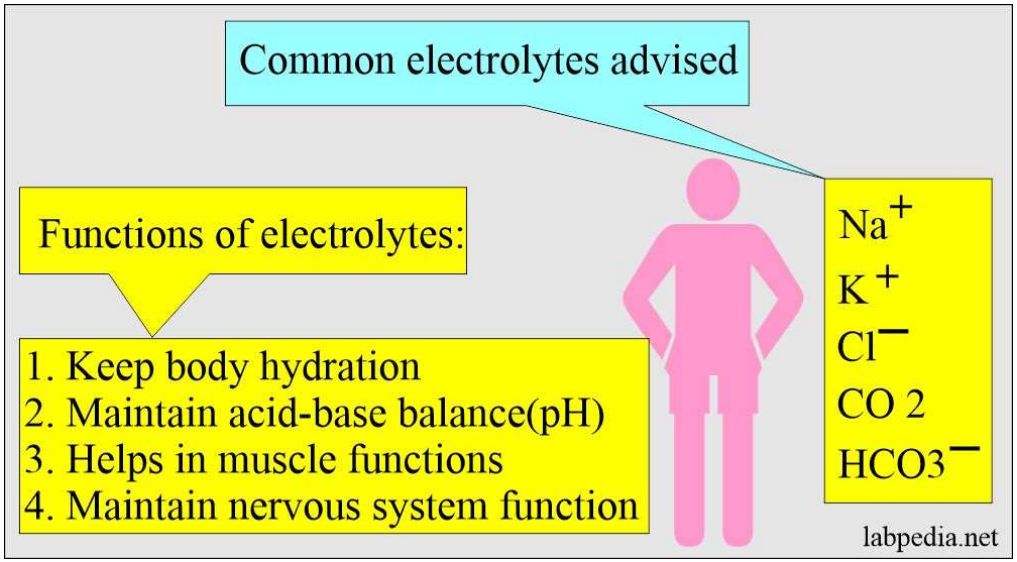


Figure 27.06 Tortora - PAP 12/e

Functions Of Body Electrolytes

- **Electrolytes are well distributed in the body compartments.**
- Electrolytes in the medium/compartments **produce osmotic pressure.**
- This osmotic pressure **helps in maintaining water balance.**



Electrolytes

- **Na^+:** Most abundant electrolyte in the ECF.
- **K^+:** Essential for normal membrane excitability for nerve impulse
- **Cl^-:** Regulates osmotic pressure and assists in regulating acid-base balance
- **Ca^{2+}:** Promotes nerve impulse and muscle contraction/relaxation
- **Mg^{2+}:** Plays role in carbohydrate and protein metabolism, storage and use of intracellular energy and **neural transmission. Important in the functioning of the heart, nerves, and muscles**

Movement of Water and Electrolytes

- **Diffusion –** movement of particles down a concentration gradient.
- **Diffusion:** the random movement of particles in all directions through a solution

- **Osmosis:** movement of water across a membrane from a less concentrated solution to a more concentrated solution
- **Osmosis –** diffusion of water across a selectively permeable membrane

Osmolarity: The number of moles **per liter of solution**

Osmolality: The number of moles **per Kg of Solvent.**

Important

- **Sodium** and its associated ions in plasma make the **largest contribution** (90%) for **plasma Osmolality.**

- **Osmolality is measured by Osmometer**

- **Osmolality:** concentration of a solution determined by the number of dissolved particles per kilogram of water.

- **Osmolality controls water movement and distribution in body fluid compartments**

Active transport

- Movement of solutes across membranes;
- **Requires transporters** and **expenditure of energy**
- Movement of particles **is up a concentration gradient**

Filtration

- Transfer of water and solutes through a membrane
- From a **region of high pressure to a region of low pressure**

Normal Fluid and Electrolytes Exchanges In Body

- **Water And Electrolytes Movement INN and OUT of Cells.**
- Normally in a healthy body there **is osmotic equilibrium maintained in each compartment.**
- In a healthy body the **semipermeable cell membrane → Allows only passage of Water but not Electrolytes through it**

- **Disturbance in osmotic equilibrium of compartments :**
  - **Draws water from the compartment** with **lower osmotic pressure (Hypotonic)**
  - **Into the compartment with higher osmotic pressure (Hypertonic)**

→ Until equilibrium is restored

- In the **concentration gradient of K^+ and Cl^-**
  - **K^+ tends to diffuse out of the cells** and **Cl^- enters into cells.**

- During difference **in electrical potential**
  - For example **in relative negativity inside the cells**
  - **There tend to keep Cl^- out and K^+ inn.**

