physiology
lecture (11)
part (1) and (2)

body fluids constitute

- 55% females
- 60%males

Body fluid compartments

- intracellular fluid (ICF) or cytosol (two-thirds)
- extracellular fluid (ECF) (other third)
  - 80% is interstitial fluid
  - 20% is plasma (the liquid portion)

Two general "barriers" separate intracellular fluid, interstitial fluid, and blood plasma:

- The plasma membrane (separates intracellular fluid from the surrounding interstitial fluid)
- Blood vessel walls (interstitial fluid from blood plasma)

Water is the largest single component of the body.

fluid balance is closely related to electrolyte balance → most solutes in body fluids are electrolyte (inorganic compounds that dissociate into ions)

SOURCES OF BODY WATER GAIN

- ingested liquids (about 1600 mL)
- moist foods (about 700 mL)(absorbed from GI)

→ main sources with total (2300 mL/day)

- metabolic water(electrons are accepted by oxygen during aerobic respiration)

SOURCES OF BODY WATER LOSS

- kidneys excrete about 1500 mL in urine
- skin evaporates about 600 mL (400 mL through insensible perspiration- sweat that evaporates before it is perceived as moisture-and 200 mL as sweat)
- lungs exhale about 300 mL as water vapor
- gastrointestinal tract eliminates about 100 mL in feces

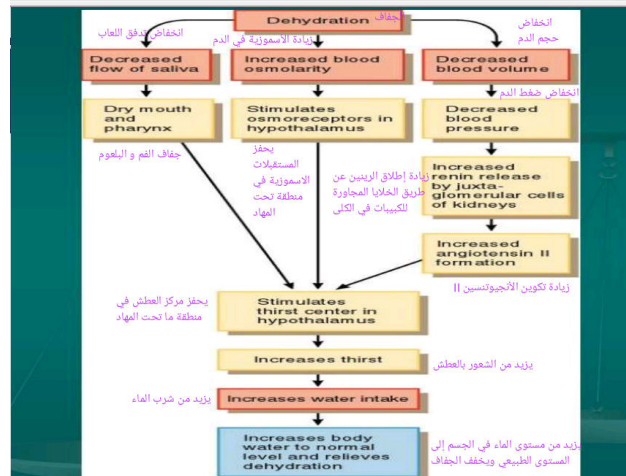
In women of reproductive age, additional water is lost in menstrual flow

daily water loss totals about 2500 mL.

water loss equals water gain.

when water loses greater than water gain

المخطط كثير مهم



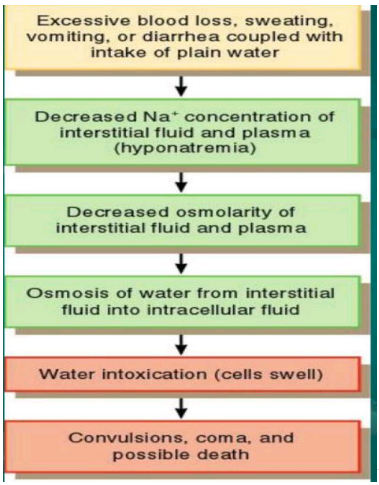
important hormones that regulate the extent of renal sodium and chloride ions reabsorption (how much is lost in the urine)

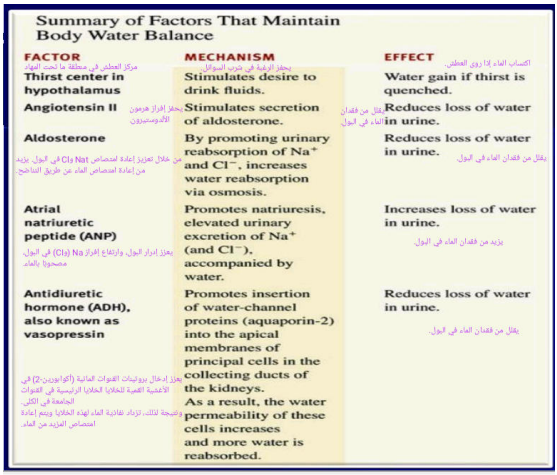
- angiotensin II
- aldostero
- atrial natriuretic peptide (ANP).

shrink slightly: increase in the osmolarity of interstitial fluid draws water out of cells

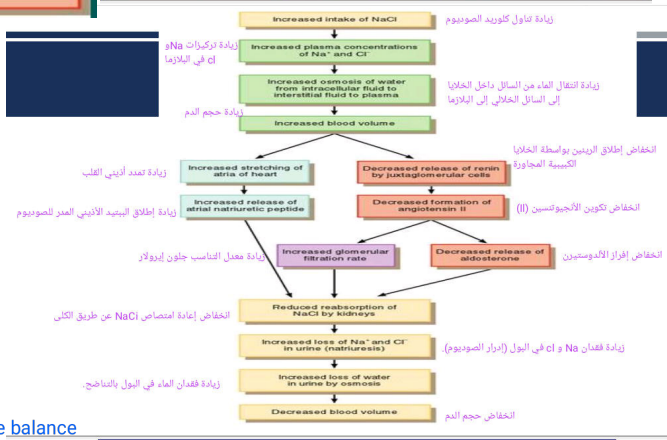
swell : decrease in the osmolarity of interstitial fluid, by contrast.

