Chapter 26

The Urinary System

Lecture Presentation by
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Introduction

- The urinary system does more than just get rid of liquid waste. It also:
  - Regulates plasma ion concentrations
  - Regulates blood volume and blood pressure
  - Helps to stabilize blood pH
  - Prevents the loss of valuable nutrients
  - Eliminates organic matter
  - Synthesizes calcitriol (active form of vitamin D)
  - Prevents dehydration
  - Aids the liver with some of its functions
Introduction

• The urinary system consists of:
  • **Kidneys**
    • And the associated **nephrons**
  • **Ureters**
  • **Urinary bladder**
  • **Urethra**
### Components of the Urinary System

<table>
<thead>
<tr>
<th>Component</th>
<th>Function</th>
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<tbody>
<tr>
<td><strong>Kidney</strong></td>
<td>Produces urine</td>
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<tr>
<td><strong>Ureter</strong></td>
<td>Transports urine toward the urinary bladder</td>
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<tr>
<td><strong>Urinary Bladder</strong></td>
<td>Temporarily stores urine prior to elimination</td>
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<td><strong>Urethra</strong></td>
<td>Conducts urine to exterior; in males, transports semen as well</td>
</tr>
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</table>

- Suprarenal gland
- Renal artery and vein
- Inferior vena cava
- Aorta
- Urinary Bladder
- Ureter
- Urethra
- Kidney
- Aorta
- Suprarenal gland
- Renal artery and vein
- Inferior vena cava
- Aorta
The Kidneys

• The Right Kidney
  • Covered by the liver, hepatic flexure, and duodenum

• The Left Kidney
  • Covered by the spleen, stomach, pancreas, splenic flexure, and jejunum
The Kidneys

• The left kidney is positioned higher than the right kidney
• Both kidneys are capped with the suprarenal glands
Figure 26.1 An Introduction to the Urinary System

Components of the Urinary System

**Kidney**
- Produces urine

**Ureter**
- Transports urine toward the urinary bladder

**Urinary Bladder**
- Temporarily stores urine prior to elimination

**Urethra**
- Conducts urine to exterior; in males, transports semen as well
The Kidneys

• There are three layers of connective tissue that serve to protect the kidneys
  • Fibrous capsule
  • Perinephric fat
  • Renal fascia
Connective Tissue Layers Protecting the Kidneys

- Fibrous capsule
- Perinephric fat
- Renal fascia

Diagrammatic cross section, as viewed from above

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The Kidneys

• Superficial Anatomy of the Kidney
  • A typical kidney
    • Size
      • 10 cm long
      • 5.5 cm wide
      • 3 cm thick
      • 150 g
    • Sectional view
      • The medial indentation is the hilum
      • Renal arteries enter at the hilum
      • Renal veins and ureters exit at the hilum
Diagrammatic anterior view of the abdominopelvic cavity showing the kidneys, suprarenal glands, ureters, urinary bladder, and blood supply to the kidneys
The Kidneys

- Sectional Anatomy of the Kidney
  - Consists of:
    - Renal cortex
    - Renal medulla, which consists of:
      - Several renal lobes
      - Renal pyramids
      - Renal papillae
      - Renal columns
    - Renal pelvis (comprises most of the renal sinus) consists of:
      - Minor calyx
      - Major calyx
Figure 26.4a Structure of the Kidney

Frontal section through the left kidney showing major structures. The outlines of a renal lobe and a renal pyramid are indicated by dotted lines.
Shadow drawing to show the arrangement of the calyces and renal pelvis within the kidney.
The Kidneys

• The Blood Supply to the Kidneys
  • Beginning with blood in the renal arteries, blood flows to:
    • Segmental arteries
    • Interlobar arteries
    • Arcuate arteries
    • Cortical radiate arteries
    • Afferent arterioles
    • Glomerular capillaries
  • Waste is dropped in the nephrons
Sectional view showing major arteries and veins. Compare with Figures 26.3 and 26.8.
Figure 26.5b Blood Supply to the Kidneys

Circulation in the renal cortex.
The Blood Supply to the Kidneys (continued)

After waste is dropped off at the nephrons, blood leaves the kidneys via the following vessels:

- Glomerular capillaries
- Efferent arteriole
- Peritubular capillaries or vasa recta capillaries
- Interlobular veins
- Arcuate veins
- Interlobar veins
- Renal vein
- Inferior vena cava
Sectional view showing major arteries and veins.

