Chapter 2

Fluid, Electrolyte, and Acid-Base Imbalances

Review of Concepts and Processes

- The major component of the body is water in these compartments:
  - Intercellular fluid (ICF) compartment
  - Extracellular fluid (ECF) compartment
- Balance of water in the compartments essential for homeostasis

Fluid Compartments

- About 60% of an adult's body weight is water.
- About 70% of an infant's body weight is water.
- Females—higher percentage of fatty tissue, lower water content than males
- Older adults and obese persons—lower proportion of water
- Individuals with less fluid reserve are more likely to be adversely affected by any fluid or electrolyte imbalance.

Fluid Compartments (cont'd.)

- Intracellular compartment (ICF)
- Extracellular compartment (ECF)
  - Intravascular fluid (IVF) or blood
  - Interstitial fluid (ISF) or intercellular fluid

Fluid Compartments in the Body

70 kg male (154 pounds) as prototypic example

Intracellular	28 L
Extracellular	15 L
- plasma	4.5 L
- interstitial	10.5 L

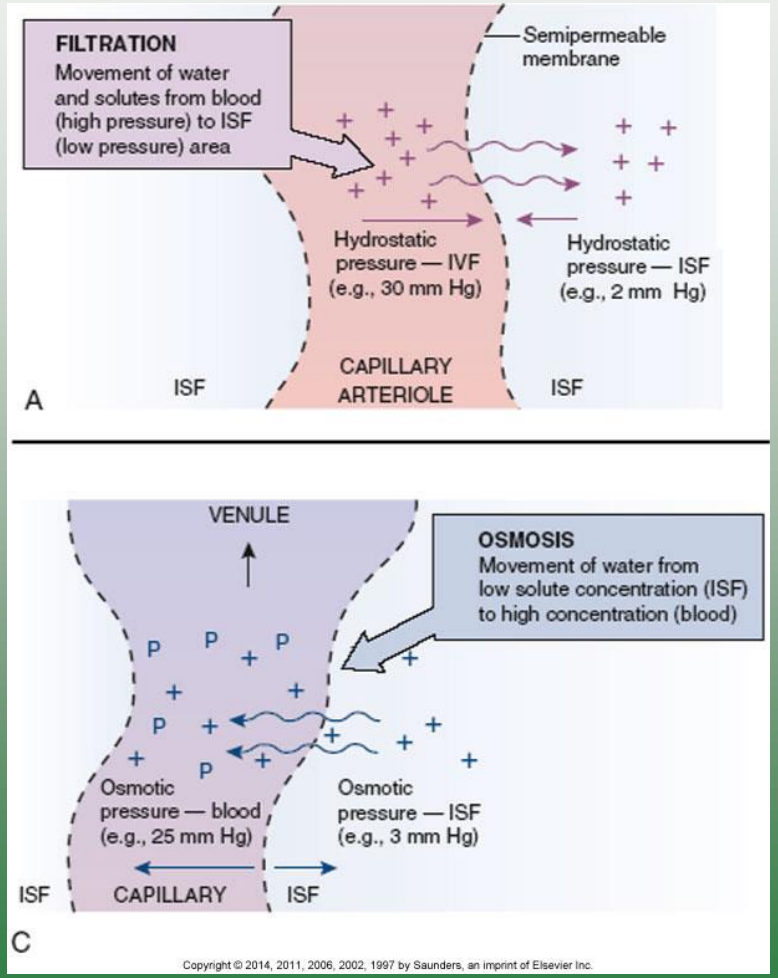
Intake and Output of Water

- The amount of water entering the body should equal the amount of water leaving the body (approximately 2.5 L).

