Chapter 15
The Urinary System

Slides 15.1 – 15.20
Functions of the Urinary System

- Elimination of waste products
  - Nitrogenous wastes
  - Toxins
  - Drugs
Functions of the Urinary System

- Regulate aspects of homeostasis
  - Water balance
  - Electrolytes
  - Acid-base balance in the blood
  - Blood pressure
  - Red blood cell production
  - Activation of vitamin D
Organs of the Urinary system

- Kidneys
- Ureters
- Urinary bladder
- Urethra
Location of the Kidneys

- Against the dorsal body wall
- At the level of $T_{12}$ to $L_3$
- The right kidney is slightly lower than the left
- Attached to ureters, renal blood vessels, and nerves at renal hilus
- Atop each kidney is an adrenal gland
Coverings of the Kidneys

- Renal capsule
  - Surrounds each kidney
- Adipose capsule
  - Surrounds the kidney
  - Provides protection to the kidney
  - Helps keep the kidney in its correct location
Regions of the Kidney

- Renal cortex – outer region
- Renal medulla – inside the cortex
- Renal pelvis – inner collecting tube
Kidney Structures

- Medullary pyramids – triangular regions of tissue in the medulla
- Renal columns – extensions of cortex-like material inward
- Calyces – cup-shaped structures that funnel urine towards the renal pelvis
Blood Flow in the Kidneys

Aorta → Renal artery → Segmental artery → Lobar artery → Interlobar artery → Arcuate artery → Interlobular artery → Afferent arteriole

Inferior vena cava → Renal vein → Interlobar vein → Arcuate vein → Interlobular vein → Glomerulus (capillaries)

Peritubular capillaries and vasa recta → Efferent arteriole

Figure 15.2c
Nephrons

- The structural and functional units of the kidneys
- Responsible for forming urine
- Main structures of the nephrons
  - Glomerulus
  - Renal tubule
Glomerulus

- A specialized capillary bed
- Attached to arterioles on both sides (maintains high pressure)
  - Large afferent arteriole
  - Narrow efferent arteriole

Figure 15.3c
Glomerulus

- Capillaries are covered with podocytes from the renal tubule

- The glomerulus sits within a glomerular capsule (the first part of the renal tubule)

Figure 15.3c
Renal Tubule

- Glomerular (Bowman’s) capsule
- Proximal convoluted tubule
- Loop of Henle
- Distal convoluted tubule
Types of Nephrons

- **Cortical nephrons**
  - Located entirely in the cortex
  - Includes most nephrons
Types of Nephrons

- Juxtamedullary nephrons
- Found at the boundary of the cortex and medulla
Peritubular Capillaries

- Arise from efferent arteriole of the glomerulus
- Normal, low pressure capillaries
- Attached to a venule
- Cling close to the renal tubule
- Reabsorb (reclaim) some substances from collecting tubes
Urine Formation Processes

- Filtration
- Reabsorption
- Secretion

Figure 15.4
Filtration

- Nonselective passive process
- Water and solutes smaller than proteins are forced through capillary walls
- Blood cells cannot pass out to the capillaries
- Filtrate is collected in the glomerular capsule and leaves via the renal tubule
Reabsorption

- The peritubular capillaries reabsorb several materials
  - Some water
  - Glucose
  - Amino acids
  - Ions
- Some reabsorption is passive, most is active
- Most reabsorption occurs in the proximal convoluted tubule
Materials Not Reabsorbed

- Nitrogenous waste products
  - Urea
  - Uric acid
  - Creatinine
- Excess water
Secretion – Reabsorption in Reverse

- Some materials move from the peritubular capillaries into the renal tubules
  - Hydrogen and potassium ions
  - Creatinine
- Materials left in the renal tubule move toward the ureter
Formation of Urine

Figure 15.5

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Characteristics of Urine Used for Medical Diagnosis

- Colored somewhat yellow due to the pigment urochrome (from the destruction of hemoglobin) and solutes
- Sterile
- Slightly aromatic
- Normal pH of around 6
- Specific gravity of 1.001 to 1.035
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
Urinary Bladder

- Smooth, collapsible, muscular sac
- Temporarily stores urine
Urinary Bladder

- Trigone – three openings
  - Two from the ureters
  - One to the urethrea
Urinary Bladder Wall

- Three layers of smooth muscle (detrusor muscle)
- Mucosa made of transitional epithelium
- Walls are thick and folded in an empty bladder
- Bladder can expand significantly without increasing internal pressure
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)
  - External urethral sphincter (voluntary)
Urethra Gender Differences

- **Length**
  - Females – 3–4 cm (1 inch)
  - Males – 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
  - Activation is from an impulse sent to the spinal cord and then back via the pelvic splanchnic nerves
  - The external urethral sphincter must be voluntarily relaxed
Maintaining Water Balance

• Normal amount of water in the human body
  • Young adult females – 50%
  • Young adult males – 60%
  • Babies – 75%
  • Old age – 45%

• Water is necessary for many body functions and levels must be maintained
Distribution of Body Fluid

- **Intracellular fluid** (inside cells)
- **Extracellular fluid** (outside cells)
  - Interstitial fluid
  - Blood plasma

### Figure 15.7

<table>
<thead>
<tr>
<th></th>
<th>Total body water volume = 40 L, 60% body weight</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Extracellular fluid</strong> volume = 15 L, 20% body weight</td>
<td></td>
</tr>
<tr>
<td><strong>Intracellular fluid volume</strong> = 25 L, 40% body weight</td>
<td></td>
</tr>
<tr>
<td><strong>Interstitial fluid volume</strong> = 12 L, 80% of ECF</td>
<td></td>
</tr>
<tr>
<td><strong>Plasma volume</strong> = 3 L, 20% of ECF</td>
<td></td>
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</tbody>
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The Link Between Water and Salt

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

- 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

- Regulation is primarily by hormones
  - Antidiuretic hormone (ADH) prevents excessive water loss in urine
  - Aldosterone regulates sodium ion content of extracellular fluid
    - Triggered by the rennin-angiotensin mechanism
- Cells in the kidneys and hypothalamus are active monitors
Maintaining Water and Electrolyte Balance

Figure 15.9

KEY:
- (+) = stimulates
- Renin-angiotension system
- Neural regulation (sympathetic nervous system effects)
- Effects of ADH release
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
- Most ions originate as byproducts of cellular metabolism
Maintaining Acid-Base Balance in Blood

- Most acid-base balance is maintained by the kidneys
- Other acid-base controlling systems
  - Blood buffers
  - Respiration
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 (H$_2$CO$_3$) and sodium bicarbonate (NaHCO$_3$)
- Bicarbonate ions (HCO$_3^-$) react with strong acids to change them to weak acids
- Carbonic acid dissociates in the presence of a strong base to form a weak base and 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 or generate new bicarbonate ions if needed
- Urine pH varies from 4.5 to 8.0
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
Developmental Aspects of the Urinary System

- Control of the voluntary urethral sphincter does not start until age 18 months
- Urinary infections are the only common problems before old age
Aging and the Urinary System

- There is a progressive decline in urinary function
- The bladder shrinks with aging
- Urinary retention is common in males