

## Body water content

Infants have low body fat, low bone mass, and are 73% or more water  
Total water content declines throughout life  
Healthy males are about 60% water; females 50%  
This difference reflects females:  
    Higher body fat  
    Smaller amt of skeletal muscle  
Old age, about 45% body weight is water

## Fluid compartments

Water occupies 2 main fluid compartments  
Intracellular fluid ICF – about 2/3s by volume, contained in cells  
    Plasma – the fluid portion of the blood  
    Interstitial fluid IF – fluid in spaces btwn cells  
Other ECF – lymph, cerebrospinal fluid, eye humors, synovial fluid, serous fluid, and gastrointestinal secretions

## Regulation of water output

Obligatory water losses include:  
    Insensible water losses from lungs and skin  
    Water that accompanies undigested food residues in feces  
Obligatory water loss reflects the fact that:  
    Kidneys excrete 900-1200 mOsm of solutes to maintain bld homeostasis  
    Urine solutes must be flushed out of the body in water

## Water balance and ECF osmolality

water output  
    urine (60%) and feces (4%)  
    insensible losses (28%), sweat (8%)  
increases in plasma osmolality trigger thirst and release of antidiuretic hormone (ADH)

## Regulation of water intake

the hypothalamic thirst center is stimulate:  
    by a decline in plasma volume of 12-15%  
    by increases in plasma osmolality of 1-2%  
    via baroreceptor input, angiotensin II, and other stimuli  
thirst is quenched as soon as we begin to drink water  
feedback signals that inhibit the thirst centers include:  
    moistening of the mucosa of the mouth and throat

activation of stomach and intestinal stretch receptors

### **Disorders of Water Balance: Dehydration**

- Water loss exceeds water intake and the body is in negative fluid balance
- Causes include: hemorrhage, severe burns, prolonged vomiting or diarrhea, profuse sweating, water deprivation, and diuretic abuse
- Signs and symptoms: cottonmouth, thirst, dry flushed skin, and oliguria
- Prolonged dehydration may lead to weight loss, fever, and mental confusion
- Other consequences include hypovolemic shock and loss of electrolytes

### **Disorders of Water Balance: Hypotonic Hydration**

- Renal insufficiency or an extraordinary amount of water ingested quickly can lead to cellular overhydration, or water intoxication
- ECF is diluted - sodium content is normal but excess water is present
- The resulting hyponatremia promotes net osmosis into tissue cells, causing swelling
- These events must be quickly reversed to prevent severe metabolic disturbances, particularly in  
neurons

### **Disorders of Water Balance: Edema**

- Atypical accumulation of fluid in the interstitial space, leading to tissue swelling
- Caused by anything that increases flow of fluids out of the bloodstream or hinders their return
- Factors that accelerate fluid loss include:
  - \* Increased blood pressure, capillary permeability

- \* Incompetent venous valves, localized blood vessel blockage
- \* Congestive heart failure, hypertension, high blood volume
- Hindered fluid return usually reflects an imbalance in colloid osmotic pressures
- Hypoproteinemia - low levels of plasma proteins
- \* Forces fluids out of capillary beds at the arterial ends
- \* Fluids fail to return at the venous ends
- \* Results from protein malnutrition, liver disease, or glomerulonephritis
- Blocked (or surgically removed) lymph vessels:
- \* Cause leaked proteins to accumulate in interstitial fluid
- \* Exert increasing colloid osmotic pressure, which draws fluid from the blood
- Interstitial fluid accumulation results in low blood pressure and severely impaired circulation

## Electrolyte concentration

expressed in milliequivalents per liter (mEq/L), a measure of the number of electrical charges in one liter of solution

$$\text{mEq/L} = (\text{concentration of ion in } \{\text{mg/L}\} / \text{the atomic weight of ion}) \times \text{number of electrical charges of one ion}$$

for single charged ions, 1 mEq = 1 mOsm  
 for bivalent ions, 1 mEq =  $\frac{1}{2}$  mOsm

## Overview of where we find the electrolytes, and why:

### A. Sodium and Potassium

## **-1. Sodium - Homeostasis**

- Primary concern - excretion of dietary excess

\* ~0.5 g/day needed, typical diet has 3 to 7 g/day

- Aldosterone - "salt retaining hormone"

\* increase # of renal Na<sup>+</sup>/K<sup>+</sup> pumps, increased Na<sup>+</sup> and decreased K<sup>+</sup> reabsorbed