In:		Out:	
Liquid	1200 ml	Urine	1400 ml
Solid Food	1000 ml	Feces	200 ml
Cell metabolism	300 ml	Lungs*	400 ml
		Skin*	500 ml

* Lungs and Skin are “Insensible fluid loss”

Movements of Water between Compartments

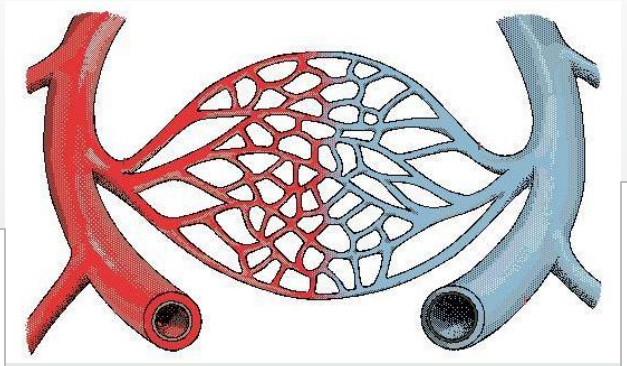


Hydrostatic (water) pressure: from blood pressure.

Osmotic Pressure: from protein concentration.

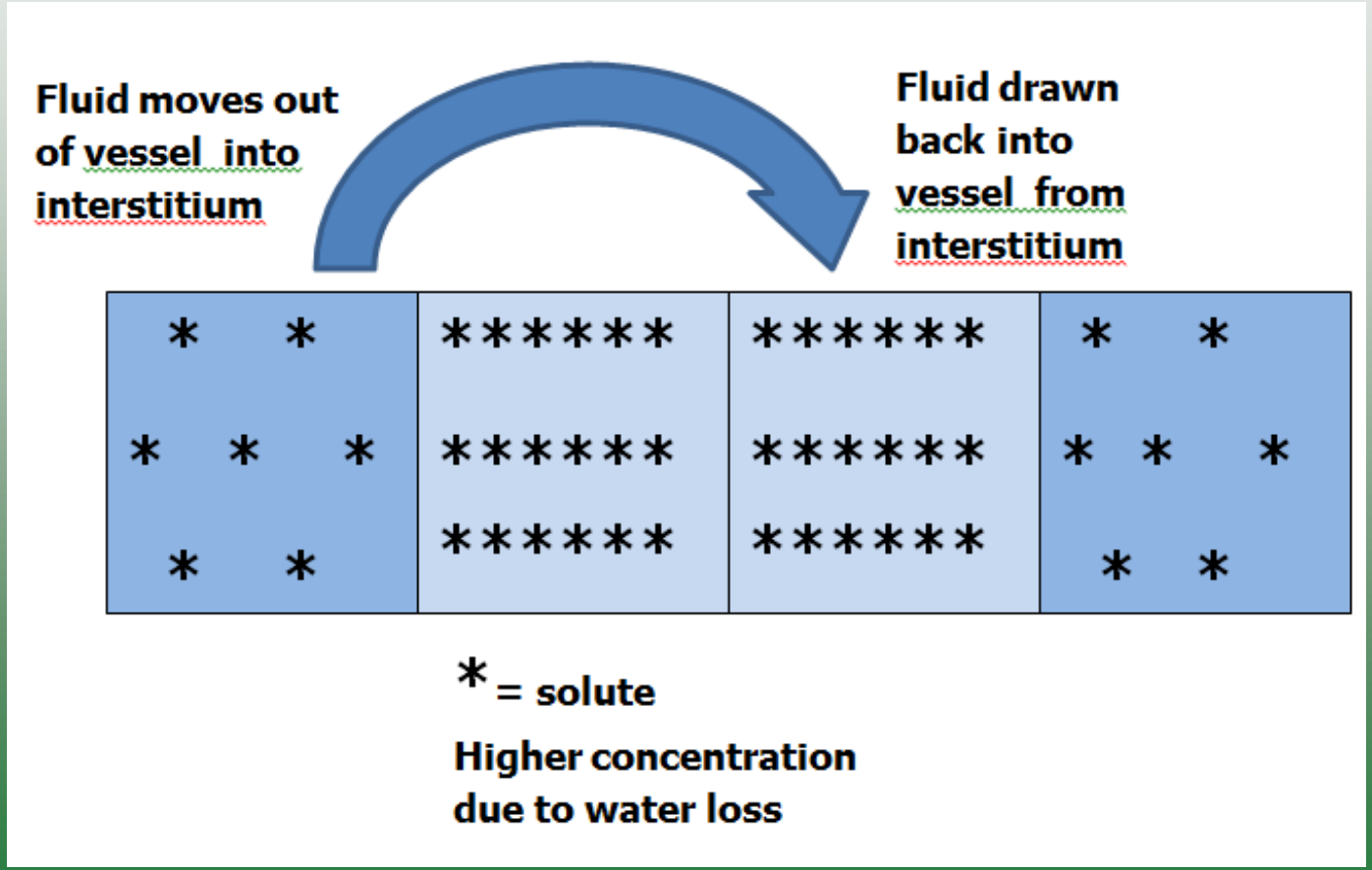
Fluid flows from high to low Hydosatic pressure. Hydrosatic Pushes