Compare with Figures 26.3 and 26.8.
The Kidneys

• Innervation of the Kidneys
  • Urine production is regulated by autoregulation
    • Involves reflexive changes in the diameter of nephron arterioles
  • Receives sympathetic nerve fibers from the celiac and inferior mesenteric ganglia
    • Nerve innervation serves to:
      • Regulate renal blood flow and pressure
      • Stimulate renin release
      • Stimulate water and sodium ion reabsorption
The Kidneys

- Structure and Function of the Nephron
  - Waste (glomerular filtrate) material leaves the glomerular capillaries and enters:
    - Glomerular capsule
    - Proximal convoluted tubule (PCT)
    - Nephron loop
    - Distal convoluted tubule (DCT)
Figure 26.8a Histology of the Nephron

Orientation of cortical and juxtamedullary nephrons.
The Kidneys

• Structure and Function of the Nephron
  • The filtrate that enters the DCT of various nephrons empties into a common tube called the collecting duct
    • The collecting duct passes through the renal pyramids
  • Filtrate then enters the:
    • Papillary duct / Minor calyx / Major calyx
  • Filtrate leaves the kidneys:
    • Ureter / Urinary bladder / Urethra
Figure 26.7 A Typical Nephron

**NEPHRON**

**PROXIMAL CONVOLUTED TUBULE**
- Nucleus
- Microvilli
- Mitochondria
- Reabsorption of water, ions, and all organic nutrients

**DISTAL CONVOLUTED TUBULE**
- Secretion of ions, acids, drugs, toxins
- Variable reabsorption of water, sodium ions, and calcium ions (under hormonal control)

**RENAL CORPUSCLE**
- Parietal (capsular) epithelium
- Capsular space
- Visceral (glomerular) epithelium
- Capillaries of glomerulus
- Production of filtrate

**NEPHRON LOOP**
- Thin descending limb
- Thick ascending limb
- Further reabsorption of water (descending limb) and both sodium and chloride ions (ascending limb)

**COLLECTING SYSTEM**

**CONNECTING TUBULES AND COLLECTING DUCT**
- Connecting tubules
- Collecting duct
- Variable reabsorption of water and secretion of sodium, potassium, hydrogen, and bicarbonate ions

**PAPILLARY DUCT**
- Delivery of urine to minor calyx
The Kidneys

• Structure and Function of the Nephron
  • Two main types of nephrons
    • Cortical nephrons
      • 85 percent of the nephrons are cortical
      • Most of the nephron is located in the cortex
      • Have a relatively short nephron loop
    • Juxtamedullary nephrons
      • 15 percent of the nephrons are juxtamedullary
      • Capsule is located near the border of the cortex and the medulla
      • Have a long nephron loop
Figure 26.8a Histology of the Nephron

- Cortex
- Cortical nephron
- Juxtamedullary nephron
- Proximal convoluted tubule
- Renal corpuscle
- Distal convoluted tubule
- Connecting tubules
- Nephron loop
- Thin descending limb
- Thick ascending limb
- Collecting duct
- Papillary duct
- Renal papilla
- Minor calyx

Orientation of cortical and juxtamedullary nephrons.
The Kidneys

- Structure and Function of the Nephron
  - Main functions of the nephron
    - Reabsorbs useful organic material from the filtrate
      - Urine processing
    - Reabsorbs more than 80 percent of the water from the filtrate
      - Prevents dehydration
    - Secretes waste into the filtrate that was missed in an earlier process
      - Urine processing
The Kidneys

• The Renal Corpuscle
  • Consists of:
    • Glomerular capsule
    • Glomerular capillaries (*glomerulus*)
  • Glomerular capsule consists of:
    • Parietal layer
      • Made of squamous cells that are continuous with the lining of the PCT
      • Folds back to form the visceral layer
    • Visceral layer
      • Makes up the epithelial lining of the capillaries
Figure 26.9 The Renal Corpuscle

Plasma is filtered across the walls of the glomerulus and into the capsular space. The solution produced by this filtration process is called glomerular filtrate. This filtration process involves three barriers, which collectively form the filtration membrane.
Glomeruli and associated blood vessels

SEM × 94
Podocytes

Podocyte (visceral epithelial cell)

Glomerular capillary

Secondary processes

Podocytes

SEM × 20,800
The Kidneys

• The Renal Corpuscle
  • Filtration within the renal corpuscle involves three layers
    • Capillary endothelium
    • Basal lamina
    • Glomerular epithelium
The Kidneys

• The Renal Corpuscle
  • Filtration within the renal corpuscle
    • Capillary endothelium
      • The glomerular capillaries are fenestrated
      • Have openings 0.06–0.1 microns
      • Too small for blood to pass through (RBC = 7 microns)
The Kidneys

• The Renal Corpuscle
  • Filtration within the renal corpuscle
    • Basal lamina
      • Surrounds the capillary endothelium
      • This dense layer restricts the passage of large proteins but permits smaller proteins
      • Permits the passage of ions and nutrients
The Kidneys