•Remember

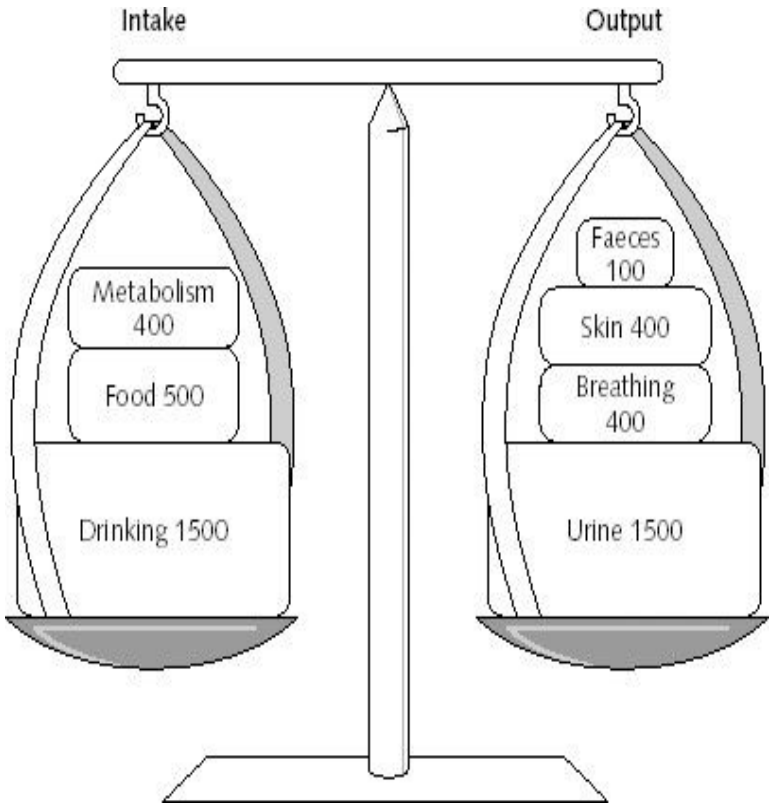
- Cells do not allow accumulation of Na^+
- **Na rapidly enters in the cells**
- **By the Sodium pump, Na is effectively extrudes out from ICF**
- **By active transport of Na out of cells.**
- However in case of Na^+ diffusion into cells
  - It is **favored by both the concentration gradient and electrical potential.**
- **Where Sodium goes, Water follows**

Homeostasis Of Body Water
OR
Regulation Of Body Water

Water Balance

- An **healthy adult individual always try**
  - **To maintain water balance** by the homeostatic mechanisms.
- Since **Water balance is vital for human body**
- A body is said to be in **water balance In a day**
  - When the amount of **water intake in the body is equal**
  - **To the amount of water output by that body**
- A healthy body tries to regulate the body water
  - **Proportionately distribute the water in ICF and ECF**

Electrolyte Balance



Water Input 2100ml	=	Water Out put 2100 ml
Drinking Water 1000 ml		Urine 1000 ml
Cooked Foods 700 ml		Feces 100 ml
Metabolic Water 400 ml		**Insensible loss** Skin Feces 100 Ml - 600 ml Lungs 400 ml

Electrolyte Balance

- Healthy body obeys the **law of electrical neutrality.**
  - Fluid in any body compartment **contain, equal number of Cations and Anions**.
- **Specific concentrations of Electrolytes** in the body compartments are of most important
  - **In distribution and retention of body water.**
- In healthy state **the Osmotic pressure due to Cations** is **equal to the osmotic pressure due to Anions.**
  - Which is **predominantly due to equal concentrations of Cations and Anions in each compartment.**

Factors Regulating Water And Electrolyte Balance

- In human body **Water and Electrolytes go togetherly**.
- That means the **osmotic equilibrium created by Electrolytes help in maintaining water balance.**
- If there is **imbalance in Electrolytes it directly affects Water balance.**
- Since the **Electrolytes and Water balance go hand in hand in human body**.
- Hence **factors regulating the water and electrolytes are same.**

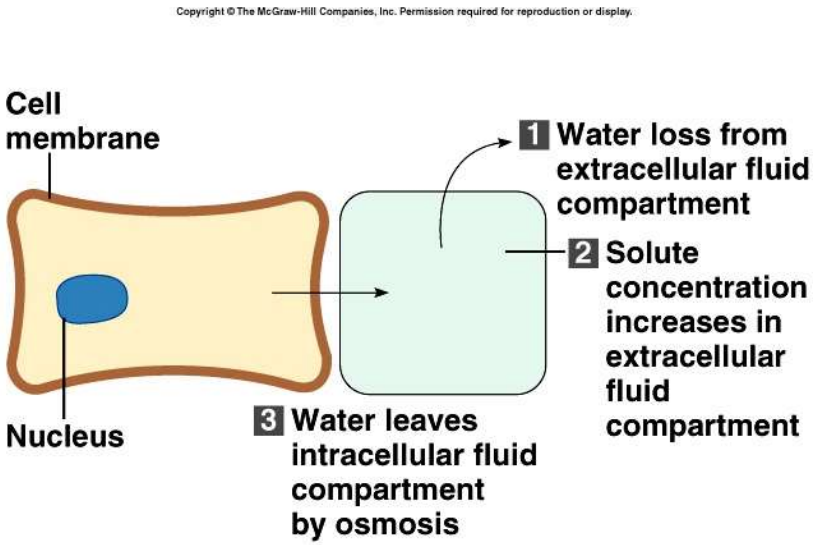
Homeostasis of Water And Electrolytes Is Maintained By

Solute Homeostasis Maintained by:

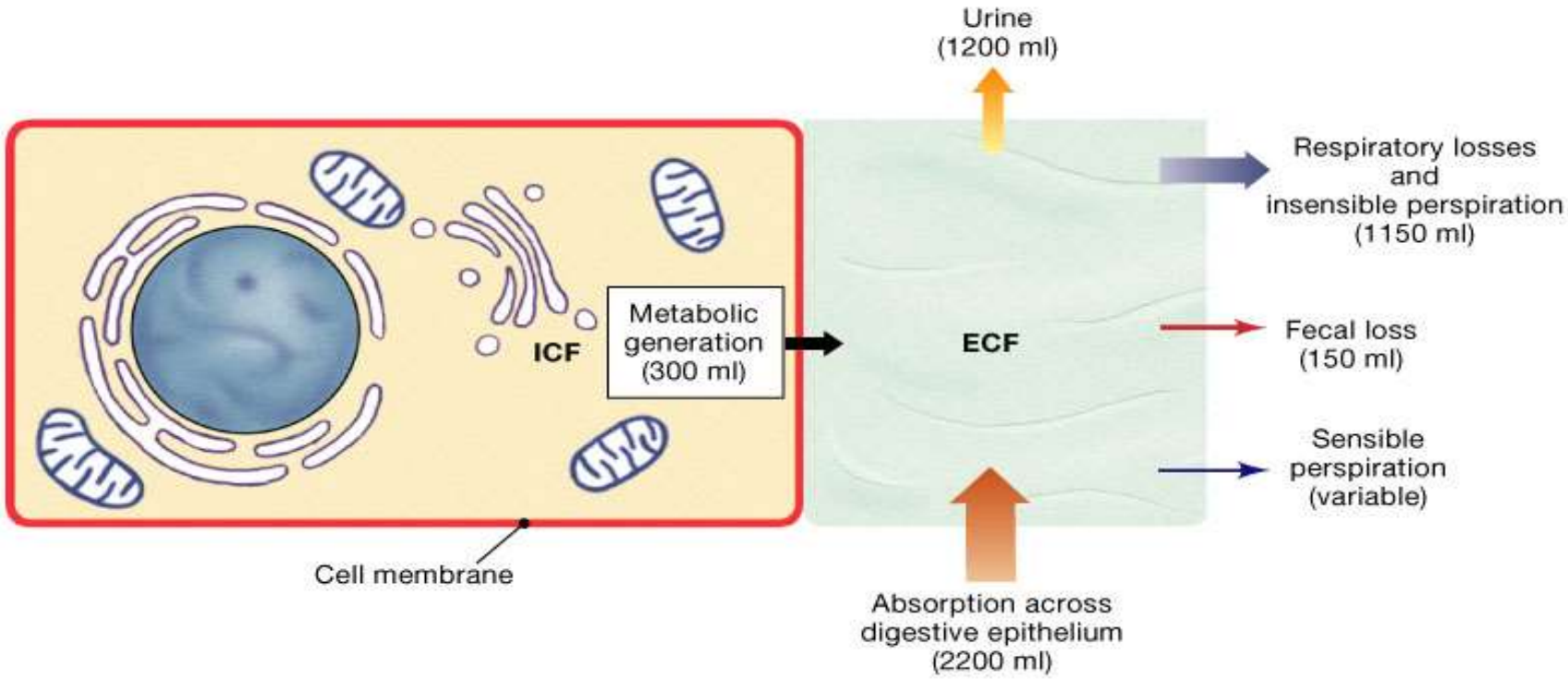
- Ion transport
- Water movement
- Kidney function

These functions act to keep body fluids:

- Electrically neutral
- Osmotically stable



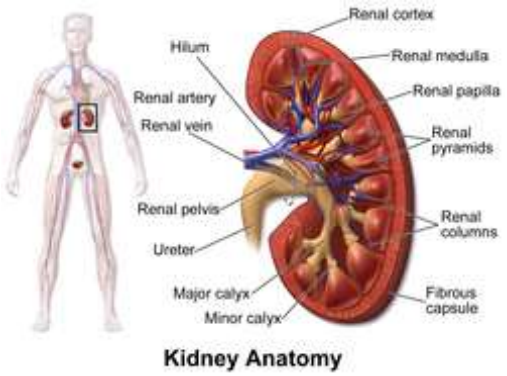
Fluid Exchanges



A body consume fluids and food items variably depending upon habits and climatic condition.

Intake of water and electrolytes is rarely proportional.

Kidneys play a predominant role



Kidney Anatomy

- In **regulating water and electrolyte balance** in the body normally.

Kidneys play role to excrete
Excess water through urine (Dilute form of Urine)

OR

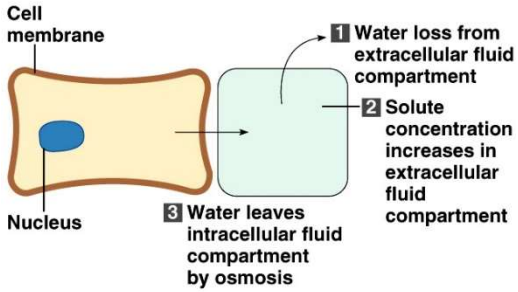
Excess Electrolytes through urine (Concentrated form of Urine)

Biochemical Factors Regulating Water And Electrolyte Balance

- Neural Mechanism- Thirst Mechanism
- Antidiuretic Hormone/Vasopressin
- Renin Angiotensin System
- Aldosterone
- Atrial Natriuretic Peptide(ANP)
- Kinins (Increases Salt and Water excretion)