Fluid flows from low to high osmotic pressure. Osmotic Pulls



- **Arteriolar end of capillary bed:**
  - - hydrostatic pressure moves fluid out of the vessels into the interstitium

- **Venous end of capillary bed:**
  - - because fluid was lost on the arteriolar side, solute concentration is higher. This produces osmotic pressure that pulls the fluid back into the circulation



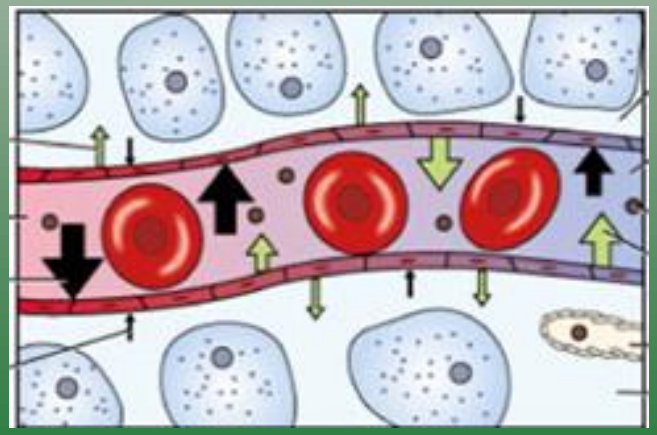
Fluid Imbalance

- Edema—excessive amount of fluid in the interstitial compartment.
- Dehydration – shortage of body fluid.

Causes of Edema

- Increased capillary hydrostatic pressure
  - Caused by higher blood pressure or increased blood volume
  - Forces increased fluid out of capillaries into tissue
- Loss of plasma proteins
  - Particularly albumin
  - Results in decreased plasma osmotic pressure
  - Tissue pulls fluid out of vessels to normalize blood protein concentration.

Also from:
Lymphatic Blockage
Local Inflammation



Effects of Edema

- Swelling
  - Pale or red in color
- Pitting edema
  - Presence of excess interstitial fluid
  - Moves aside when pressure is applied by finger
  - Depression—“pit” remains when finger is removed
- Increase in body weight
  - With generalized edema

Effects of Edema (cont'd.)

From Bloom A, Ireland J: Color Atlas of Diabetes, ed 2, St. Louis, Mosby, 1992.

Fluid Deficit—Dehydration

Insufficient body fluid

- Inadequate intake
- Excessive loss (vomiting, diarrhea)
- Both

Vomiting loses acid (HCl) - hydrogen ions (H^+)

Diarrhea loses base - bicarbonate ions (HCO_3^-)

Effects of Dehydration

- Dry mucous membranes in the mouth
- Decreased skin turgor or elasticity
- Lower blood pressure, weak pulse, and fatigue
- Decreased mental function, confusion, loss of consciousness

Attempts to Compensate for Fluid Loss

- Increasing thirst
- Increasing heart rate
- Constriction of cutaneous blood vessels
- Producing less urine (retains fluid)
- Concentration of urine

