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Fluids and Electrolytes

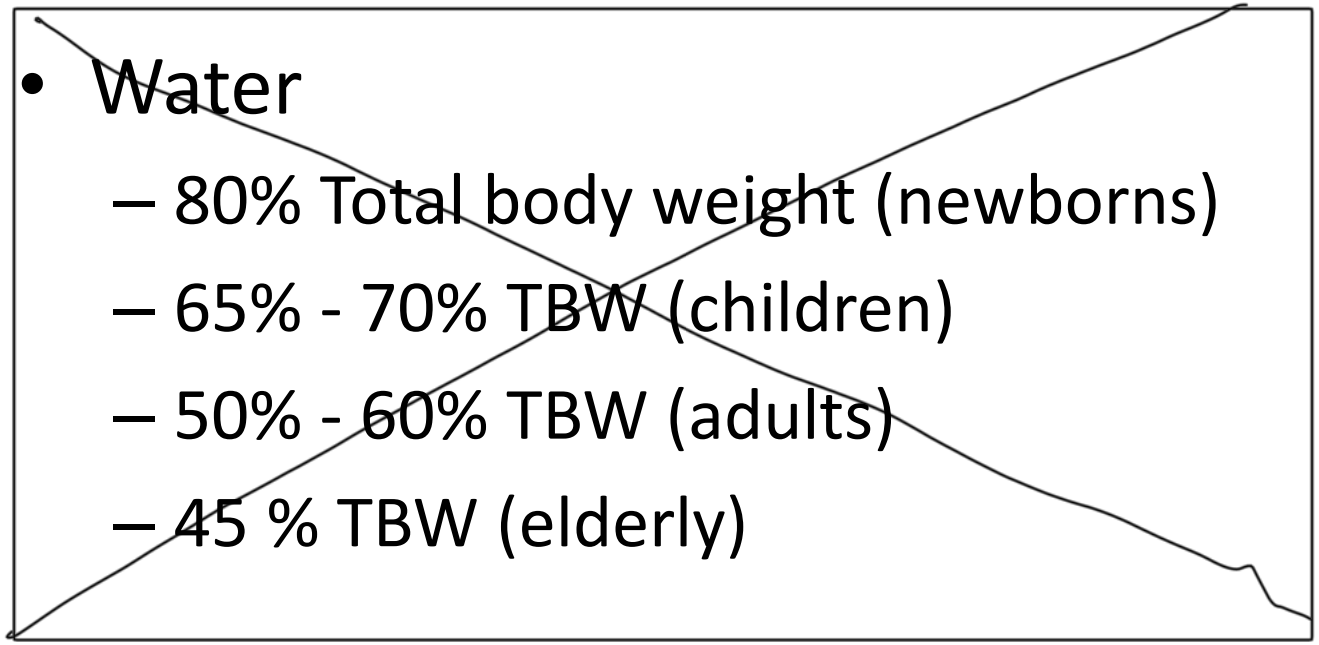
Primary Care Paramedicine

Module:04

Section:04

Total Body Water

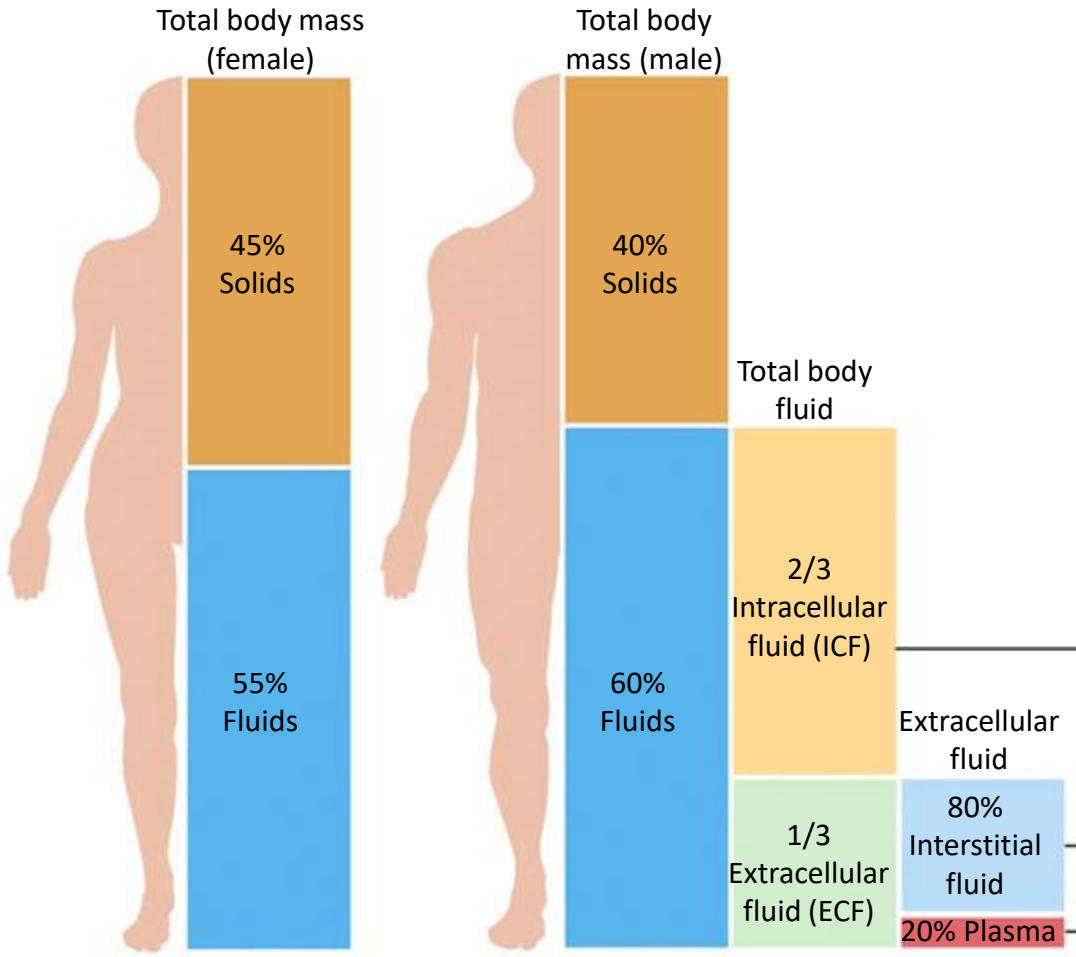
- Normal values expressed as a percentage
- Differences occur due to age, sex and fat content



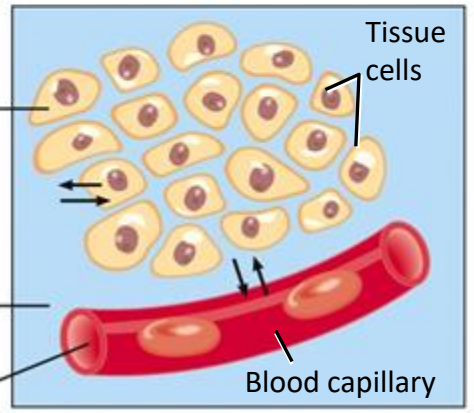
- Water
  - 80% Total body weight (newborns)
  - 65% - 70% TBW (children)
  - 50% - 60% TBW (adults)
  - 45 % TBW (elderly)

Body Fluid Compartments

- Extracellular
  - Plasma and interstitial fluid
  - Lymph, CSF, joint fluids and humors of the eye (transcellular fluid)
- Intracellular
  - Water inside the cells



