Fluid–Electrolyte Balance

☒ Water makes up 55 - 75% of the total body weight.

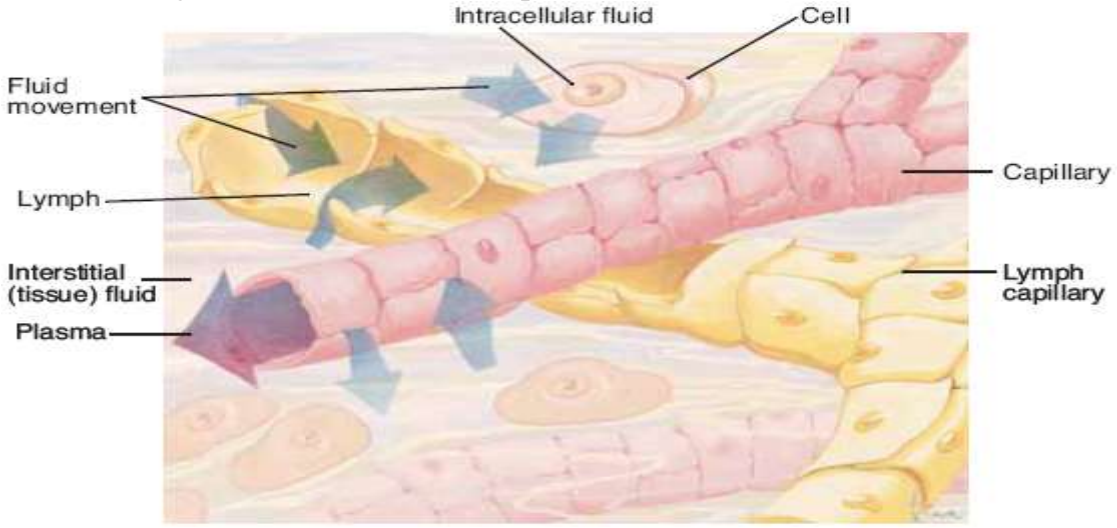
☒ Electrolytes are the ions found in body fluids; most are minerals.

Water Compartments

☒ Intracellular fluid (ICF); water within cells; about two-thirds of total body water.

☒ Extracellular fluid (ECF); water outside cells; includes plasma, lymph, tissue fluid, & specialized fluids (cerebrospinal fluid, synovial fluid, aqueous humor,& serous fluid.).

❖ Water constantly moves from one compartment to another.



Water compartments.

WATER INTAKE AND OUTPUT

Intake		*Output*	
Liquids	1600	Urine	1500
Food	700	Sweat (and insensible water loss)	500
Metabolic water	200	Exhaled air (water vapor)	300
		Feces	200

REGULATION OF WATER INTAKE & OUTPUT

❖ Hypothalamus

- It contains **osmoreceptors** that detect changes in osmolarity of body fluids. Dehydration raises osmolarity of blood, & we feel thirst.
- It stimulates release of ADH from posterior pituitary in dehydration. ADH ↑ reabsorption of water by kidney tubules.

❖ Aldosterone ↑ reabsorption of Na ions & water by kidney back to blood.

❖ Atrial natriuretic peptide (ANP), secreted by atria

- when ↑blood volume or blood pressure→secretion of ANP→↓ reabsorption of Na ions by kidneys, →↑ urinary output of Na & H2O.

ELECTROLYTES

- They are chemicals that dissolve in water & dissociate into ions; most are inorganic.
- Cations are positive ions such as Na+ & K+.
- Anions are negative ions such as Cl_ & HCO3 _.
- By creating osmotic pressure, electrolytes regulate osmosis of water between compartments.
- Tissue fluid—same as plasma(principal cation is Na+; principal anion is Cl-)except that in tissue fluid; protein anions are insignificant.

INTAKE, OUTPUT, AND REGULATION

- Intake—electrolytes are part of food & beverages.
- Output—urine, sweat, feces.
- Regulation; through;
  - aldosterone—Na+ & K+;
  - ANP—Na+;
  - PTH & calcitonin—Ca+2 & HPO_4^{-2}.

ACID–BASE BALANCE

- Normal pH Ranges;
  - blood: 7.35 - 7.45; tissue fluid: similar to blood.
  - ICF: 6.8 - 7.0;
- Normal pH of body fluids is maintained by;
  - Buffer systems (Bicarbonate , phosphate, & protein) respond within fraction of second.
  - Respiration. Respond within 1- 3 min.
  - Kidneys.respond within several hours – days.

BUFFER SYSTEMS

- Each consists of a weak acid & a weak base; react with strong acids or bases to change them to substances that do not greatly affect pH.
- React within a fraction of a second, but have the least capacity to prevent pH changes, because a limited number of molecules of these buffers are present in body fluids.