Distribution of Major Electrolytes (mEq/L)

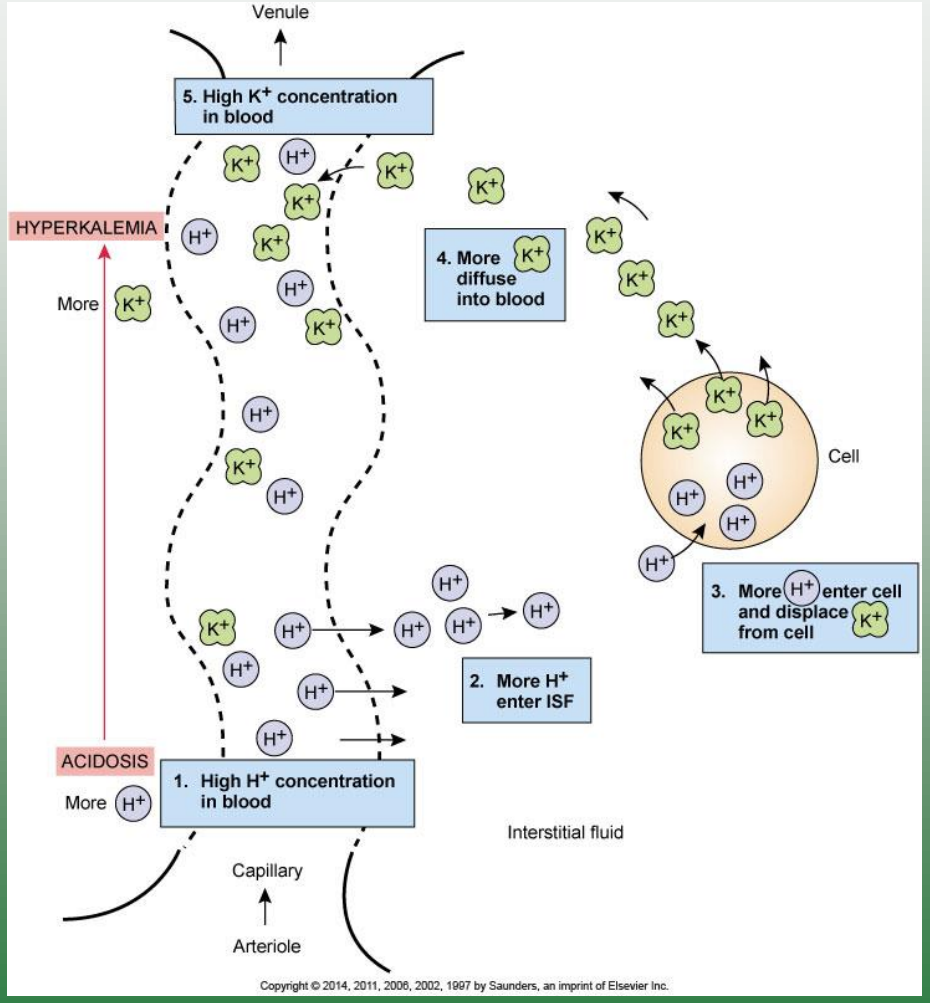
Ion	Intracellular	Blood
Sodium (Na^+)	10	142
Potassium (K^+)	160	4
Calcium (Ca^{++})	variable	5
Magnesium (Mg^{++})	35	3
Bicarbonate (HCO3-)	8	27
Chloride (Cl-)	2	103
Phosphate (HPO4-)	140	2

Positive = cations; Negative = anions

Major Ions

- Sodium *(hyper, hyponatremia)*:
  - primary **cation** in **blood and extracellular fluid**
  - 90% of solute in extracellular fluid (affecting osmotic pressure).
  - Lost in sweat, vomiting and diarrhea.
  - Affected by water consumption and kidney function.
- Potassium *(hyper, hypokalemia)*:
  - primary **cation** in **intracellular fluid**
  - blood levels have profound effect on heart
  - abnormal potassium levels cause changes in cardiac conduction and are ***life-threatening!***

Relationship of Hydrogen and Potassium Ions



Acidosis (low blood pH) is characterized by increased hydrogen ions (H^+) in the blood.