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

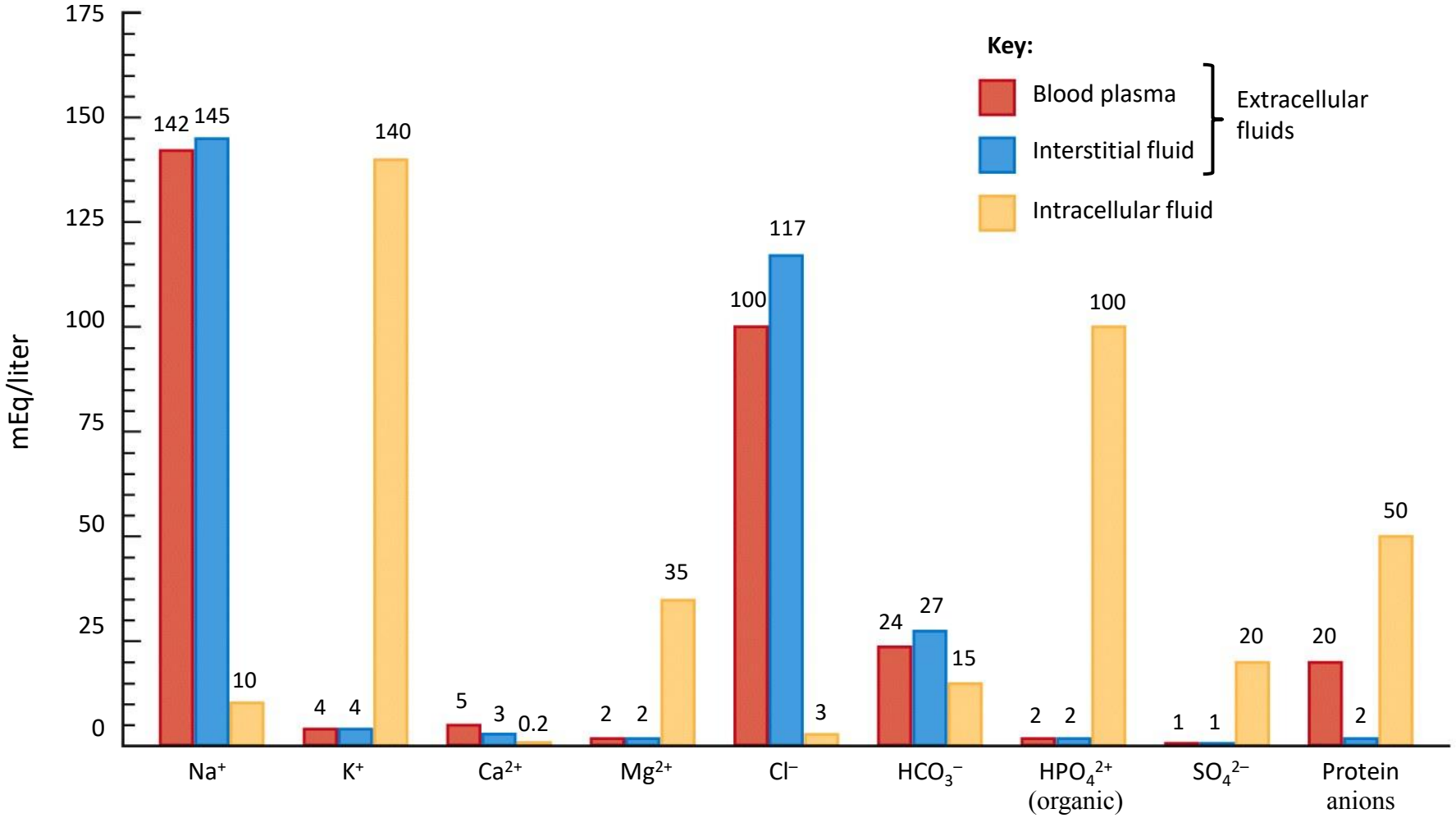


(b) Exchange of water among body fluid compartments

Fluid Composition

- A constant balance between the fluid and the electrolytes must exist for homeostasis
  - Water
  - Electrolytes
    - Salt substances that dissociate into charged components when dissolved in water (Na^+, K^+)
  - Non-electrolytes
    - Substances that do not carry an electrical charge in water (glucose, urea)

Distribution



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Electrolytes

- Positively Charged Electrolytes (Cation)
  - Intracellular
    - Potassium K^+
    - Calcium Ca^{++}
    - Magnesium Mg^{++}

important

  - Extracellular
    - Sodium Na^+

Electrolytes

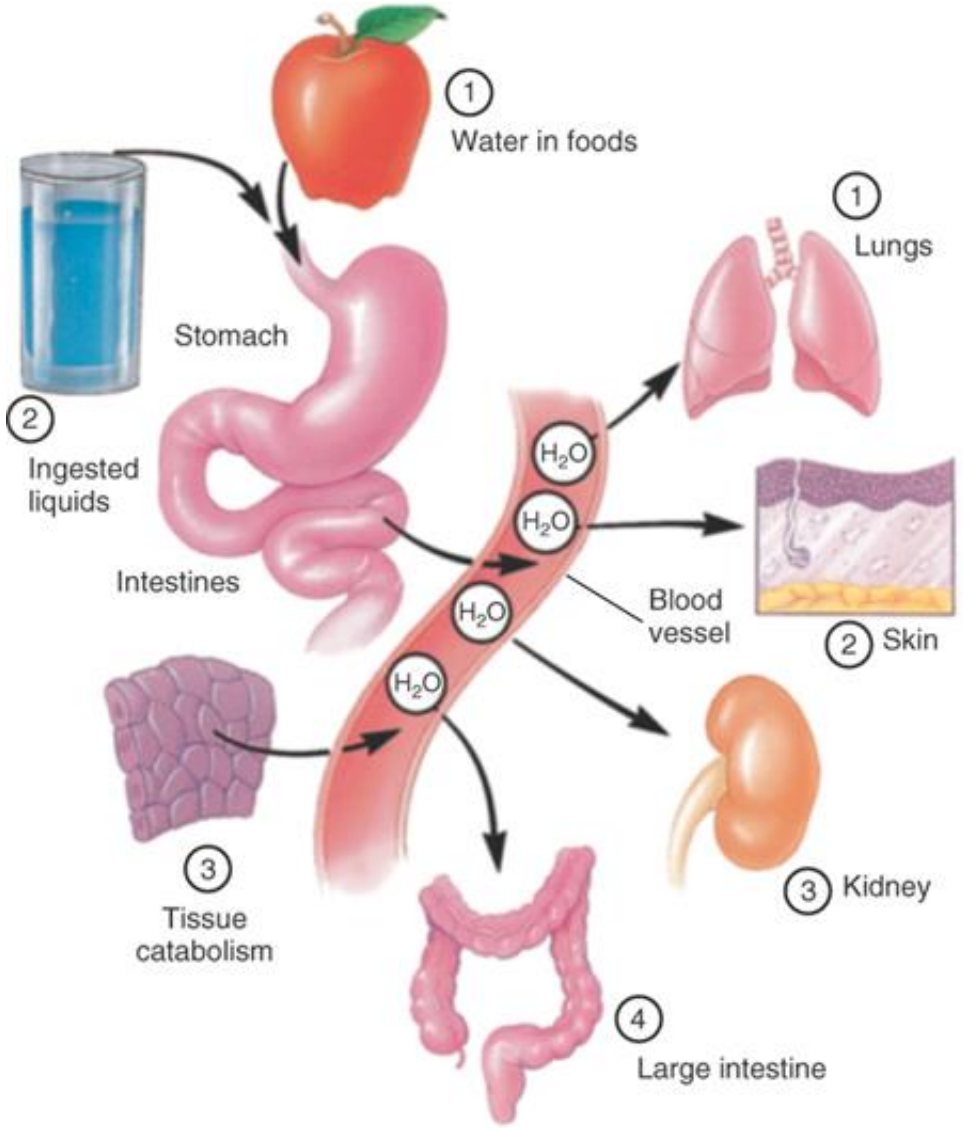
- Negatively Charged Electrolytes (Anion)
  - Intracellular
    - Phosphate PO_4^{3-}
  - Extracellular
    - Chloride Cl^-
    - Bicarbonate HCO_3^-

Electrolytes

- Aldosterone is the primary regulator of electrolyte concentrations
- Accomplishes this through reabsorption of Na^+ and excretion of K^+

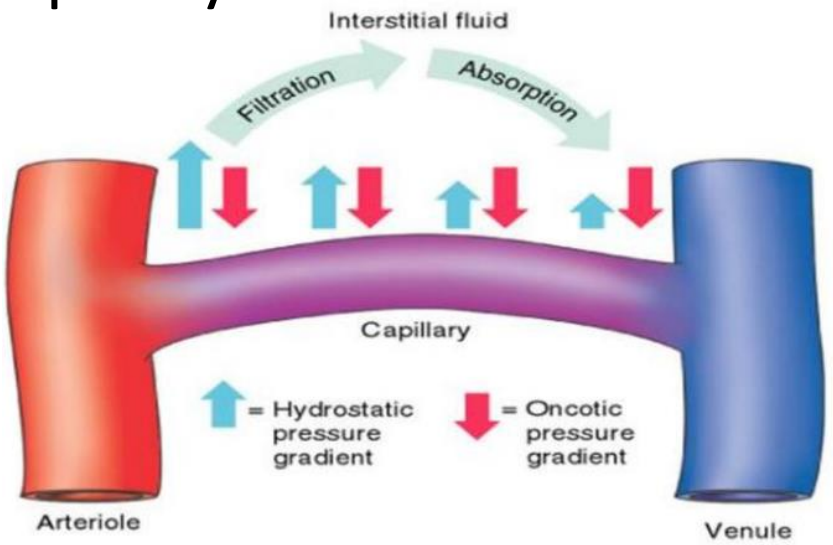
Avenues

- Water enters the body
  - Digestive system
  - Cellular metabolism
- Water exits the body
  - Kidneys
  - Lungs
  - Sweat
  - Feces
- Input = Output



Factors Affecting Movement

- Starling's law of the capillaries
  - Fluid movement due to filtration across the wall of a capillary is dependent on the balance between the hydrostatic pressure gradient and the oncotic pressure gradient across the capillary
  - Forces affecting this are:
    - Hydrostatic
    - Osmotic