Water intoxication: excessive body water causes cells to swell



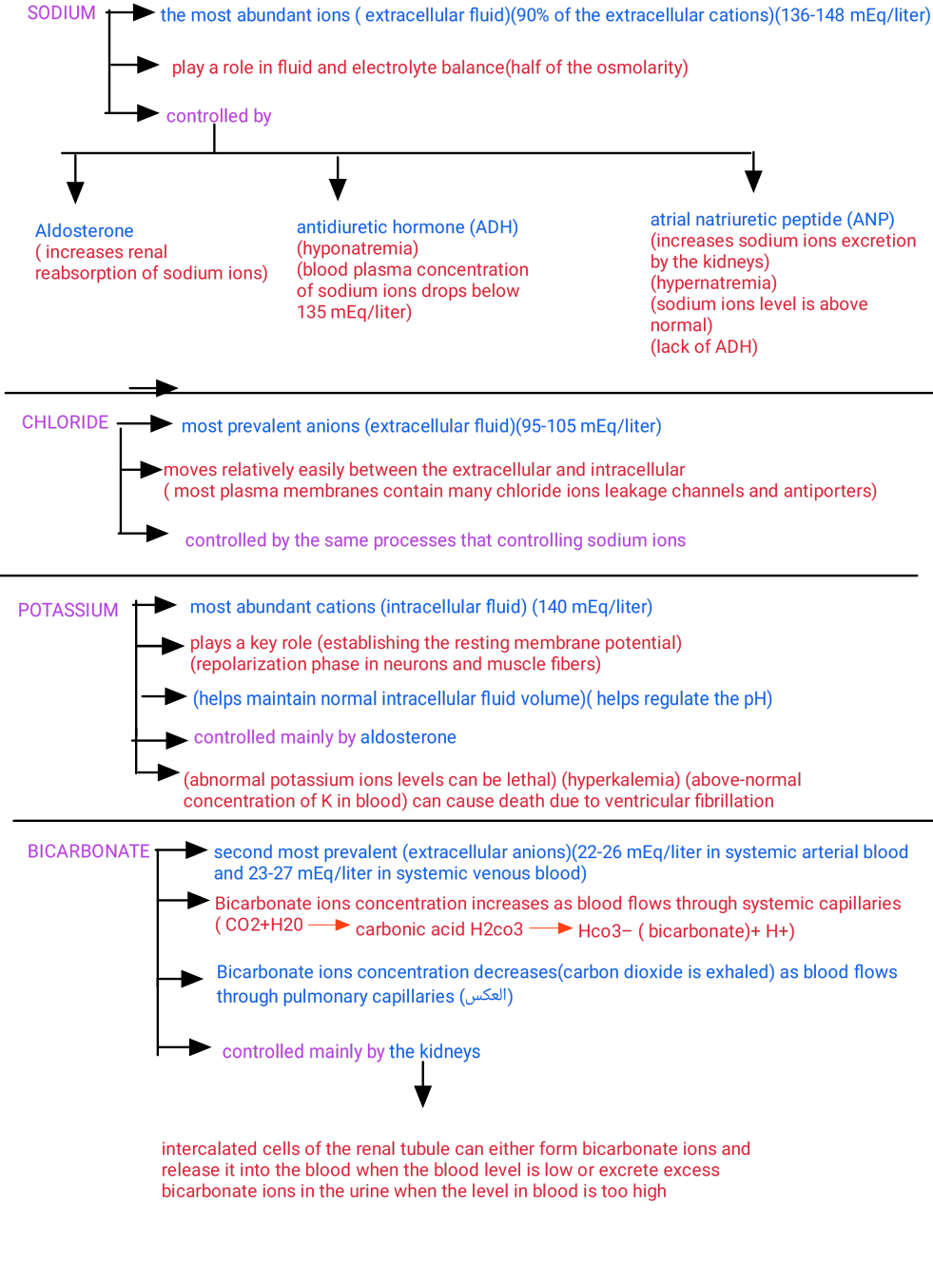


concentration of ions is typically expressed in units of milliequivalents per liter (mEq/liter).



four general functions for ions

- control the osmosis of water between fluid compartments (largely confined to particular fluid compartments and more numerous)
- help maintain the acid- base balance
- carry electrical current (allow production of action potentials and graded potentials)
- cofactors (needed for optimal activity of enzymes)