H^+ moves to interstitium then into cells pushing potassium (K^+) out.

K^+ gets back into blood stream producing increased blood K^+ (hyperkalemia)

Calcium Imbalance

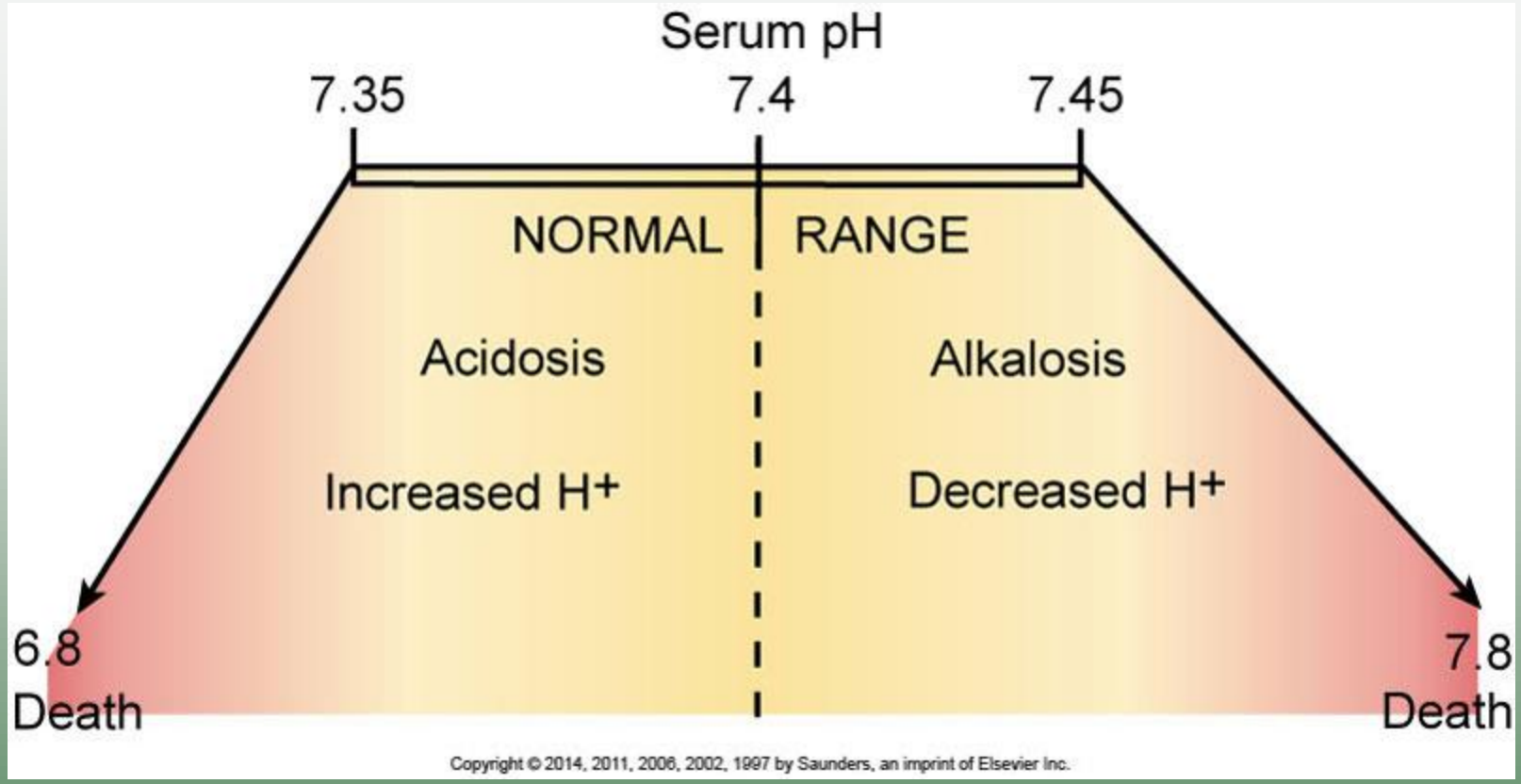
- Review of calcium *(hyper, hypocalcemia)*:
  - Stored in bone
  - Balance controlled by hormones:
    - parathyroid hormone (PTH) raises calcium in blood
    - calcitonin lowers calcium in blood *(tones the bones).*
  - Vitamin D promotes calcium absorption from intestine
    - Ingested or synthesized in skin in the presence of ultraviolet rays
    - Activated in kidneys