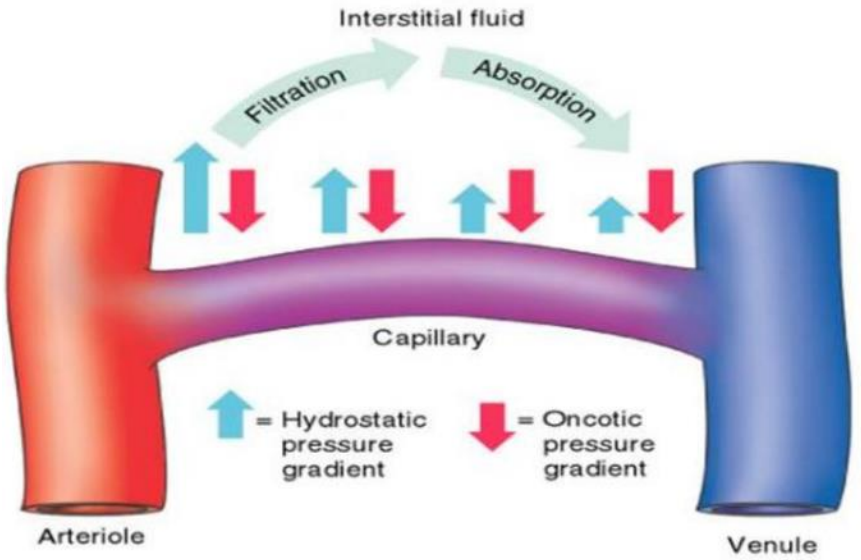
Tonicity and membrane permeability can affect this as well

Hydrostatic Pressure

- The primary force driving fluid transport between the capillaries and tissues is hydrostatic pressure - which can be defined as the pressure of any fluid enclosed in a space.
- Main hydrostatic forces
  - Blood hydrostatic pressure (BHP)
  - Interstitial fluid hydrostatic pressure (IFHP)

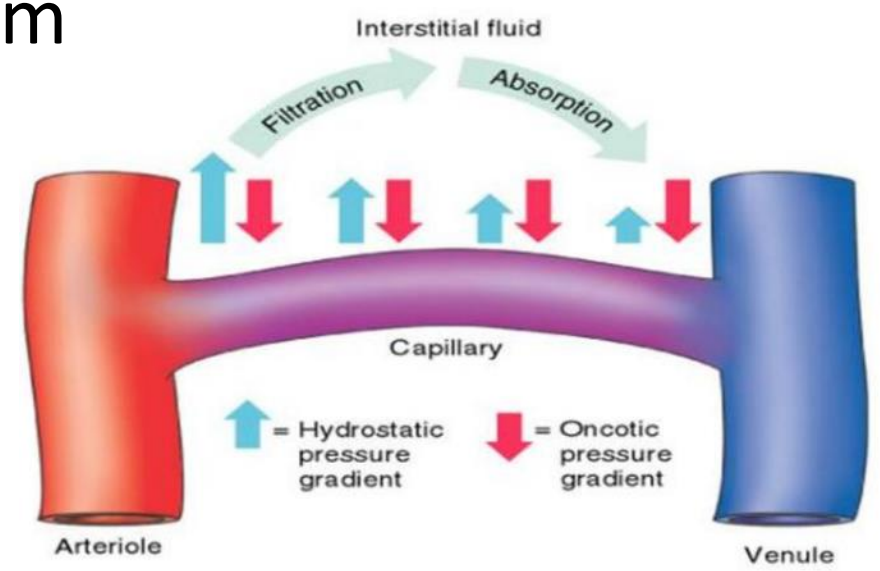
Blood Hydrostatic Pressure (BHP)

- The force exerted by the blood confined within blood vessels (pressure exerted by blood against the wall of capillary)
- The force that drives fluid out of capillaries into tissues.
- As fluid exits a capillary and moves into tissues, the hydrostatic pressure in the interstitial fluid rises.
- This opposing hydrostatic pressure is called the interstitial fluid hydrostatic pressure



Interstitial Fluid Hydrostatic Pressure (IFHP)

- The mechanical force of water within the interstitium against cellular membranes
- Works with plasma osmotic pressure against filtration
- Keeps small quantities of plasma proteins which have leaked into the interstitium within the interstitium

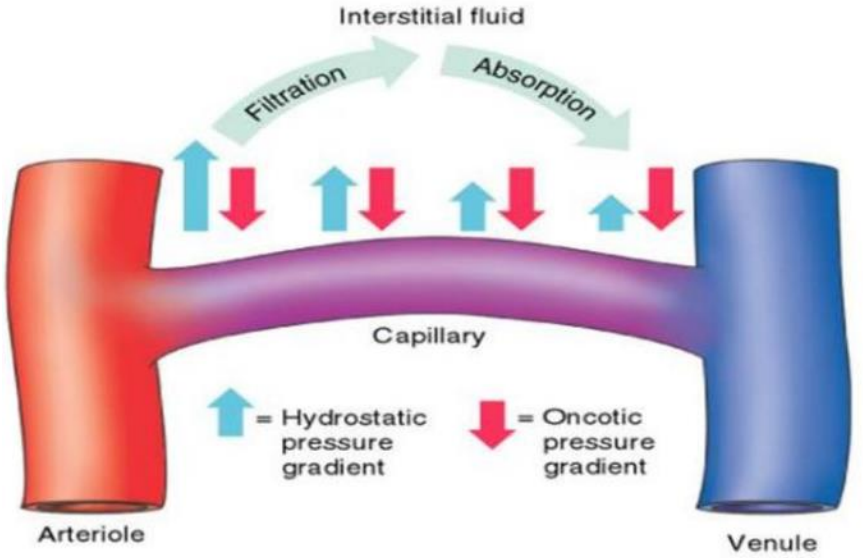


Osmotic Pressure

- The net pressure that drives reabsorption - the movement of fluid from the interstitial fluid back into the capillaries = osmotic pressure (sometimes referred to as oncotic pressure).
- Osmotic pressure draws fluid back in
- Main osmotic forces
  - Blood colloid osmotic pressure (BCOP)
  - Interstitial fluid colloid osmotic pressure (IFCOP)

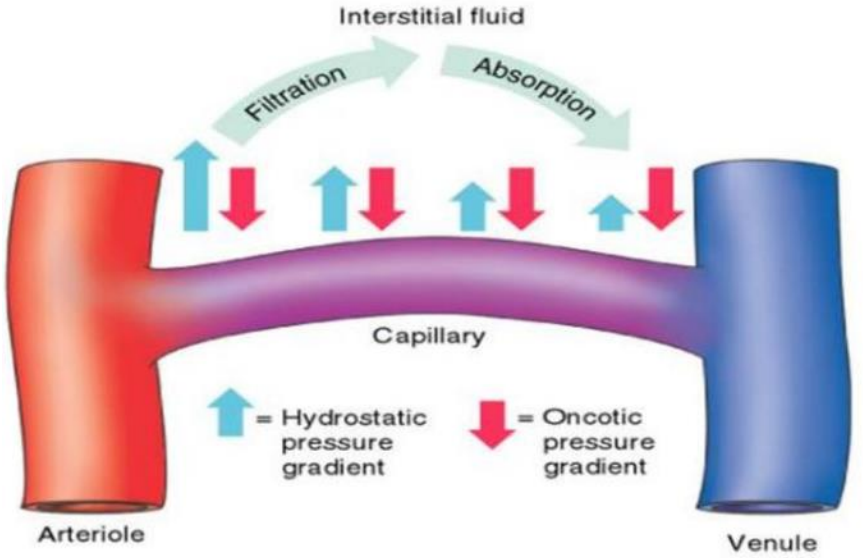
Blood Colloid Osmotic Pressure (BCOP)

- Pressure exerted by proteins in the intravascular fluid which then accounts for the reabsorption of water
- Maintains levels of intravascular fluids



Interstitial Fluid Colloid Osmotic Pressure (IFCOP)

- Generally a negative pressure
- Causes a suction of fluid into the interstitium
- Present due to solute concentration in the interstitium
- Works with capillary hydrostatic pressure in filtration



