The Urinary System
- Urinary anatomy (non kidney)
- Fluid and electrolyte balance

Ureters
- Slender tubes attaching the kidney to the bladder
  - Continuous with the renal pelvis
  - Enter the posterior aspect of the bladder
- Runs behind the peritoneum
- Peristalsis aids gravity in urine transport

Organs of the Urinary System

Urinary Bladder
- Smooth, collapsible, muscular sac
- Temporarily stores urine
- Trigone—triangular region of the bladder base
  - Three openings
    - Two from the ureters
    - One to the urethra
  - In males, the prostate gland surrounds the neck of the bladder

Female Urinary Bladder and Urethra

Urinary Bladder Wall
- Three layers of smooth muscle collectively called the detrusor muscle
- Mucosa made of transitional epithelium
- Walls are thick and folded in an empty bladder
- Bladder can expand significantly without increasing internal pressure

Urinary Bladder Capacity
- A moderately full bladder is about 5 inches long and holds about 500 mL of urine
- Capable of holding twice that amount of urine

Position and Shape of a Distended and an Empty Urinary Bladder in an Adult Man

Urethra
- Thin-walled tube that carries urine from the bladder to the outside of the body by peristalsis
- Release of urine is controlled by two sphincters
  - Internal urethral sphincter
    - Involuntary and made of smooth muscle
  - External urethral sphincter
    - Voluntary and made of skeletal muscle

Female Urinary Bladder and Urethra

Urethra Gender Differences
- Length
  - Females is 3–4 cm (1 inch)
  - Males is 20 cm (8 inches)
- Location
  - Females—along wall of the vagina
• Males—through the prostate and penis

**Urethra Gender Differences**

- Function
  - Females—only carries urine
  - Males—carries urine and is a passageway for sperm cells

**Micturition (Voiding)**

- Both sphincter muscles must open to allow voiding
- The internal urethral sphincter is relaxed after stretching of the bladder
- Pelvic splanchnic nerves initiate bladder to go into reflex contractions
- Urine is forced past the internal urethra sphincter and the person feels the urge to void
- The external urethral sphincter must be voluntarily relaxed to void

**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

**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

**Major Fluid Compartments of the Body**

**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
  - 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

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

**Water Intake and Output**
- 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 vasconstriction and aldosterone release
- Result is increase in blood volume and blood pressure

Maintaining Water and Electrolyte Balance

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

Maintaining Acid-Base Balance in Blood
- 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

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.

36 Renal Mechanisms of Acid-Base Balance
- Excrete bicarbonate ions if needed
- Conserve (reabsorb) or generate new bicarbonate ions if needed

37 Renal Mechanisms of Acid-Base Balance
- 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 8.0

38 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)

39 Aging and the Urinary System
- There is a progressive decline in urinary function
- The bladder shrinks and loses bladder tone with aging

40 Aging and the Urinary System
- Associated problems with aging
  - Urgency—feeling that it is necessary to void
  - Frequency—frequent voiding of small amounts of urine
  - Nocturia—need to get up during the night to urinate
  - Incontinence—loss of control
  - Urinary retention—common in males, often the result of hypertrophy of the prostate gland