Functions of Calcium

- Provides structural **strength for bones** and teeth
- Maintenance of the stability of nerve membranes
- **Required for muscle contractions**
- Necessary for many metabolic processes and enzyme reactions
- **Essential for blood clotting**

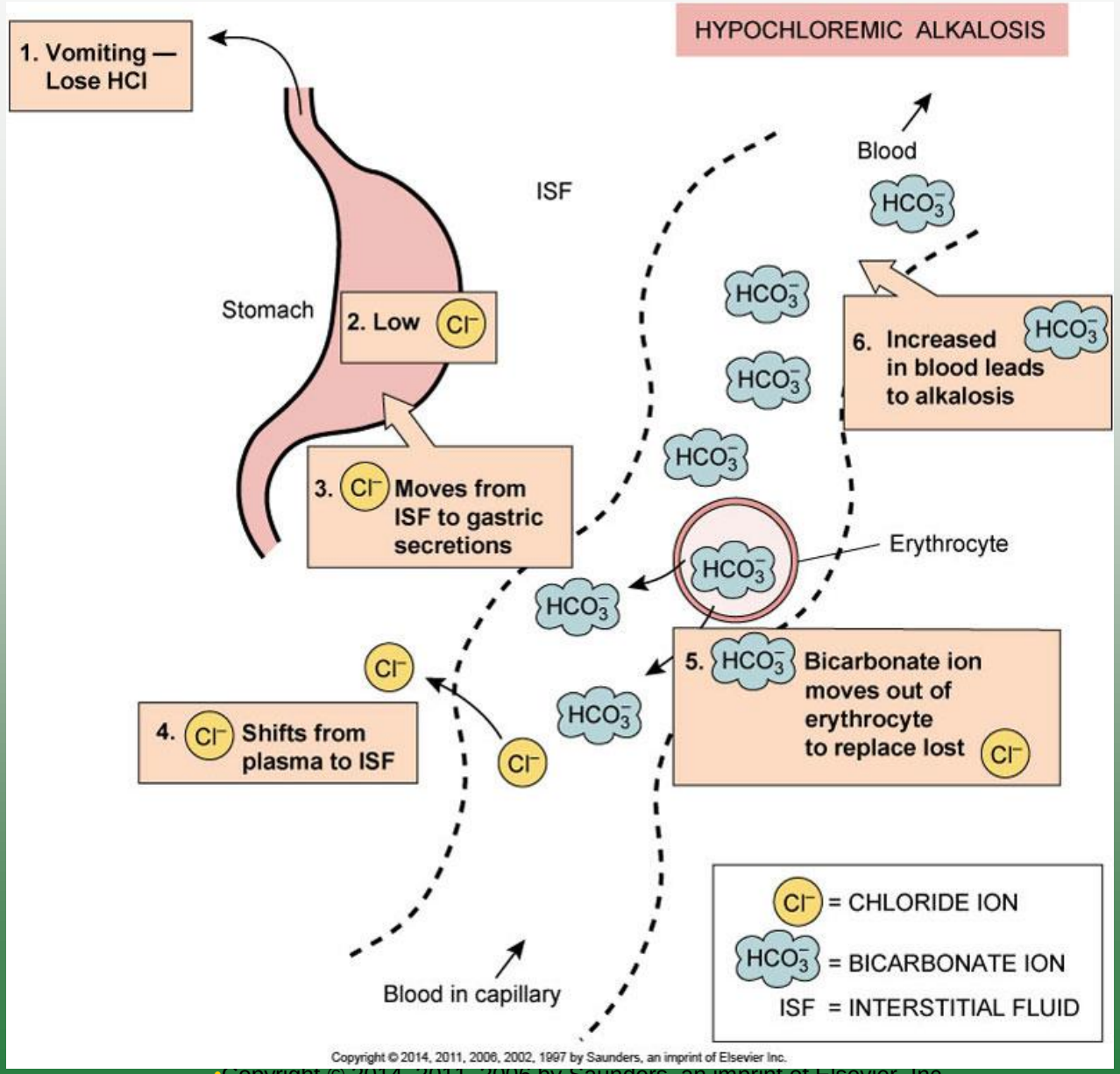
- Magnesium
  - Intracellular ion
  - Hyper, Hypomagnesemia
- Phosphate
  - Bone and tooth mineralization
  - Phosphate buffer system—acid-base balance
  - Reciprocal relationship with serum calcium
  - Hyper, Hypophosphatemia
- Chloride
  - Major extracellular anion
  - Chloride levels related to sodium levels
  - Can shift in response to acid-base imbalances.
  - Hyper, Hypochloremia