Net filtration

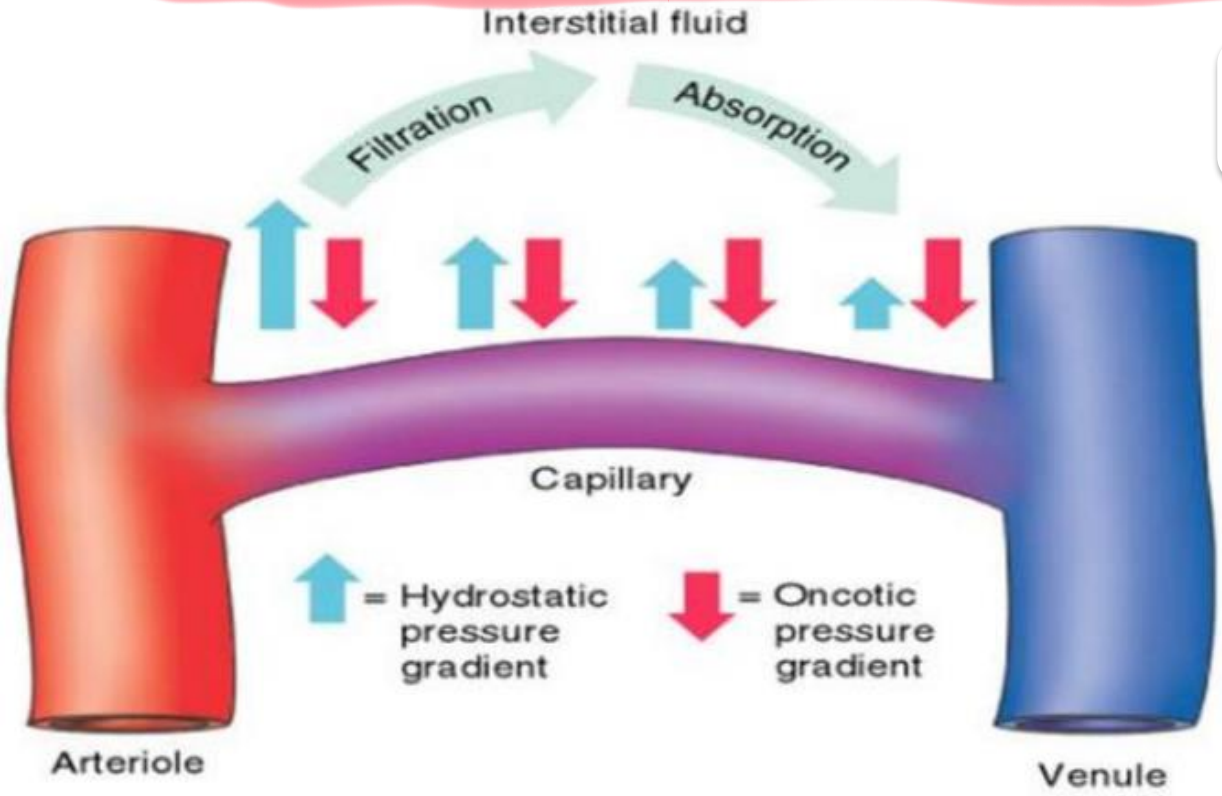
- Represents the interaction of the hydrostatic and osmotic pressures, driving fluid out of the capillary

$$NFP = (BHP - IFHP) - (BCOP - IFCOP)$$

90%

Arteriole End

- ***Hydrostatic*** forces dominate
- movement from bloodstream into the interstitum is favoured by BHP and IFCOP



Venule End

- ***Oncotic*** forces dominate
- Movement from interstitum into the bloodstream is favoured by BCOP and IFHP

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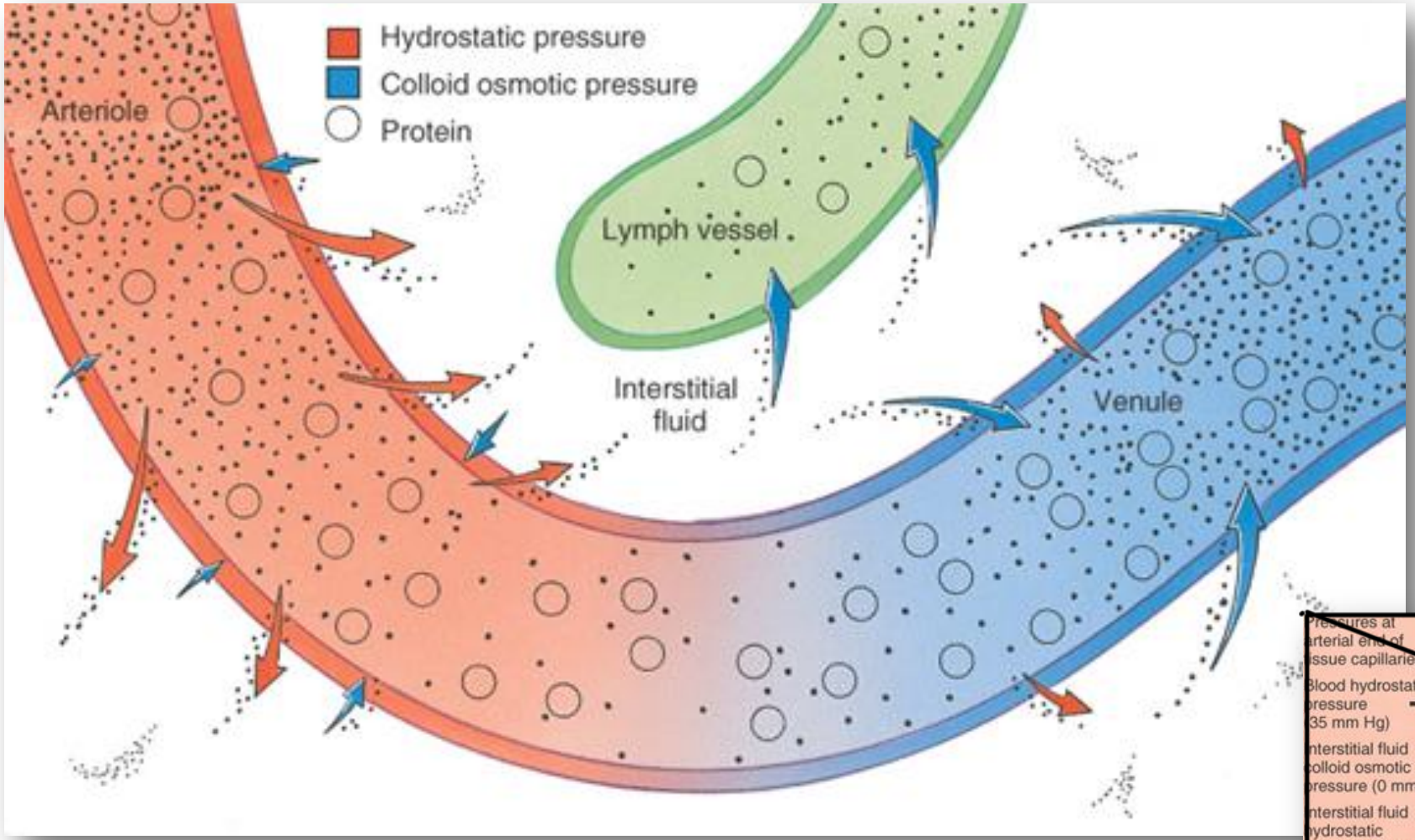
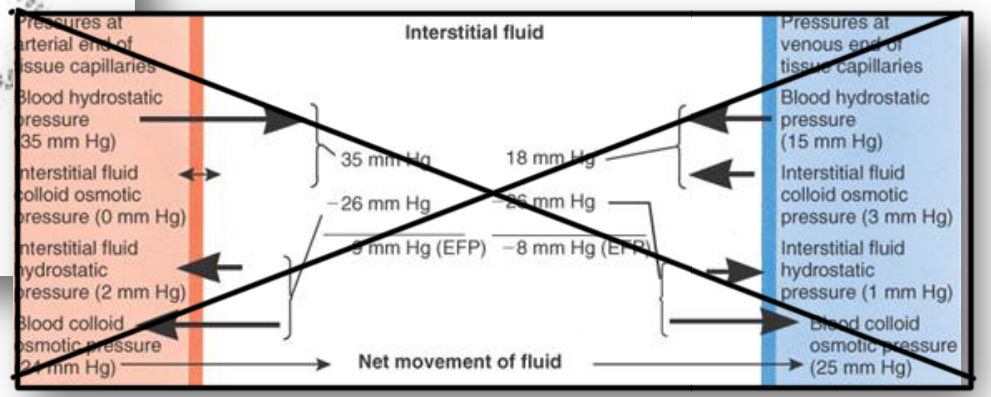
Movement of Fluids