1. Neural Mechanism/Thirst Mechanism Regulate Low Body Water

- When the **body water is lowered due to:**
  - **No intake of fluids**
  - **Body fluids lost through obligatory losses (Urine and Feces).**
- This leads to **decrease in volume of body fluids with respect to solutes** and **rise in osmotic pressure**

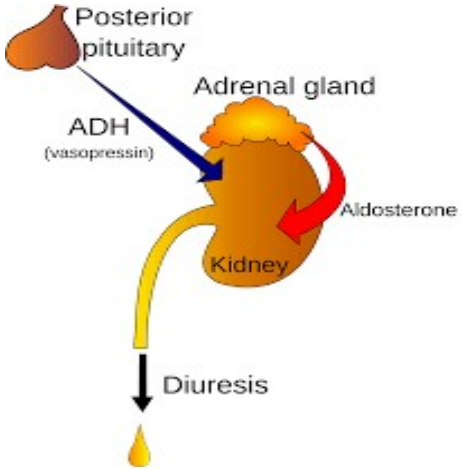


- The **ECF volume decreases and becomes hypertonic**.
- This **tends to draw water from ICF causing cellular dehydration**.

The **cellular dehydration stimulates The thirst centre located in hypothalamus.**

- In response to the stimulus to thirst center
  - **There occurs dryness of mouth and Pharynx .**
  - Feeling of thirst makes drink water
  - **Water ingested orally quench** the **thirst to regulate the body water**

2. Antidiuretic Hormone (ADH)/Vasopressin



- Anti Diuretic Hormone(ADH) is **produced in Hypothalamus**
  - **Stored in posterior pituitary gland**
- **An increase in Osmolality** (**Na^+ conc**) of plasma
  - **Promotes ADH secretion and vice versa**.
- **ADH** is **water conservation hormone**
  - It **acts on renal collecting tubule**
  - **For reabsorption of water by renal tubules**

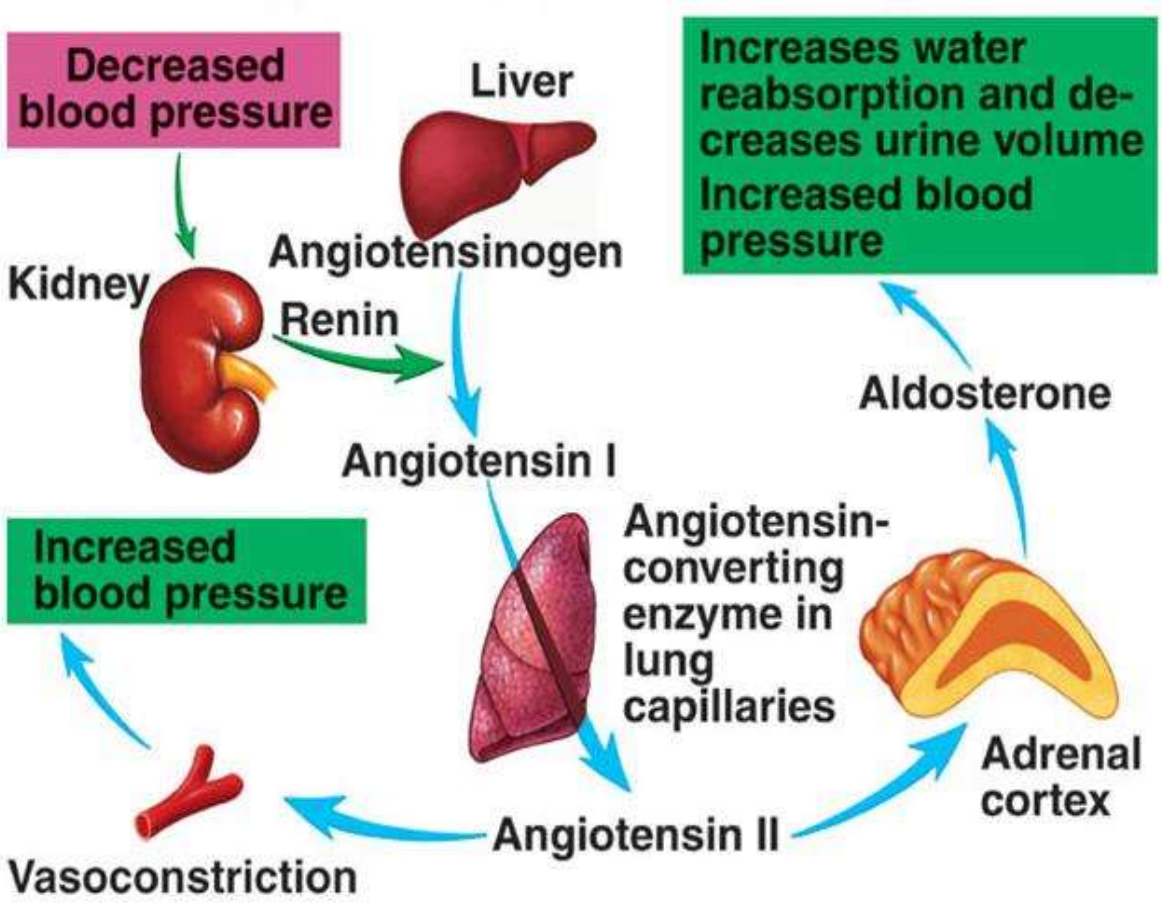
- **Role Of Anti Diuretic Hormone (ADH)**
  - When the **body water is depleted**
  - ADH exerts **Antidiuretic effect**

