16
The Urinary System
The Urinary System

OUTLINE:

- Eliminating Waste
- Components of the Urinary System
- Kidneys and Homeostasis
- Dialysis and Transplant Surgery
- Urination
- Urinary Tract Infections
Eliminating Waste

- Excretion
  - Elimination of wastes and excess substances from the body
  - Metabolic wastes include carbon dioxide, water, heat, salts, and nitrogen-containing wastes (ammonia, urea, uric acid, creatinine)
Eliminating Waste

- Several organs eliminate wastes and excess essential ions
  - Lungs
    - Heat, water, and carbon dioxide
  - Skin
    - Heat, water, bicarbonate ions, salts, urea, uric aid
  - Organs of the GI tract
    - Solid wastes and some metabolic wastes
  - Kidneys
    - Form urine (mix of water and solutes): water, bicarbonate ions, inorganic salts, hydrogen ions, urea, uric acid, and creatinine
Figure 16.1 *Organs from several systems eliminate wastes of different kinds from the body.*
Components of the Urinary System

- The urinary system consists of two kidneys, two ureters, one urinary bladder, and one urethra

  - Functions
    - Regulates the volume, pH, pressure, and composition of the blood

  - Organs
    - Kidneys
      - Regulate the amount of water and dissolved substances that are removed from and returned to the blood
      - Substances not returned to the blood form urine
Components of the Urinary System

- Organs (cont’d)
  - Ureters
    - Transport urine from kidneys to bladder
  - Urinary bladder
    - Stores urine
  - Urethra
    - Transports urine from urinary bladder to outside the body
Figure 16.2 Organs of the urinary system.

**Kidney**
- Produces urine
- Conserves water
- Regulates pH
- Stimulates production of red blood cells
- Transforms vitamin D into active form

**Ureter**
- Transports urine from kidneys to bladder

**Urinary bladder**
- Stores urine

**Urethra**
- Transports urine from urinary bladder to outside the body

- Heart
- Diaphragm
- Adrenal gland
- Renal artery
- Renal vein
- Inferior vena cava
- Aorta
Kidneys and Homeostasis

- Kidneys are reddish brown in color and shaped like beans
- Each one is about the size of a fist
- Three regions
  1. Renal cortex
  2. Renal medulla
  3. Renal pelvis
Kidneys and Homeostasis

- Nephrons
  - Microscopic functional units of the kidneys
  - Responsible for formation of urine
  - Each nephron consists of
    - Renal corpuscle
    - Renal tubule
Figure 16.3 *Structure of a kidney.*

(a) Blood vessels and protective layers around kidneys

(b) Internal kidney structure

(c) Nephrons

- Renal cortex
- Renal medulla
- Renal pyramid (of renal medulla)
- Renal column (extension of renal cortex)
- Renal pelvis
- Nephron
- Collecting duct

Adrenal gland
Renal artery
Renal vein
Ureter
Outermost connective tissue layer
Innermost connective tissue layer
Adipose capsule

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Structure of the Kidneys

- Renal corpuscle
  - Site of filtration
  - Consists of
    - Glomerulus: tuft of capillaries
    - Glomerular capsule: surrounds glomerulus
Structure of the Kidneys

- Renal tubule
  - Site of reabsorption and secretion
  - Consists of three sections
    - Proximal convoluted tubule
    - Loop of the nephron
    - Distal convoluted tubule
Figure 16.4 Structure of a nephron.

(a) Simplified view of a nephron, showing the basic structural components but not the associated capillaries

(b) A nephron and its blood supply
Nephrons

- Nephrons perform three functions
  - Glomerular filtration
  - Tubular reabsorption
  - Tubular secretion
Nephrons

- Glomerular filtration
  - Occurs as blood pressure forces water, ions, and other small molecules from the blood in the glomerulus to the space inside the glomerular capsule
  - The concentration of the filtrate within the glomerular capsule is close to that of blood
Figure 16.5 The renal corpuscle is the site of glomerular filtration.

(a) The renal corpuscle consists of the glomerular capsule and a ball of capillaries called the glomerulus.