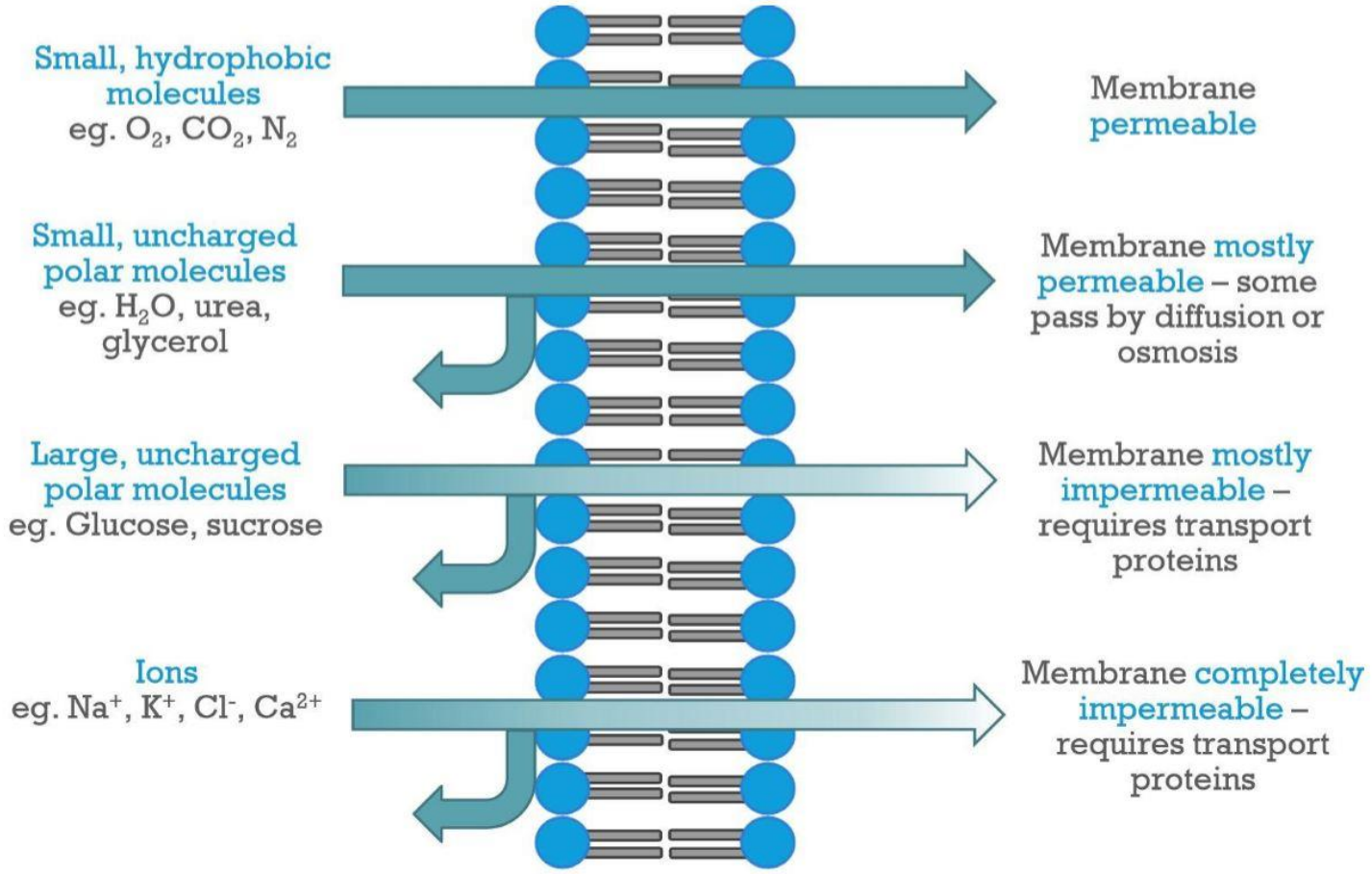
Tonicity

- Isotonic
  - Of **equal** solute concentration…
  - Same pressure
- Hypotonic
  - Of **lesser** solute concentration…
  - Less pressure
- Hypertonic
  - Of **higher** solute concentration…
  - More pressure

…than the fluid being compared

Membrane Permeability

- Only a small portion of plasma proteins cross capillary membranes
- Fluid passes easily, depending on the tonicity of each side of the membrane

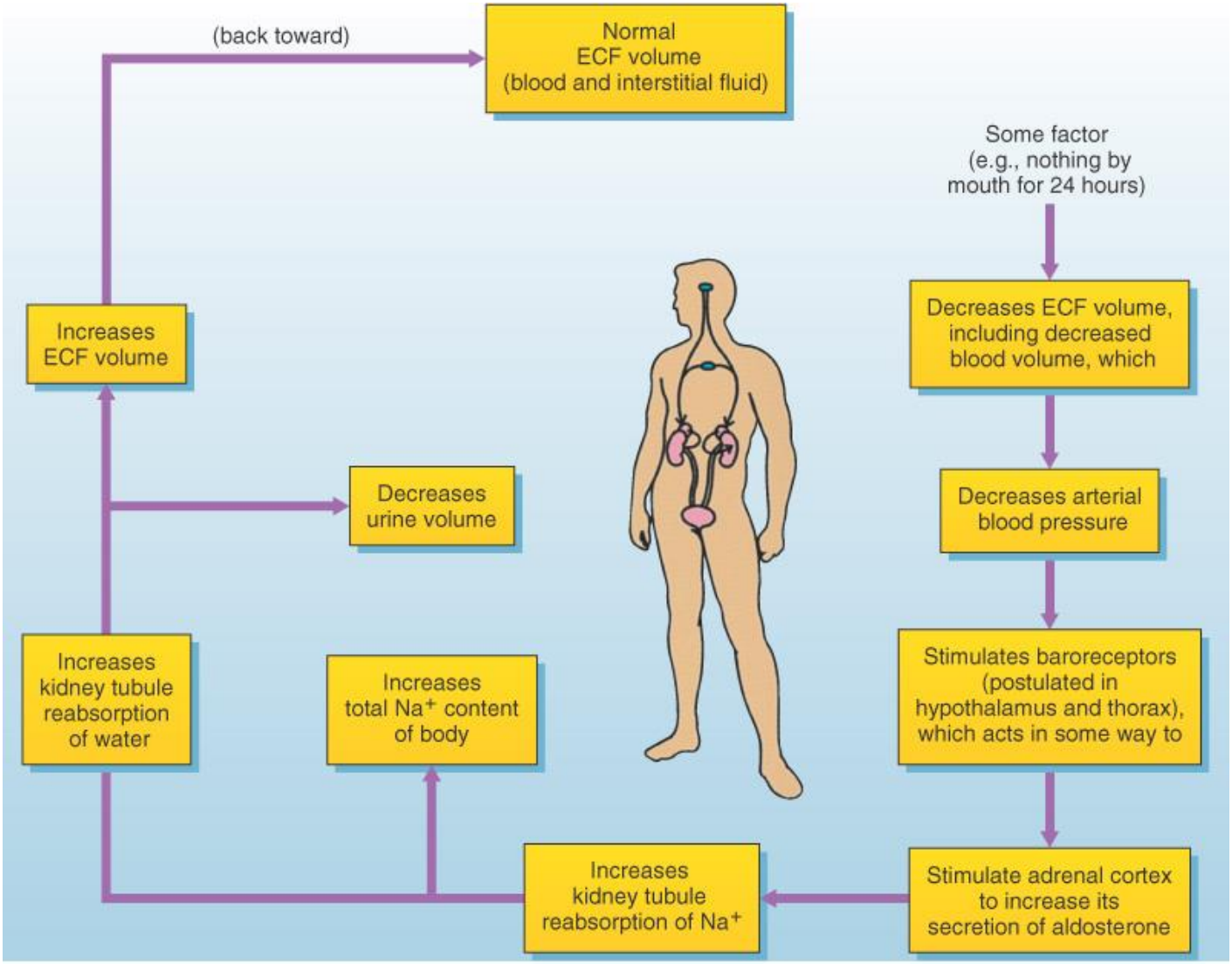


Solvent, Solute and Particulate Transport

- Osmosis
  - The diffusion of water through a selectively permeable membrane
- Diffusion
  - Movement of atoms, ions or molecules from a region of high concentration to a region of low concentration
- Active Transport
  - Moves substances against (“uphill”) a concentration gradient
- Facilitated Diffusion
  - Moves substances down the gradient by use of a carrier protein

Water Balance

- Water balance regulated by ADH and perception of thirst.
- ADH released due to:
  - Increased plasma osmolality
  - Decreased circulating blood volume
  - Lowered venous and arterial pressure
- Following the release of ADH water is reabsorbed from renal tubules and collecting ducts of the kidneys