ADH affects renal tubules
Provides for the **facultative reabsorption of water from distal tubules.**

- **Urine output will be lower**
- **Urine concentration will be increased**
- **Body water will be maintained**

3. Renin Angiotensin Mechanism

- Renin-Angiotensin System works when the:
  - Blood volume is low
  - Blood pressure is low

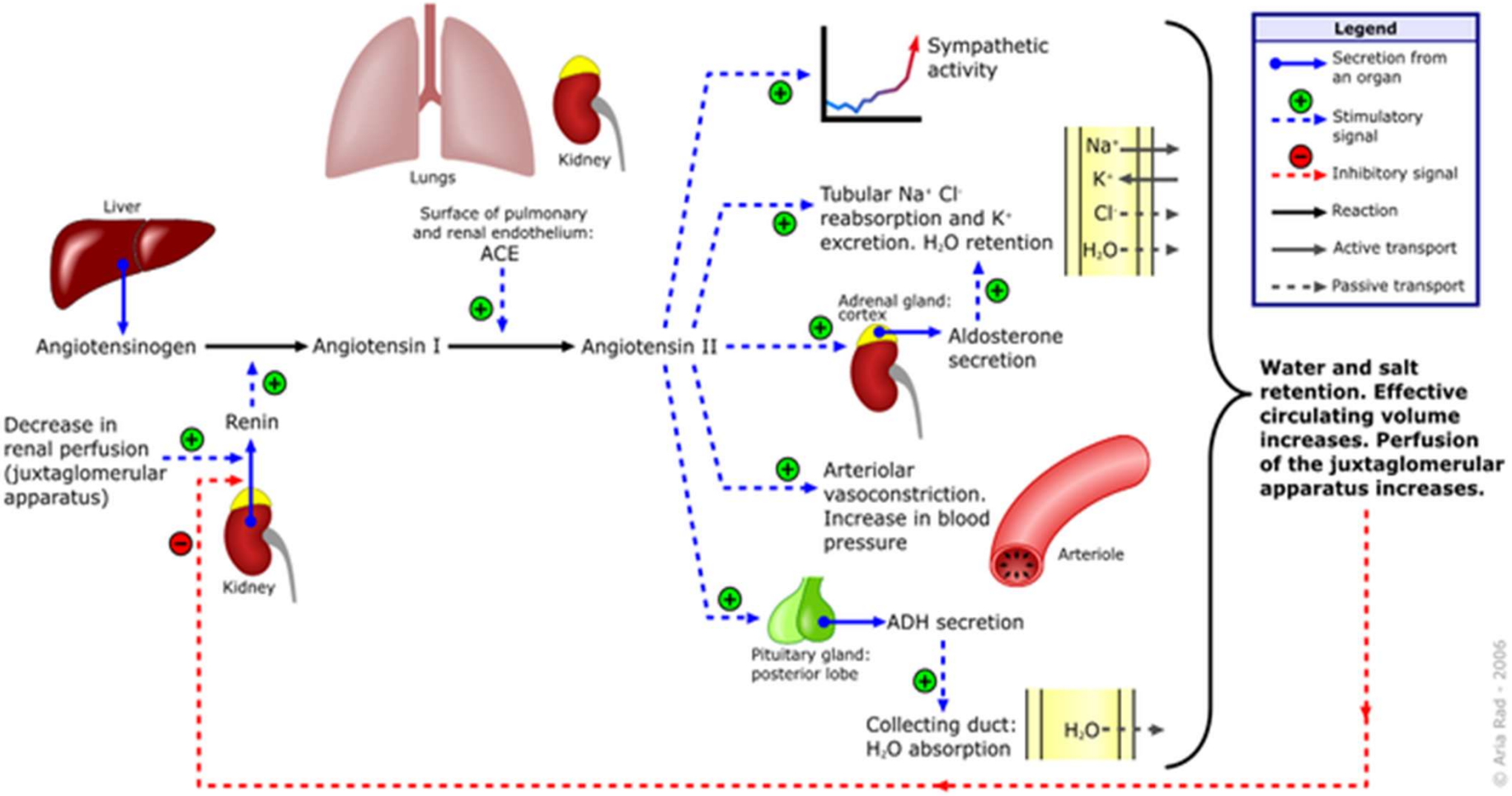


- **Renin is released by kidneys** in response to decreased blood volume
- **Renin causes Angiotensinogen** (plasma protein formed in Liver) **to split & produce Angiotensin I**

- **Lungs convert Angiotensin I to Angiotensin II By Angiotensin Converting Enzyme.**
- **Angiotensin II** then stimulates adrenal gland to **release Aldosterone**
- Aldosterone then **increase the peripheral vasoconstriction**
- Renin Angiotensin System **regulates Aldosterone hormone from Adrenal gland**
  - During homeostatic mechanism of Water and Electrolyte Balance.
  - Fall in E.C.F volume
  - Decreases blood pressure

- Sensed by Juxtaglomerular apparatus of Nephrons of Kidneys to **secrete Renin**
- Renin then stimulate **Liver Angiotensinogen** to produce **Angiotensin I**