Bicarbonate Buffer System

- Important in both blood & tissue fluid; base to acid ratio is 20 to 1.
- The two components of this buffer system are
  i. Carbonic acid (H2CO3), a weak acid.
  ii. Sodium bicarbonate (NaHCO3), a weak base.

- If a potential pH change is created by a strong acid, the following reaction takes place:

$$HCl + NaHCO_3 \rightarrow NaCl + H_2CO_3$$

(strong acid) (weak acid)

- If a potential pH change is created by a strong base, the following reaction takes place:

$$NaOH + H_2CO_3 \rightarrow H_2O + NaHCO_3$$

(strong base) (weak base)

Phosphate Buffer System

- Important in regulation of pH in ICF & in kidneys.
- The two components of this buffer system are;

i. Sodium dihydrogen phosphate (NaH2PO4), a weak acid,
ii. Sodium monohydrogen phosphate (Na2HPO4), a weak base.

❖ If a potential pH change is created by a strong acid, the following reaction takes place:

$HCl + Na_2HPO_4 \rightarrow NaCl + NaH_2PO_4$
(strong acid) (weak acid)

If a potential pH change is created by a strong base, the following reaction takes place:

$NaOH + NaH_2PO_4 \rightarrow H_2O + Na_2HPO_4$
(strong base) (weak base)

Protein Buffer System

- The most important buffer system in ICF.
- Hb buffers H+ ions formed during CO2 transport.
- a.a that make up proteins each have a **carboxyl group** (COOH) & an **amine group** (NH2).
  - ☒ Carboxyl group act as an acid because it can donate H+ ion to fluid to counteract ↑ing alkalinity:
  - ☒ Amine group act as a base because it can pick up an excess H+ ion from fluid to counteract ↑ing acidity.

RESPIRATORY MECHANISMS

❖ It affects pH because it regulates amount of CO2 present in body fluids.
❖ Resp. system may be the cause or may correct pH imbalance (from other causes).

Respiratory acidosis

Causes;↓ rate or efficiency of respiration(eg asthma, & pneumonia)→excess CO2 → excess H+ ions formation→ lower pH of body fluids:

$CO_2 + H_2O \rightarrow H_2CO_3 \rightarrow H^+ + HCO_3$.

Compensation; Kidneys excrete H+ ions & reabsorb Na+ ions & HCO3- ions.

Respiratory alkalosis (less common)

Causes ↑rate of respiration (eg; anxiety, high altitude) →↑ amount of CO2 exhaled. Because there are fewer CO2 molecules in body fluids→ fewer H+ ions are formed, & pH tends to rise.

Compensation; Kidneys retain H+ ions & excrete Na+ ions & HCO3- ions

Respiratory Compensation for Metabolic pH Changes

Metabolic acidosis or alkalosis are changes in pH caused by other than a respiratory disorders. Respiratory mechanism does not have the capacity to fully compensate an ongoing metabolic pH imbalance (In such cases, respiratory compensation is 50 - 75% effective).

Metabolic acidosis

Causes; e.g kidney disease, uncontrolled diabetes mellitus, excessive diarrhea or vomiting.

Compensation; excess H+ ions in body fluids→ stimulates respiratory centers in medulla→↑ rate of respiration to exhale more CO2 → ↓ H+ ion formation.

Metabolic alkalosis is not common,

Causes; eg overuse of antacid medications or vomiting of stomach contents only.

Compensation; As pH begins to rise→ breathing slows & ↓ amount of CO2 exhaled (CO2 retained within body)→ ↑ H+ ions formation.

RENAL MECHANISMS

- Kidneys regulate pH of ECF by excreting or conserving H+ ions & by reabsorbing (or not) Na+ ions & HCO3- ions.
- Although renal mechanisms have the greatest capacity to buffer

- E.g ketoacidosis in untreated diabetes mellitus (metabolic acidosis).
  - ☒ As ketones (acid) accumulate in blood,
  - ☒ capacity of ECF buffer systems is quickly exhausted.
  - ☒ Breathing rate then ↑, & more CO2 is exhaled to ↓ H+ ion formation. There is a limit to how much respiratory rate can ↑,
  - ☒ Renal buffering mechanisms will then become effective.

EFFECTS OF pH CHANGES

A**cidosis** is most detrimental to CNS, causing ↓ impulse transmission at synapses. A person in acidosis becomes confused & disoriented, then lapses into a coma.

Alkalosis affects both CNS & PNS.↑ synaptic transmission, even without stimuli. It is first indicated by irritability & muscle twitches & Progress to muscle spasms & convulsions.

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