SODIUM
the most abundant ions (extracellular fluid)(90% of the extracellular cations)(136-148 mEq/liter)
play a role in fluid and electrolyte balance(half of the osmolarity)
controlled by
Aldosterone
(increases renal
reabsorption of sodium ions)
antidiuretic hormone (ADH)
(hyponatremia)
(blood plasma concentration
of sodium ions drops below
135 mEq/liter)
atrial natriuretic peptide (ANP)
(increases sodium ions excretion
by the kidneys)
(hypernatremia)
(sodium ions level is above
normal)
(lack of ADH)
CHLORIDE
most prevalent anions (extracellular fluid)(95-105 mEq/liter)
moves relatively easily between the extracellular and intracellular
(most plasma membranes contain many chloride ions leakage channels and antiporters)
controlled by the same processes that controlling sodium ions
POTASSIUM
most abundant cations (intracellular fluid) (140 mEq/liter)
plays a key role (establishing the resting membrane potential)
(repolarization phase in neurons and muscle fibers)
(helps maintain normal intracellular fluid volume)(helps regulate the pH)
controlled mainly by aldosterone
(abnormal potassium ions levels can be lethal) (hyperkalemia) (above-normal
concentration of K in blood) can cause death due to ventricular fibrillation
BICARBONATE
second most prevalent (extracellular anions)(22-26 mEq/liter in systemic arterial blood
and 23-27 mEq/liter in systemic venous blood)
Bicarbonate ions concentration increases as blood flows through systemic capillaries
(CO2+H20 carbonic acid H2co3 Hco3− (bicarbonate)+ H+)
Bicarbonate ions concentration decreases(carbon dioxide is exhaled) as blood flows
through pulmonary capillaries (العكس)
controlled mainly by the kidneys
intercalated cells of the renal tubule can either form bicarbonate ions and
release it into the blood when the blood level is low or excrete excess
bicarbonate ions in the urine when the level in blood is too high

CALCIUM

- most abundant mineral in the body(large amount of calcium is stored in bone)(98% of the calcium in adults is located in the skeleton and teeth)(it is combined with phosphates to form a crystal lattice of mineral salts)
- (hardness of bones and teeth)(blood clotting)(neurotransmitter release)(maintenance of muscle tone)(excitability of nervous and muscle tissue)
- controlled mainly by the parathyroid hormone (PTH) and calcitriol

low level of calcium ion

- stimulates osteoclasts in bone tissue to release calcium (and phosphate) from bone extracellular matrix.(PTH increases bone resorption)
- enhances reabsorption of calcium ion from glomerular filtrate through renal tubule cells and back into blood(in the kidneys)
- increases production of calcitriol (the form of vitamin D that acts as a hormone), which in turn increases calcium ion absorption from food in the gastrointestinal tract.

PHOSPHATE

- Three phosphate ions (intracellular anions)(85% of the phosphate in adults is present as calcium phosphate salts)(structural components of bone and teeth)
- controlled by the same hormones and the same processes that controlling calcium ions

but there is one difference → PTH increases urinary excretion of phosphate and lowers blood phosphate level(in the kidneys)(while stimulating reabsorption of calcium ions by renal tubular cells)

MAGNESIUM

- (54% part of bone matrix as magnesium salts)(intracellular fluid 45%)(extracellular fluid 1%)
- second most common (intracellular cation) (35 mEq/liter)
- cofactor for certain enzymes (needed for the metabolism of carbohydrates and proteins and for the sodium-potassium pump.)
- (normal neuromuscular activity)(synaptic transmission)(myocardial functioning)(secretion of parathyroid hormone (PTH))
- (hypercalcemia)(hypermagnesemia) (increases in extracellular fluid volume)(decreases in parathyroid hormone)(acidosis)(kidneys increase urinary excretion of magnesium ions)

The removal of hydrogen ions from body fluids depend on

- Buffer systems → raise pH of body fluids but do not remove hydrogen ions from the body.
- Exhalation of carbon dioxide → (increasing the rate and depth of breathing) (more carbon dioxide can be exhaled)(reduces the level of carbonic acid)(raises the blood pH)(reduces blood hydrogen ions level).
- Kidney excretion of hydrogen ions → (The slowest mechanism)(the only way to eliminate acids other than carbonic acid) is through their excretion in urine

buffer systems → weak acid + the salt of that acid(functions as a weak base)

(prevent rapid, drastic changes in the pH of body fluids)
(converting strong acids and bases into weak acids and weak bases)