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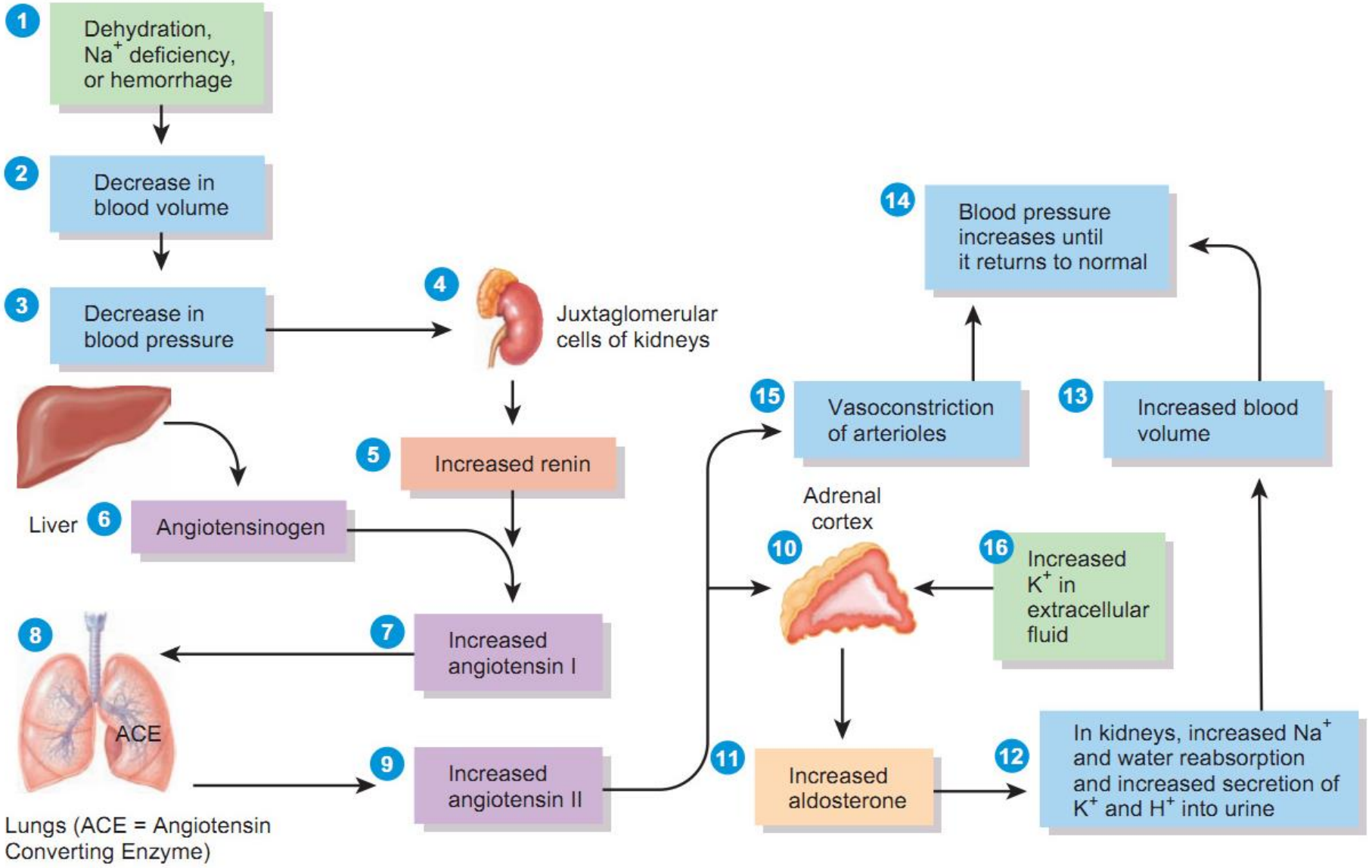
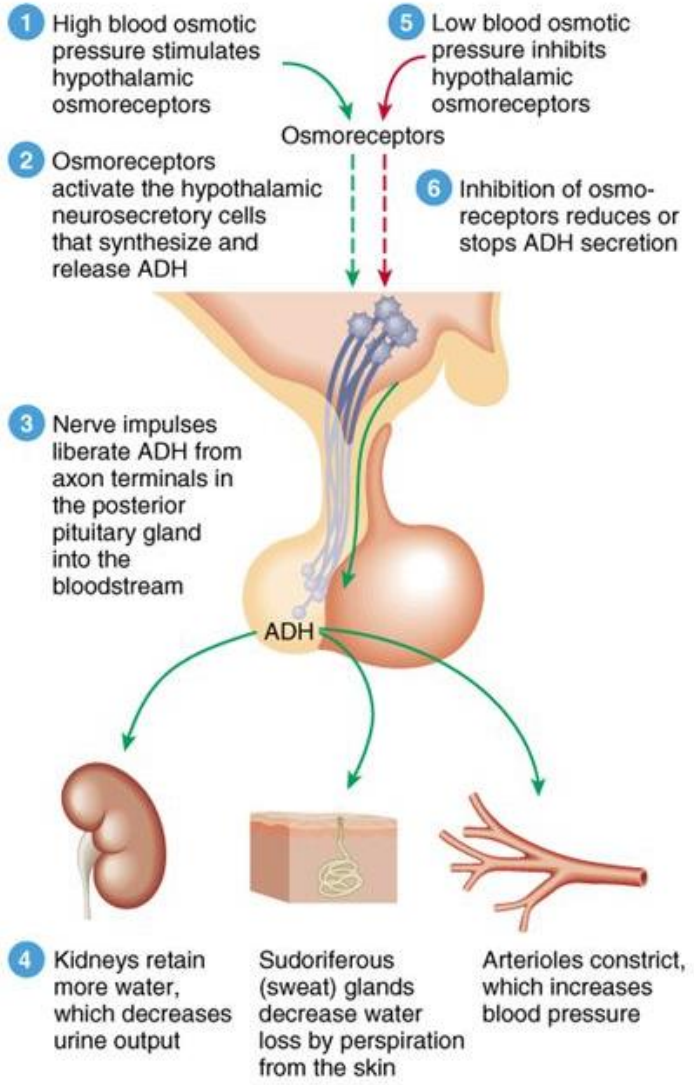
Renin-Angiotensin-Aldosterone System (RAAS)



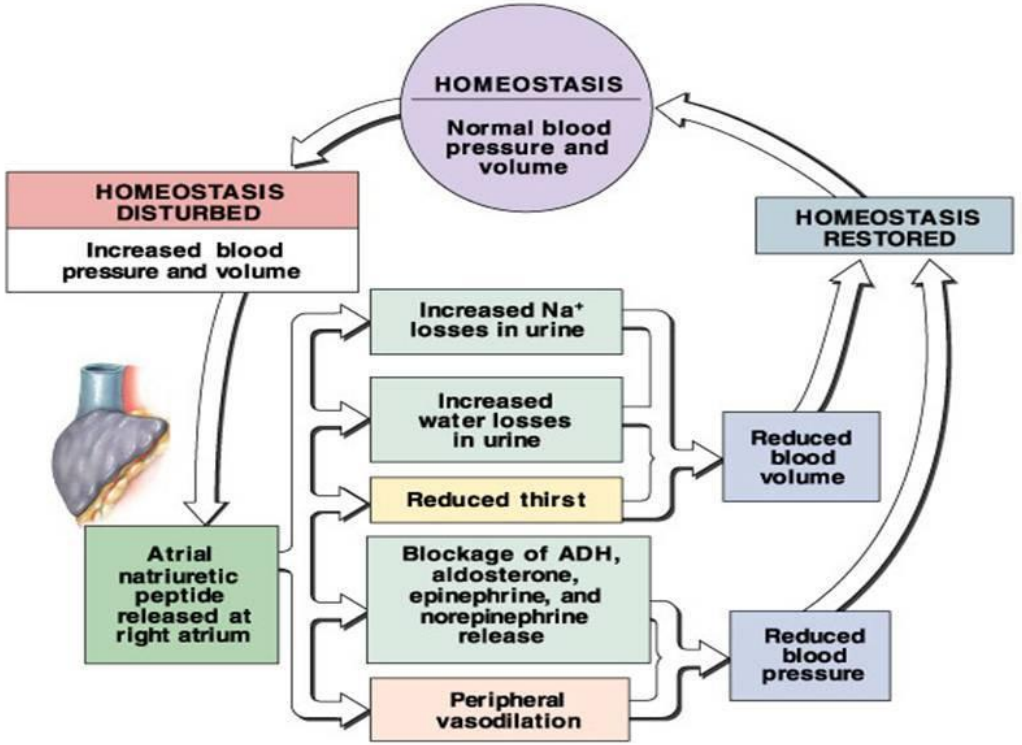
Antidiuretic Hormone (ADH)

- ADH also referred to as Vasopressin
  - Created in the hypothalamus and stored in the posterior pituitary gland
- Stimulated to be released as a result of Angiotensin II (that was released due to a drop in blood volume)