\* hypernatremia/hypokalemia inhibits release

- ADH - increased blood Na<sup>+</sup> levels stimulate ADH release

\* kidneys reabsorb more water (without retaining more Na<sup>+</sup>)

- ANP (atrial natriuretic peptide) – from stretched atria

\* kidneys excrete more Na<sup>+</sup> and H<sub>2</sub>O, thus ↓ BP/volume

- Others - estrogen retains water during pregnancy, progesterone has diuretic effect

## **2. Sodium - Imbalances**

Hypernatremia

- plasma sodium > 145 mEq/L

\* from IV saline

- water retention, hypertension and edema

Hyponatremia

- plasma sodium < 130 mEq/L

- result of excess body water, quickly corrected by excretion of excess water

## **3. Potassium - Homeostasis**

- 90% of K<sup>+</sup> in glomerular filtrate is reabsorbed by the PCT
- DCT and cortical portion of collecting duct secrete K<sup>+</sup> in response to blood levels
- Aldosterone stimulates renal secretion of K<sup>+</sup>

#### **4. Potassium - Imbalances**

- Most dangerous imbalances of electrolytes
- Hyperkalemia-effects depend on rate of imbalance
  - \*if concentration rises quickly, (crush injury) the sudden increase in extracellular K<sup>+</sup> makes nerve and muscle cells abnormally excitable
  - \*slow onset, inactivates voltage-gated Na<sup>+</sup> channels, nerve and muscle cells become less excitable
- Hypokalemia
  - \*from sweating, chronic vomiting or diarrhea
  - \*nerve and muscle cells less excitable
  - \*muscle weakness, loss of muscle tone, ? reflexes, arrhythmias

### **B. Chloride Ion**

#### **1. Chloride - Functions**

- ECF osmolarity
  - \*most abundant anions in ECF
- Stomach acid
  - \*required in formation of HCl
- Chloride shift

\*CO<sub>2</sub> loading and unloading in RBC's

-pH

\*major role in regulating pH

## **2. Chloride - Homeostasis**

-Strong attraction to Na<sup>+</sup>, K<sup>+</sup> and Ca<sup>2+</sup>, which it passively follows

-Primary homeostasis achieved as an effect of Na<sup>+</sup> homeostasis

## **3. Chloride - Imbalances**

- Hyperchloremia

\*result of dietary excess or IV saline

- Hypochloremia

\*result of hyponatremia

- Primary effects

\*pH imbalance

## **C. Calcium Ion**

### **1. Calcium - Functions**

-Skeletal mineralization

-Muscle contraction

-Second messenger

-Exocytosis

-Blood clotting

## **2. Calcium - Homeostasis**

- PTH

- Calcitriol (vitamin D)

- Calcitonin (in children)

\* these hormones affect bone deposition and resorption, intestinal absorption and urinary excretion

- Cells maintain very low intracellular  $\text{Ca}^{2+}$  levels

\* to prevent calcium phosphate crystal precipitation

\*\* phosphate levels are high in the ICF

## **3. Calcium - Imbalances**

- Hypercalcemia

\* alkalosis, hyperparathyroidism, hypothyroidism

\* decrease membrane  $\text{Na}^{+}$  permeability, inhibits depolarization

\* concentrations  $> 12 \text{ mEq/L}$  causes muscular weakness, depressed reflexes, cardiac arrhythmias

- Hypocalcemia

\* vitamin D decrease, diarrhea, pregnancy, acidosis, lactation, hypoparathyroidism, hyperthyroidism

\* increase membrane  $\text{Na}^{+}$  permeability, causing nervous and muscular systems to be abnormally excitable

\* very low levels result in tetanus, laryngospasm, death

## **D. Phosphates**

- Concentrated in ICF as phosphate ( $\text{PO}_4^{3-}$ ), monohydrogen phosphate ( $\text{HPO}_4^{2-}$ ), and dihydrogen phosphate ( $\text{H}_2\text{PO}_4^-$ )
- Components of nucleic acids, phospholipids, ATP, GTP, cAMP, creatine phosphate
- Activates metabolic pathways by phosphorylating enzymes
- Buffers pH

### **1. Phosphates - Homeostasis**

- Renal control
  - \*if plasma concentration drops, renal tubules reabsorb all filtered phosphate
- Parathyroid hormone
  - \* increases excretion of phosphate
- Imbalances not as critical
  - \* body can tolerate broad variations in concentration of phosphate

## **E. OTHERS**

**Bicarb: see acid-base section at end**

**Organic acids: see acid-base section at end**

**Proteins: deficiencies discussed in nutrition section in A&P1**