Renin-angiotensin-aldosterone system



- **Angiotensin I** is converted to **Angiotensin**
- **By Lung** produced enzyme **Angiotensin Converting Enzyme**(ACE).
- **Angiotensin II stimulates** the **release of Aldosterone from Adrenal gland.**

4. Role Of Aldosterone

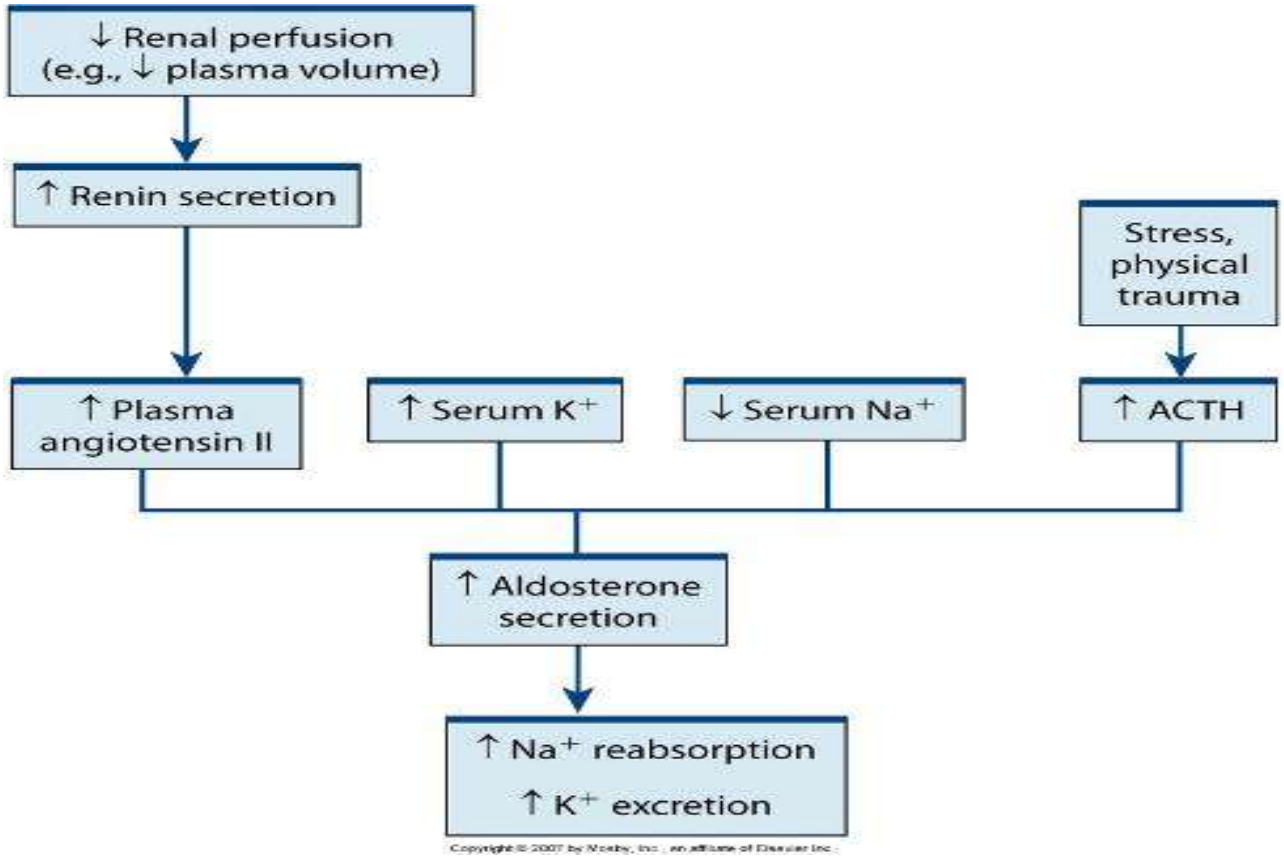
- Aldosterone is a **Steroid Hormone**.
  - It is a **Mineralocorticoid** produced by **Zona Glomerulus of Adrenal Cortex.**
  - It has most **important effect on Mineral Metabolism**
- Aldosterone is released as part of **Renin Angiotensin mechanism**
  - **Acts on renal distal convoluted tubule**

- The hormone Aldosterone by its action:
  - **Increases the rate of reabsorption of Na^+ (95 %) and Cl-**
  - **Increases K^+ loss through Urine**

Role of Aldosteron

- Aldosterone **increases Sodium uptake from the tubular fluid**
- Regulates water reabsorption by renal tubules and add into the blood
- **Makes excretion of Potassium**

- Thus **Aldosterone maintain Water and Electrolyte Balance** by its action on renal tubules:
    - **Reabsorbs Sodium**
    - **Retains Water**
    - **Looses Potassium**



5. Atrial Natriuretic Peptide or Factor (ANP)/(ANF)

- ANP is a **Cardiac hormone**
  - Secreted by **right Atrium of Heart.**
  - Chemically ANP is a **Polypeptide hormone**

- **ANP is released in response to increased blood pressure** in the atria (due to increased blood volume)
- **ANP opposes the Renin-Angiotensin-Aldosterone system**

- ANP suppresses Renin level
- Decreases the release of Aldosterone
- Decreases ADH release
- ANP stimulates excretion of Na and H2O
- Reduces vascular resistance by causing vasodilation.