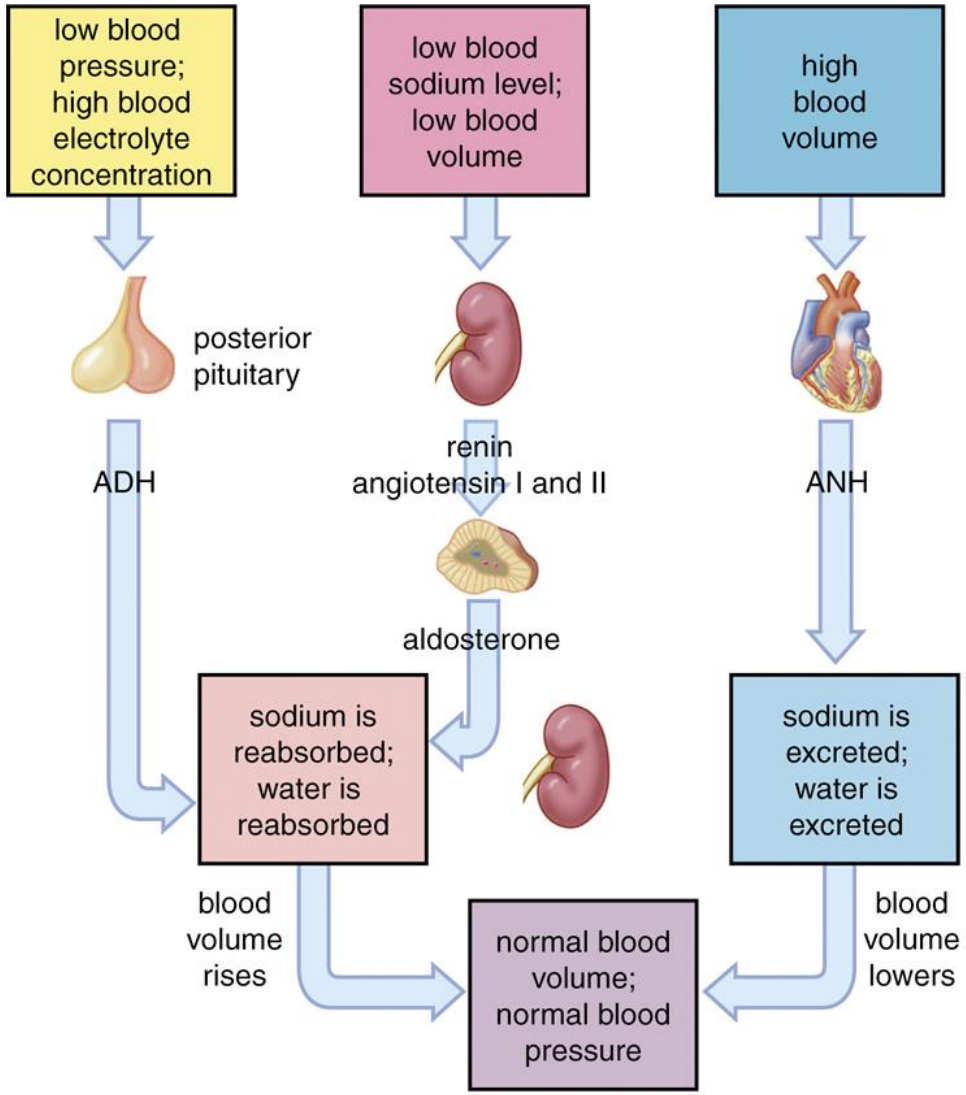


Atrial Natriuretic Hormone (ANH)

- Increasing blood volume (RAAS and ADH) and pressure causes right atrium to over stretch
- This stimulates the release of ANH from the cardiac cells into the blood stream
- ANH causes:
  - ↓ Na^+ reabsorption
  - ↑ GFR
  - Peripheral vasodilation
  - Inhibits ADH
  - Inhibits Aldosterone



Balance


low blood pressure; high blood electrolyte concentration
low blood sodium level; low blood volume
high blood volume
posterior pituitary
ADH
renin
angiotensin I and II
aldosterone
ANH
sodium is reabsorbed; water is reabsorbed
sodium is excreted; water is excreted
blood volume rises
blood volume lowers
normal blood volume; normal blood pressure

Fluid/Electrolyte Imbalances

- Hypovolemia (dehydration)
  - Isotonic
  - Hyponatremic
  - Hypernatremic
- Hypervolemia (overhydration)

Isotonic

- Excessive loss of equal amounts of Na and Water
  - Severe or long term vomiting/diarrhea
  - Systemic infection
  - Intestinal obstruction

Hyponatremic

- A serum decrease in Na^+
  - Excess loss of Na^+
  - Decrease in $[Na^+]$ relative to water
- Causes
  - Use of salt-wasting diuretics
  - Excessive perspiration
  - Salt losing renal disorders
  - Increased water intake
  - Excessive use of water enemas

Hyponatremic

- S/S
  - Muscle cramps
  - N/V
  - Postural BP changes
  - Poor skin turgor
  - Fatigue
  - Dyspnea
  - Confusion, hemiparesis, seizures and coma (due to cerebral swelling in severe cases)

Hypernatremic

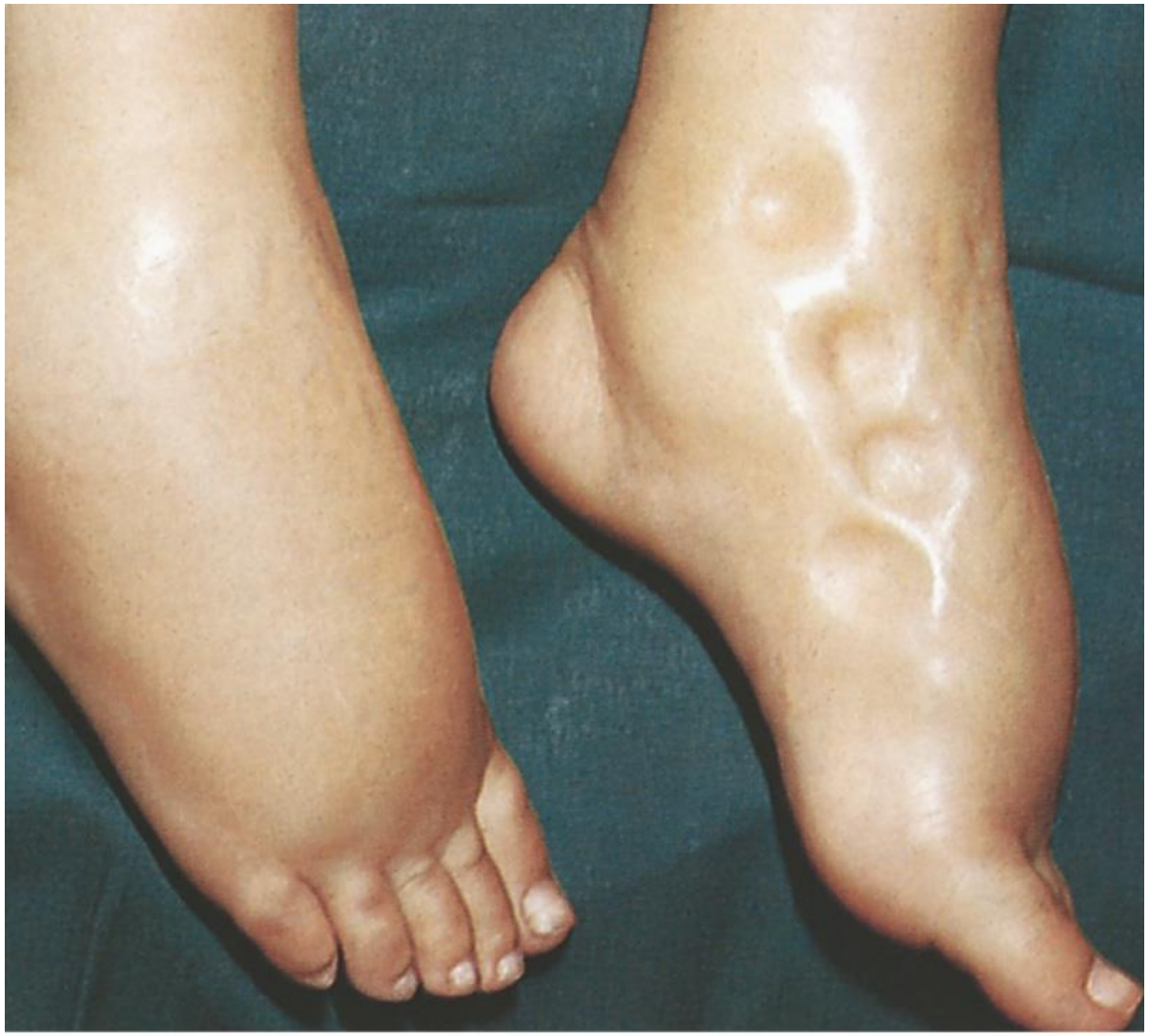
- Elevation of serum levels
  - Loss of water in excess of Na
  - Elevated Na levels
- Causes
  - Lack of fluid intake
  - Diabetes Insipidus
  - CHF
  - Renal failure
  - Excessive misuse of diuretics
  - Na intake in absence of water
  - Profuse watery diarrhea

Hypernatremic

- S/S
  - Similar to hyponatremia
  - Thirst
  - Disorientation
  - Lethargy
  - Seizures

Overhydration

- Increased body water with a decrease in solute concentration
  - Excessive IV fluid administration
  - Impaired cardiac function
  - Impaired renal function
  - Endocrine dysfunction