Hydrogen Ion and pH Scale

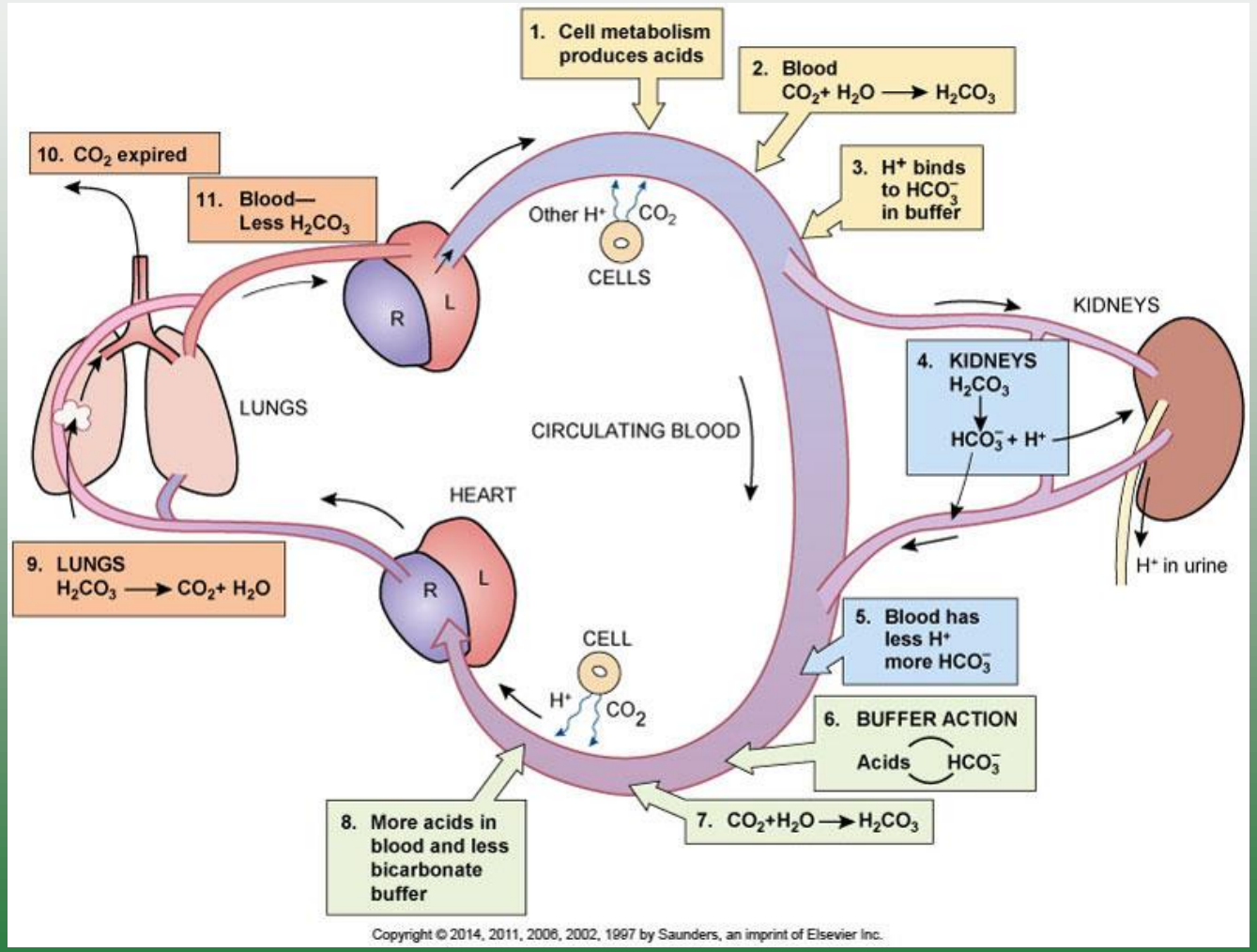


H+ concentration is pH but Cl^- and HCO_3^- are most important for acid-base balance in body.

Chloride Shift



Changes in Acids, Bicarbonate Ion, and Serum pH in Circulating Blood



Acid-Base Imbalance

- Acidosis
  - Excess hydrogen ions
  - Decrease in serum pH
- Alkalosis
  - Deficit of hydrogen ions
  - Increase in serum pH

Two ways to produce acidosis and alkalosis:
1. Respiratory
2. Metabolic

Ways to control:
1. Respiratory (quick but obtrusive)
2. Buffers
3. Kidneys (slowest but most effective).

Respiratory Acidosis

- Lungs are not getting rid of the CO_2, acid builds up in blood.
  - Acute problems
    - Pneumonia, airway obstruction, chest injuries
    - Drugs that depress the respiratory control center
  - Chronic respiratory acidosis
    - Common with chronic obstructive pulmonary disease
  - Kidneys compensate respiratory acidosis by dumping H+ in urine (lowering urine pH) and retaining HCO_3^- (increasing blood HCO_3^-)
  - Body uses respiratory acidosis to compensate for metabolic alkalosis.

Respiratory Alkalosis

- Lungs getting rid of too much CO_2, depletes acid in blood
  - Hyperventilation
    - Caused by anxiety, high fever, overdose of aspirin
    - Head injuries
    - Brainstem tumor
  - Kidneys compensate respiratory alkalosis by retaining H+ from urine (raising urine pH) and dump HCO_3^- (decreasing blood HCO_3^-)
  - body uses respiratory alkalosis to compensate for metabolic acidosis.

Metabolic Acidosis

- Excessive loss of bicarbonate ions to buffer hydrogen (HCO_3^- levels decrease in blood)
  - Diarrhea—loss of bicarbonate from intestines
- Renal disease or failure
  - Decreased excretion of acids
  - Decreased production of bicarbonate ions
- Metabolic imbalance
  - Lactic acidosis from anaerobic metabolism.
    - Hypoxia, hypoperfusion
    - Sepsis
    - Shock
    - Inborn errors in metabolism.

Metabolic Alkalosis

- Metabolic alkalosis
  - Increase in serum bicarbonate ion
    - Loss of hydrochloric acid from stomach (chloride lost from stomach compensated by chloride in blood, compensated by bicarbonate from red blood cells)
    - Hypokalemia (potassium going into cells, opposite of acidosis with potassium coming ot of cells).
    - Excessive ingestion of antacids (bicarbonate).