Role Of Atrial Natriuretic Peptide :
ANP increases the urinary excretion of Na^+ and regulates the electrolytes balance

6. Role of Kinins

- **Kinins** are proteins in the blood
- **Kinins cause inflammation** and affect blood pressure (especially **lowers the blood pressure**).
- **Kinins increases Salt and Water excretion**

Osmolarity of a Solutions

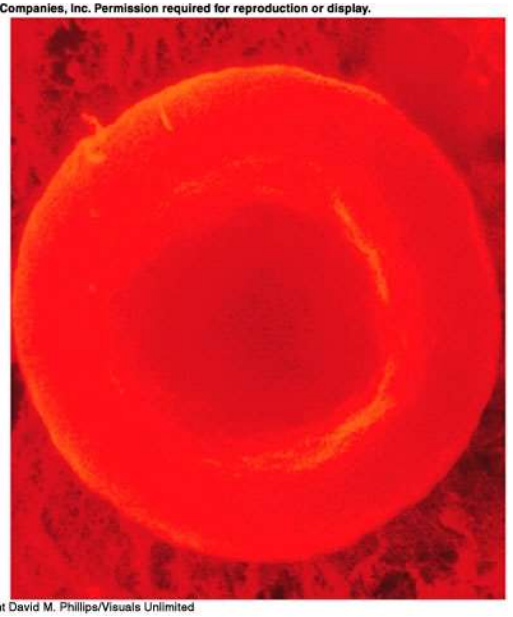
- **Isotonic Solution**
  - **Same** concentration of **solutes** as **plasma**
- **Hypertonic Solution**
  - **Greater** concentration of **solutes** than **plasma**
- **Hypotonic Solution**
  - **Lesser** concentration of **solutes** than **plasma**

Example Of ISOTONIC SOLUTIONS

- **0.9% Sodium Chloride Solution / Normal Saline**
- **Ringer's Solution** typically contains
  1. Sodium Chloride
  2. Potassium Chloride
  3. Calcium Chloride
  4. Sodium Bicarbonate
- **Lactate Ringer's Solution**