PROTEIN BUFFER SYSTE➤ (the most abundant buffer in intracellular fluid and blood plasma)

hemoglobin → good buffer within red blood cells

albumin → main protein buffer in blood plasma

functional components of the protein buffer system
- carboxyl group (-COOH) → releasing hydrogen ions when pH rises
- amino group (-NH2) → combining with hydrogen ions when pH falls

hemoglobin → H_2O (Water) + $Co2$ → H_2CO_3 (Carbonic acid) → $HCo3^-$ (bicarbonate) + H+

Hb-O2 (Oxyhemoglobin (in RBCs)) + H+ → Hb-H (Reduced hemoglobin) + O2

The carbonic acid-bicarbonate buffer system is based on
- bicarbonate ion (HCO3-)(weak base)
- carbonic acid (H2CO3)(weak acid)

this buffer system cannot protect against pH changes due to respiratory problems in which there is an excess or shortage of CO2

phosphate buffer system
- monohydrogen phosphate $HPO4^{-2}$
- ions dihydrogen phosphate $[H_2PO_4]^-$

concentration of phosphates is highest in intracellular fluid, the phosphate buffer system is an important regulator of pH in the cytosol. It also acts to a smaller degree in extracellular fluids and buffers acids in urine

H+ + $HPO4^{-2}$ (monohydrogen phosphate) → $[H_2PO_4]^-$ (dihydrogen phosphate)

EXHALATION OF CARBON DIOXIDE → (An increase in the carbon dioxide (CO2)) (increases hydrogen ion concentration)(lowers the pH)(makes body fluids more acidic).(pHال واذا عكسنا بترتفع)

$$\underset{\text{Carbon dioxide}}{CO_2} + \underset{\text{Water}}{H_2O} \rightleftharpoons \underset{\text{Carbonic acid}}{H_2CO_3} \rightleftharpoons \underset{\text{Hydrogen ion}}{H^+} + \underset{\text{Bicarbonate ion}}{HCO_3^-}$$

The normal pH range of systemic arterial blood is between 7.35 and 7.45.

Acidosis (or acidemia) → condition in which blood pH is below 7.35

alkalosis (or alkalemia) → condition in which blood pH is higher than 7.45

TABLE 27.3

Mechanisms That Maintain pH of Body Fluids

MECHANISM	COMMENTS
Buffer systems	Most consist of a weak acid and its salt, which functions as a weak base. They prevent drastic changes in body fluid pH.
Proteins	The most abundant buffers in body cells and blood. Hemoglobin inside red blood cells is a good buffer.
Carbonic acid–bicarbonate	Important regulator of blood pH. The most abundant buffers in extracellular fluid (ECF).
Phosphates	Important buffers in intracellular fluid and urine.
Exhalation of CO_2	With increased exhalation of CO_2, pH rises (fewer H^+). With decreased exhalation of CO_2, pH falls (more H^+).
Kidneys	Renal tubules secrete H^+ into urine and reabsorb HCO_3^- so it is not lost in urine.

ملخص

acidosis → depression of the central nervous system (depression of synaptic transmission) → pH falls below 7 (individual becomes disoriented, comatose, and may die) (Patients with severe acidosis usually die while in a coma.)

alkalosis → overexcitability in both the central nervous system and peripheral nerves → (nervousness) (muscle spasms)(convulsions and death)

Change in blood pH that leads to acidosis or alkalosis may be countered by compensation

ACID-BASE IMBALANCES

RESPIRATORY ACIDOSIS (Inadequate exhalation of CO2)

(pulmonary edema) (injury to the respiratory center of the medulla oblongata) (airway obstruction) (disorders of the muscles involved in breathing)

If the respiratory problem is not too severe, the kidneys can help raise pH

increase the exhalation of CO2

providing ventilation

intravenous administration of HCO3-

RESPIRATORY ALKALOSIS (The cause is the increase of pH) (hyperventilation)

(high altitude or pulmonary disease) (cerebrovascular accident (stroke)) (severe anxiety)

Again, renal compensation may bring blood pH into the normal range

increasing the level of CO2

person inhale and exhale into a paper bag for a short period

METABOLIC ACIDOSIS (pH to decrease.) (lower the blood level of HCO3)

(severe diarrhea or renal dysfunction) (accumulation of an acid other than carbonic acid,ketosis) (failure of the kidneys)

the problem is not too severe, hyperventilation can help bring blood pH into the normal range (respiratory compensation).

administering intravenous solutions of sodium bicarbonate and correcting the cause of the acidosis

METABOLIC ALKALOSIS (nonrespiratory loss of acid)

Excessive vomiting of gastric contents, which results in a substantial loss of hydrochloric acid, is probably the most frequent cause of metabolic alkalosis.

Respiratory compensation through hypoventilation may bring blood pH into the normal range.

giving fluid solutions to correct chloride ions, potassium ions, and other electrolyte deficiencies plus correcting the cause of alkalosis