(b) Diagram of the glomerular filter. Water and small solutes in the blood move first through the pores in the endothelium of the capillary, then through the basement membrane, and finally through slits in the inner lining of the glomerular capsule.
Nephrons

- Tubular reabsorption
  - Removes useful materials from the filtrate as it passes through proximal convoluted tubule
  - About 99% of filtrate is returned to the blood
  - Reabsorbed substances include water, essential ions, and glucose

- Tubular secretion
  - Occurs along the proximal and distal convoluted tubules and collecting ducts
  - Removes wastes and excess ions from blood
## Table 16.1 Reabsorption by Nephrons of Some Substances

<table>
<thead>
<tr>
<th>Substance</th>
<th>Amount Filtered per Day (in liters or grams)</th>
<th>% Reabsorbed (Removed from Filtrate and Returned to Blood)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>180 L</td>
<td>99</td>
</tr>
<tr>
<td>Glucose</td>
<td>180 g</td>
<td>100</td>
</tr>
<tr>
<td>Urea</td>
<td>52 g</td>
<td>50</td>
</tr>
<tr>
<td>Creatinine</td>
<td>1.6 g</td>
<td>0</td>
</tr>
<tr>
<td>Sodium ions (Na⁺)</td>
<td>620 g</td>
<td>99</td>
</tr>
<tr>
<td>Potassium ions (K⁺)</td>
<td>30 g</td>
<td>93</td>
</tr>
<tr>
<td>Bicarbonate (HCO₃⁻)</td>
<td>275 g</td>
<td>100</td>
</tr>
</tbody>
</table>
Figure 16.6 *The proximal convoluted tubule.*

Microvilli of the cells lining the tubule greatly increase the surface area for reabsorption.
Acid–Base Balance

- Kidneys help regulate blood pH by
  - Returning bicarbonate ions to the blood during tubular reabsorption
  - Removing excess hydrogen ions from the blood during tubular secretion
Figure 16.7 Overview of the different functions taking place along the nephron.
Water Conservation

- Nephrons with long loops that extend into the renal medulla are responsible for conserving water
  - Maintenance of high solute concentrations in the interstitial fluid within renal medulla is key
    - Leads to water moving out of collecting ducts for conservation by the body
    - Leads to production of concentrated urine
Figure 16.8 Some nephrons have loops that extend deep into the medulla.
Figure 16.9 The juxtaglomerular apparatus.

(a) The juxtaglomerular apparatus (within the square) is a section of the nephron where the distal convoluted tubule contacts the afferent arteriole. The nearby renal corpuscle is shown in ghosted view to reveal its components, the glomerular capsule and the glomerulus.

(b) Close-up view of the juxtaglomerular apparatus.

Juxtaglomerular cells in the afferent arteriole secrete renin in response to reduced volume of filtrate within the nephron.
Hormones and Kidney Function

- Our health depends on our keeping the salt and water levels in our body near certain optimum values.

- Three hormones play important roles in adjusting kidney function:
  1. Aldosterone
  2. Antidiuretic hormone (ADH)
  3. Atrial natriuretic peptide (ANP)
Hormones and Kidney Function

- Aldosterone
  - Released by the adrenal cortex
  - Increases reabsorption of sodium by the distal convoluted tubules and collecting ducts, resulting in more water following sodium as it moves from filtrate to blood
    - Increases blood volume and pressure
    - Production of concentrated urine
  - Released in response to blood pressure monitored by juxtaglomerular apparatus
Hormones and Kidney Function

- Antidiuretic hormone (ADH)
  - Produced by the hypothalamus and released by the posterior pituitary gland
  - Increases permeability to water of collecting ducts, resulting in more water moving from filtrate to blood
    - Increases blood volume and pressure
    - Production of concentrated urine
Figure 16.10 Regulation of blood volume and blood pressure by ADH.
Hormones and Kidney Function

- Atrial natriuretic peptide (ANP)
  
  - Released from the right atrium of the heart in response to increased blood volume and pressure
  
  - Decreases reabsorption of sodium by the distal convoluted tubules and collecting ducts, resulting in more sodium and water remaining in the filtrate
    
    - Decreases blood volume and pressure
    
    - Production of dilute urine
Kidneys have two homeostatic functions unrelated to the urinary system

- Release erythropoietin
  - Hormone that stimulates the production of red blood cells in red bone marrow
- Transform vitamin D into its active form
  - Promotes the absorption and use of calcium and phosphorus by the body
### Table 16.2 Hormones That Influence Kidney Function

