The Urinary System

- Fluid and Electrolyte balance

Fluid, Electrolyte, and Acid-Base Balance

- Blood composition depends on three factors
  - Diet
  - Cellular metabolism
  - Urine output

Fluid, Electrolyte, and Acid-Base Balance

- Kidneys have four roles in maintaining blood composition
  - Excretion of nitrogen-containing wastes (previously discussed)
  - Maintaining water balance of the blood
  - Maintaining electrolyte balance of the blood
  - Ensuring proper blood pH

Maintaining Water Balance

- Normal amount of water in the human body
  - Young adult females = 50%
  - Young adult males = 60%
  - Babies = 75%
  - The elderly = 45%
- Water is necessary for many body functions, and levels must be maintained
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**Distribution of Body Fluid**

- Intracellular fluid (ICF)
  - Fluid inside cells
  - About two-thirds of body fluid
- Extracellular fluid (ECF)
  - Fluids outside cells that includes
    - Interstitial fluid
    - Blood plasma

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**Major Fluid Compartments of the Body**

- Total body water volume = 45 L, 60% body weight
- Extracellular fluid (ECF) volume = 15 L, 30% body weight
- Intracellular fluid volume = 20 L, 40% body weight
- Interstitial fluid volume = 12 L, 90% of ECF (plasma volume = 3 L)

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**The Continuous Mixing of Body Fluids**

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**The Link Between Water and Salt**

- Solutes in the body include electrolytes like sodium, potassium, and calcium ions
- Changes in electrolyte balance causes water to move from one compartment to another
  - Water follows salt
  - Alters blood volume and blood pressure
  - Can impair the activity of cells
Maintaining Water Balance

- Water intake must equal water output
- Sources for water intake
  - Ingested foods and fluids
  - Water produced from metabolic processes
  - Thirst mechanism is the driving force for water intake

Sources for water output
- Vaporization out of the lungs
- Lost in perspiration
- Leaves the body in the feces
- Urine production

Dilute urine is produced if water intake is excessive
- Less urine (concentrated) is produced if large amounts of water are lost
- Proper concentrations of various electrolytes must be present
Regulation of Water and Electrolyte Reabsorption

- Osmoreceptors
  - Cells in the hypothalamus
  - React to changes in blood composition by becoming more active

Regulation of Water and Electrolyte Reabsorption

- Regulation occurs primarily by hormones
  - Antidiuretic hormone (ADH)
    - Prevents excessive water loss in urine
    - Causes the kidney’s collecting ducts to reabsorb more water
  - Diabetes insipidus
    - Occurs when ADH is not released
    - Leads to huge outputs of dilute urine

Regulation of Water and Electrolyte Reabsorption

- Regulation occurs primarily by hormones (continued)
  - Aldosterone
    - Regulates sodium ion content of ECF
    - Sodium is the electrolyte most responsible for osmotic water flows
    - Aldosterone promotes reabsorption of sodium ions
    - Remember, water follows salt!

Regulation of Water and Electrolyte Reabsorption

- Renin-angiotension mechanism
  - Mediated by the juxtaglomerular (JG) apparatus of the renal tubules
  - When cells of the JG apparatus are stimulated by low blood pressure, the enzyme renin is released into blood
  - Renin produces angiotension II
  - Angiotension causes vasoconstriction and aldosterone release
  - Result is increase in blood volume and blood pressure
Maintaining Acid-Base Balance in Blood

- Blood pH must remain between 7.35 and 7.45 to maintain homeostasis
- Alkalosis—pH above 7.45
- Acidosis—pH below 7.35
- Physiological acidosis—pH between 7.35 and 7.0
- Most ions originate as by-products of cellular metabolism

Acids produced by the body
- Phosphoric acid, lactic acid, fatty acids
- Carbon dioxide forms carbonic acid
- Ammonia
- Most acid-base balance is maintained by the kidneys
- Other acid-base controlling systems
- Blood buffers
- Respiration

Blood Buffers

- Acids are proton (H⁺) donors
  - Strong acids dissociate completely and liberate all of their H⁺ in water
  - Weak acids, such as carbonic acid, dissociate only partially
- Bases are proton (H⁺) acceptors
  - Strong bases dissociate easily in water and tie up H⁺
  - Weak bases, such as bicarbonate ion and ammonia, are slower to accept H⁺

Dissociation of Strong and Weak Acids
Blood Buffers

- Molecules react to prevent dramatic changes in hydrogen ion (H⁺) concentrations
- Bind to H⁺ when pH drops
- Release H⁺ when pH rises
- Three major chemical buffer systems
  - Bicarbonate buffer system
  - Phosphate buffer system
  - Protein buffer system

The Bicarbonate Buffer System

- Mixture of carbonic acid (H₂CO₃) and sodium bicarbonate (NaHCO₃)
- Carbonic acid is a weak acid that does not dissociate much in neutral or acid solutions
- Bicarbonate ions (HCO₃⁻) react with strong acids to change them to weak acids
  \[ \text{HCl} + \text{NaHCO}_3 \rightarrow \text{H}_2\text{CO}_3 + \text{NaCl} \]

  strong acid weak base weak acid salt

- Carbonic acid dissociates in the presence of a strong base to form a weak base and water
  \[ \text{NaOH} + \text{H}_2\text{CO}_3 \rightarrow \text{NaHCO}_3 + \text{H}_2\text{O} \]

  strong base weak acid weak base water

Respiratory System Controls of Acid-Base Balance

- Carbon dioxide in the blood is converted to bicarbonate ion and transported in the plasma
- Increases in hydrogen ion concentration produces more carbonic acid
- Excess hydrogen ion can be blown off with the release of carbon dioxide from the lungs
- Respiratory rate can rise and fall depending on changing blood pH
Renal Mechanisms of Acid-Base Balance

- Excrete bicarbonate ions if needed
- Conserve (reabsorb) or generate new bicarbonate ions if needed

When blood pH rises
- Bicarbonate ions are excreted
- Hydrogen ions are retained by kidney tubules

When blood pH falls
- Bicarbonate ions are reabsorbed
- Hydrogen ions are secreted

Urine pH varies from 4.5 to 6.0

Developmental Aspects of the Urinary System

- Functional kidneys are developed by the third month
- Urinary system of a newborn
  - Bladder is small
  - Urine cannot be concentrated for first 2 months
  - Void 5 to 40 times per day

Developmental Aspects of the Urinary System

- Control of the voluntary urethral sphincter does not start until age 18 months
- Complete nighttime control may not occur until the child is 4 years old
- Urinary infections are the only common problems before old age
  - Escherichia coli (E. coli), a type of bacteria, accounts for 80% of UTI (urinary tract infections)