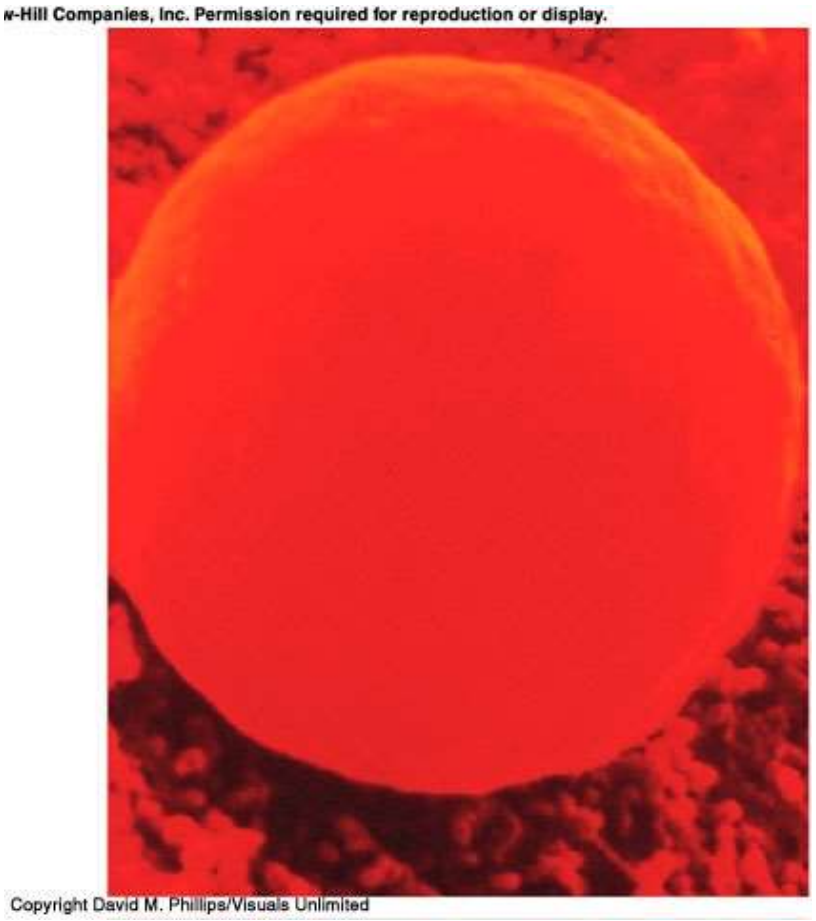
  Contains additionally Lactate

Cell in Isotonic Solution



HYPOTONIC SOLUTIONS

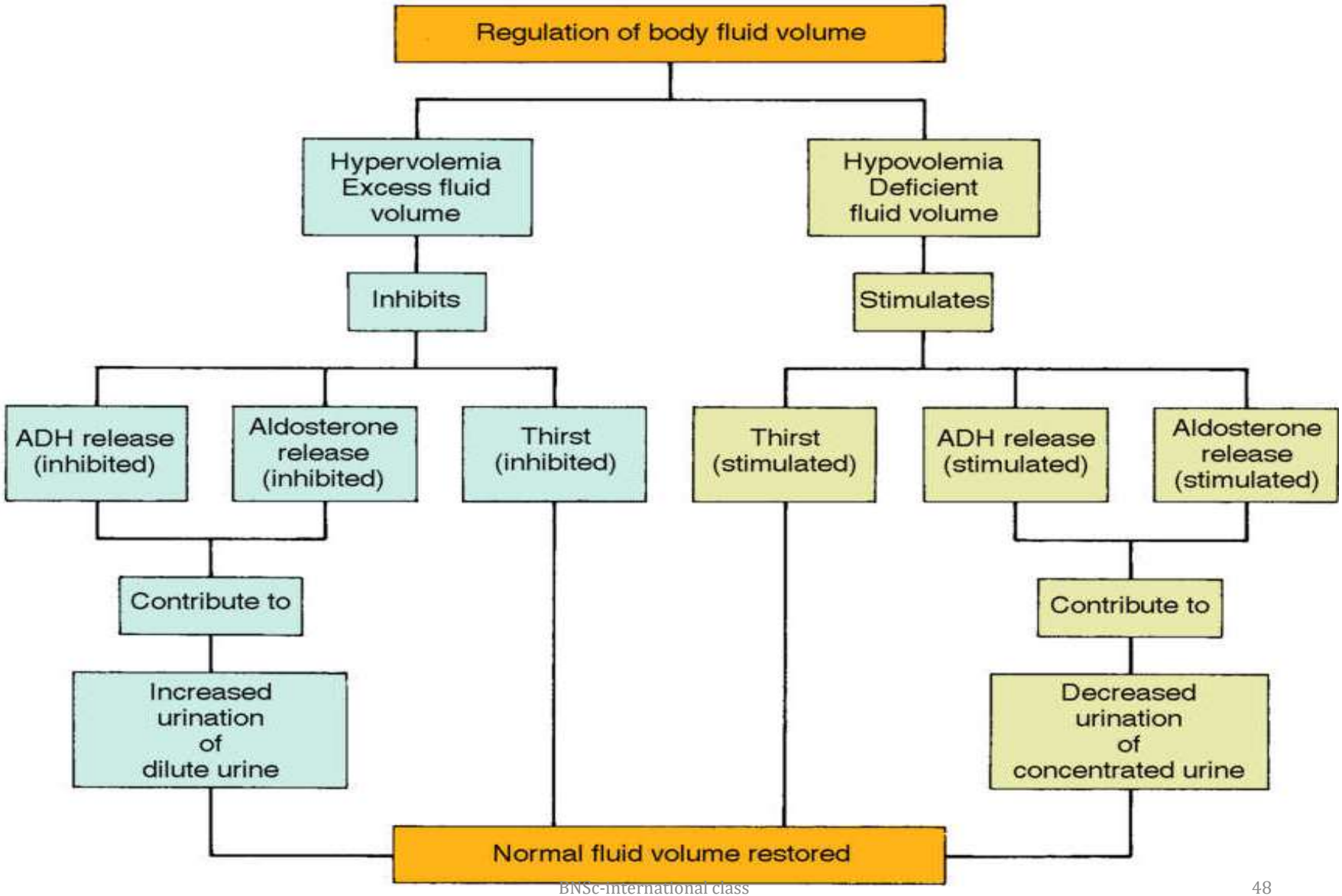
- 5% Dextrose & Water
- 0.45% Sodium Chloride
- 0.33% Sodium Chloride



HYPERTONIC SOLUTIONS

- 3% Sodium Chloride
- 5% Sodium Chloride
- Whole Blood
- Albumin
- Total Parenteral Nutrition
- Tube Feedings
- Concentrated Dextrose (>10%)

REGULATION OF FLUID VOLUME



Water Electrolyte Imbalance Conditions

- **Dehydration**
- **Over hydration**

- **Dehydration is a condition of Water imbalance.**
- Dehydration is characterized by **disturbance of Water and electrolyte balance**

Basic Cause Of Dehydration

- No Ingestion of water
- Excessive Loss of body fluids

Features Of Dehydration

- **Water Deficiency Condition**
- **Low body water**
- **Low blood volume**
- **Disturbance in body Electrolytes.**

- In a **dehydrated body** the **output of water exceeds the water intake.**
- This causes **reduction of body water below the normal level**

Over Hydration /Water Excess

- **Causes Of Water Excess**
  - **Excessive administration of parenteral fluids.**
  - Renal Failure (No/Less excretion of Urine)
  - **Hypersecretion of ADH**
  - Administration of Narcotics, Anaesthesia **causes secretion of ADH**
  - **Excess of Aldosterone** (Conn's Syndrome)

Clinical Manifestation

- Headache
- Nausea
- Incoordination of Movements
- Delirium

Edema/Swelling

- Condition in which excess fluid accumulates in the **interstitial compartment.**
- **It is a response to inflammation and injury**

Edema (swelling) of the ankles and feet

- **Increased Hydrostatic Pressure**
- **Small blood vessels become leaky and releases fluid into nearby tissues.**
  - Venous obstruction, Lymphedema, CHF, Renal failure
- **Lowered Plasma Osmotic pressure (Protein loss)**
  - Liver failure, Malnutrition, Burns
- **Increased capillary membrane permeability**
  - Inflammation, Sepsis

Thank You