<table>
<thead>
<tr>
<th>Hormone</th>
<th>Effect on Water and Solute Reabsorption in Nephron</th>
<th>Effect on Blood Volume and Pressure</th>
<th>Urine Produced</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aldosterone</td>
<td>Increases reabsorption of Na(^+) by distal convoluted tubules and collecting ducts, resulting in more water following Na(^+) as it moves from filtrate to blood</td>
<td>Increases</td>
<td>Concentrated</td>
</tr>
<tr>
<td>Antidiuretic hormone (ADH)</td>
<td>Increases permeability to water of collecting ducts, resulting in more water moving from filtrate to blood</td>
<td>Increases</td>
<td>Concentrated</td>
</tr>
<tr>
<td>Atrial natriuretic hormone (ANH)</td>
<td>Decreases reabsorption of Na(^+) by distal convoluted tubules and collecting ducts, resulting in more Na(^+) and water remaining in filtrate</td>
<td>Decreases</td>
<td>Dilute</td>
</tr>
</tbody>
</table>
Dialysis and Transplant Surgery

▪ Renal failure
  ▪ Decrease or complete cessation of glomerular filtration
  ▪ Can be acute or chronic

▪ Consequences
  ▪ Acidosis
  ▪ Anemia
  ▪ Edema
  ▪ Hypertension
  ▪ Accumulation of nitrogen-containing wastes in the blood
Dialysis and Transplant Surgery

- Treatments for renal failure
  - Hemodialysis
    - Using artificial devices (e.g., artificial kidney machine) to cleanse the blood
  - Continuous ambulatory peritoneal dialysis
    - Using patient’s own peritoneum as the dialyzing membrane
  - Kidney transplantation
    - The ultimate hope for many people whose kidneys fail is to receive a healthy kidney from another person
Dialysis and Transplant Surgery

Give Me a Break: Selling Organs
Figure 16.11 An artificial kidney machine.
Figure 16.12 A kidney transplant.
Figure 16.13 Before transplantation, donor kidneys must be kept in a cool salt solution under sterile conditions.
Urination

- Process by which the urinary bladder is emptied
  - Includes both involuntary and voluntary components
    - Internal urethral sphincter
      - Smooth muscle; involuntary
    - External urethral sphincter
      - Skeletal muscle; voluntary
Figure 16.14 The steps in urination.

**Step 1:** As the bladder fills with urine, stretch receptors in its wall send impulses to the lower part of the spinal cord.

**Step 2:** Impulses travel back to the bladder and cause the detrusor muscle to contract and the internal urethral sphincter to relax.

**Step 3:** Impulses also travel to the brain where they initiate the desire to urinate.

**Step 4:** If the time is appropriate, the brain permits voluntary relaxation of the external urethral sphincter.

**Step 5:** Urine travels down the urethra and exits the body.

- Spinal cord
- Motor neuron for external sphincter
- Motor neuron for detrusor muscle
- Section of spinal cord
- Interneuron
- Descending path from brain
- Ascending path to brain
- Sensory neuron
- Detrusor muscle of the urinary bladder
- Internal urethral sphincter
- External urethral sphincter
- Urethra
Urination

- Urinary incontinence
  - Lack of voluntary control over urination
  - Norm for infants and toddlers
  - Stress incontinence is more common in women
- Urinary retention
  - Failure to expel urine from the bladder to a normal degree
Urinary Tract Infections (UTIs)

- Caused by presence of microorganisms in organs of the urinary system
  - Bacteria can enter the urethra from the rectum or as STDs
- More common in women than men
- Symptoms include fever, blood in urine, painful and frequent urination
- Treated with antibiotics
  - Important to treat infection of lower urinary tract to prevent spread to the kidneys
Figure 16.16 The urinary bladder.

The shorter length of the urethra in females may be responsible for the greater susceptibility of females to urinary tract infections.
You Should Now Be Able To:

- Understand how waste is eliminated
- Know the components of the urinary system
- Know the functions of the nephrons
- Understand kidneys and hormones
- Understand kidneys and homeostasis
- Explain dialysis and transplant surgery
- Know the process of urination
- Understand urination conditions and urinary tract infections