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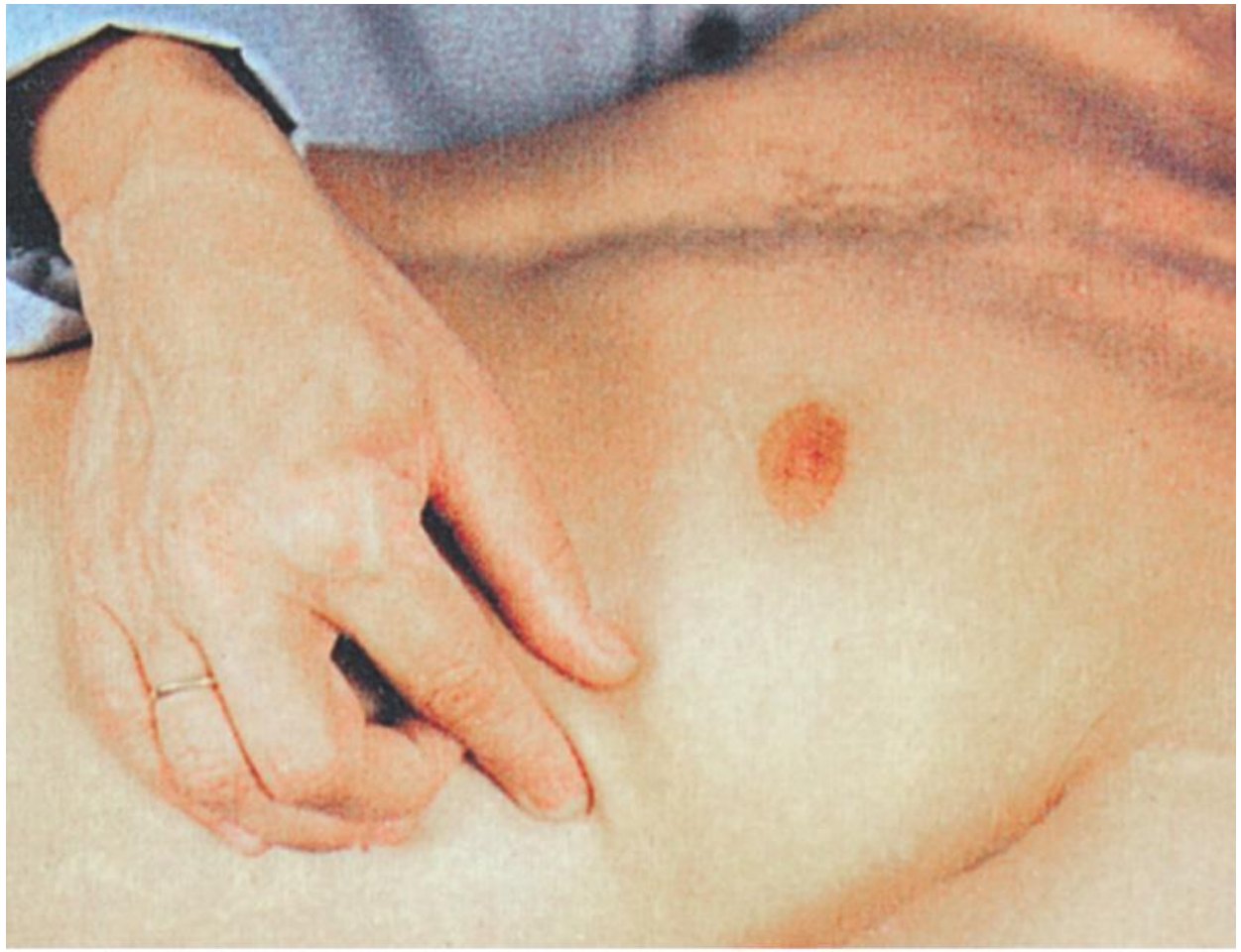

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Roles of Electrolytes

- K^+
  - Nerve, muscle and cardiac function
- Ca^{++}
  - Neurotransmission, cell membrane permeability, hormone secretion, growth, ossification of bones and muscle contraction
- Mg^{++}
  - Activates many enzymes, nervous system and MSK effects similar to calcium

TABLE 27.2

Blood Electrolyte Imbalances

	DEFICIENCY		EXCESS	
ELECTROLYTE*	NAME AND CAUSES	SIGNS AND SYMPTOMS	NAME AND CAUSES	SIGNS AND SYMPTOMS
Sodium (Na^+) **136–148 mEq/liter**	**Hyponatremia** (hī-pō-na-TRĒ-mē-a) may be due to decreased sodium intake; increased sodium loss through vomiting, diarrhea, aldosterone deficiency, or taking certain diuretics; and excessive water intake.	Muscular weakness; dizziness, headache, and hypotension; tachycardia and shock; mental confusion, stupor, and coma.	**Hypernatremia** may occur with dehydration, water deprivation, or excessive sodium in diet or intravenous fluids; causes hypertonicity of ECF, which pulls water out of body cells into ECF, causing cellular dehydration.	Intense thirst, hypertension, edema, agitation, and convulsions.
Chloride (Cl^-) **95–105 mEq/liter**	**Hypochloremia** (hī-pō-klō-RĒ-mē-a) may be due to excessive vomiting, overhydration, aldosterone deficiency, congestive heart failure, and therapy with certain diuretics such as furosemide (Lasix®).	Muscle spasms, metabolic alkalosis, shallow respirations, hypotension, and tetany.	**Hyperchloremia** may result from dehydration due to water loss or water deprivation; excessive chloride intake; or severe renal failure, hyperaldosteronism, certain types of acidosis, and some drugs.	Lethargy, weakness, metabolic acidosis, and rapid, deep breathing.
Potassium (K^+) **3.5–5.0 mEq/liter**	**Hypokalemia** (hī-pō-ka-LĒ-mē-a) may result from excessive loss due to vomiting or diarrhea, decreased potassium intake, hyperaldosteronism, kidney disease, and therapy with some diuretics.	Muscle fatigue, flaccid paralysis, mental confusion, increased urine output, shallow respirations, and changes in electrocardiogram, including flattening of T wave.	**Hyperkalemia** may be due to excessive potassium intake, renal failure, aldosterone deficiency, crushing injuries to body tissues, or transfusion of hemolyzed blood.	Irritability, nausea, vomiting, diarrhea, muscular weakness; can cause death by inducing ventricular fibrillation.

*Values are normal ranges of blood plasma levels in adults.

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TABLE 27.2

Blood Electrolyte Imbalances

	DEFICIENCY		EXCESS	
ELECTROLYTE*	**NAME AND CAUSES**	**SIGNS AND SYMPTOMS**	**NAME AND CAUSES**	**SIGNS AND SYMPTOMS**
Calcium (Ca^{2+}) **Total = 9.0–10.5 mg/dL; ionized = 4.5–5.5 mEq/liter**	**Hypocalcemia** (hī-pō-kal-SĒ-mē-a) may be due to increased calcium loss, reduced calcium intake, elevated phosphate levels, or hypoparathyroidism.	Numbness and tingling of fingers; hyperactive reflexes, muscle cramps, tetany, and convulsions; bone fractures; spasms of laryngeal muscles that can cause death by asphyxiation.	**Hypercalcemia** may result from hyperparathyroidism, some cancers, excessive intake of vitamin D, and Paget's disease of bone.	Lethargy, weakness, anorexia, nausea, vomiting, polyuria, itching, bone pain, depression, confusion, paresthesia, stupor, and coma.
Phosphate (HPO_4^{2-}) **1.7–2.6 mEq/liter**	**Hypophosphatemia** (hī-pō-fos′-fa-TĒ-mē-a) may occur through increased urinary losses, decreased intestinal absorption, or increased utilization.	Confusion, seizures, coma, chest and muscle pain, numbness and tingling of fingers, decreased coordination, memory loss, and lethargy.	**Hyperphosphatemia** occurs when kidneys fail to excrete excess phosphate, as in renal failure; can also result from increased intake of phosphates or destruction of body cells, which releases phosphates into blood.	Anorexia, nausea, vomiting, muscular weakness, hyperactive reflexes, tetany, and tachycardia.
Magnesium (Mg^{2+}) **1.3–2.1 mEq/liter**	**Hypomagnesemia** (hī′-pō-mag′-ne-SĒ-mē-a) may be due to inadequate intake or excessive loss in urine or feces; also occurs in alcoholism, malnutrition, diabetes mellitus, and diuretic therapy.	Weakness, irritability, tetany, delirium, convulsions, confusion, anorexia, nausea, vomiting, paresthesia, and cardiac arrhythmias.	**Hypermagnesemia** occurs in renal failure or due to increased intake of Mg^{2+}, such as Mg^{2+}-containing antacids; also occurs in aldosterone deficiency and hypothyroidism.	Hypotension, muscular weakness or paralysis, nausea, vomiting, and altered mental functioning.

*Values are normal ranges of blood plasma levels in adults.

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