• The Renal Corpuscle
  • Filtration within the renal corpuscle
    • Glomerular epithelium
      • Consists of special cells called podocytes
      • Podocytes have long cellular extensions that wrap around the basal lamina
      • These extensions have gaps called filtration slits
    • Filtrate passing through consists of water / ions / small organic molecules (glucose / fatty acids / amino acids / vitamins)
    • Filtrate passing through contains very few plasma proteins
    • Any potential useful products are reabsorbed in the PCT
The Kidneys

• The Proximal Convoluted Tubule (PCT)
  • Lined with cuboid epithelium
  • Reabsorbs:
    • All of the organic nutrients
    • Plasma protein
    • 60 percent of the sodium and chloride ions and water
    • Calcium / Potassium / Magnesium / Bicarbonate / Phosphate / Sulfate ions
Figure 26.7 A Typical Nephron

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- Nucleus
- Microvilli
- Mitochondria
- Reabsorption of water, ions, and all organic nutrients

**RENAL CORPUSCLE**
- Parietal (capsular) epithelium
- Capsular space
- Visceral (glomerular) epithelium
- Capillaries of glomerulus
- Production of filtrate

**DISTAL CONVOLUTED TUBULE**
- Secretion of ions, acids, drugs, toxins
- Variable reabsorption of water, sodium ions, and calcium ions (under hormonal control)

**NEPHRON LOOP**
- Thin descending limb
- Thick ascending limb
- Further reabsorption of water (descending limb) and both sodium and chloride ions (ascending limb)

**CONNECTING TUBULES AND COLLECTING DUCT**
- Variable reabsorption of water and reabsorption or secretion of sodium, potassium, hydrogen, and bicarbonate ions

**PAPILLARY DUCT**
- Delivery of urine to minor calyx

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The Kidneys

• The Nephron Loop
  • **Descending portion**
    • Water leaves this portion and enters the bloodstream (thereby preventing dehydration)
    • The capillaries surrounding the nephron loop are called the *vasa recta*
  • **Ascending portion**
    • Pumps ions (sodium ions and chloride ions) out of the ascending loop thereby preventing the loss of these ions
    • Impermeable to water
Figure 26.7 A Typical Nephron

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**COLLECTING SYSTEM**

- Connecting tubules
- Collecting duct

- **CONNECTING TUBULES AND COLLECTING DUCT**
  - Variable reabsorption of water and reabsorption or secretion of sodium, potassium, hydrogen, and bicarbonate ions

- **PAPILLARY DUCT**
  - Minor calyx
  - Delivery of urine to minor calyx

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The Kidneys

• The Distal Convoluted Tubule (DCT)
  • Active secretion of ions and acids
  • Selective reabsorption of sodium and calcium ions
  • Very little reabsorption of water
Figure 26.7 A Typical Nephron

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- Delivery of urine to minor calyx

**CONNECTING TUBULES AND COLLECTING DUCT**
- Variable reabsorption of water and reabsorption or secretion of sodium, potassium, hydrogen, and bicarbonate ions

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The Kidneys

• The Juxtaglomerular Complex
• Also Called Juxtaglomerular Apparatus
  • Located in the region of the vascular pole
  • Consists of:
    • Macula densa cells
    • Juxtaglomerular cells
    • Mesangial cells
• Produces two hormones
  • Renin: involved in regulating blood pressure
  • Erythropoietin: involved in erythrocyte production
The Kidneys

• The Collecting System
  • Consists of:
    • Connecting tubules
    • Collecting ducts
    • Papillary ducts
  • The DCTs of several nephrons drain into the collecting duct
  • The cells of the collecting ducts make final adjustments to the concentration of the urine that is about to exit the kidneys
Figure 26.7 A Typical Nephron

**NEPHRON**

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Reabsorption of water, ions, and all organic nutrients

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**PAPILLARY DUCT**
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Structures for Urine Transport, Storage, and Elimination

• The Ureters
  • Exit the kidney at the hilum area
  • Extend to the urinary bladder
  • Enter the urinary bladder on the posterior/inferior side
  • The ureteral openings enter the urinary bladder in the trigone area
Figure 26.11c Organs Responsible for the Conduction and Storage of Urine

- Median umbilical ligament (urachus)
- Ureter
- Lateral umbilical ligament
- Detrusor muscle
- Rugae
- Ureteral openings
- Internal urethral sphincter
- Prostatic urethra
- External urethral sphincter (in urogenital diaphragm)
- Trigone
- Center of trigone
- Neck of urinary bladder
- Prostate gland
- Membranous urethra

Anatomy of the urinary bladder in a male
Structures for Urine Transport, Storage, and Elimination

• Histology of the Ureters
  • Each ureter consists of three layers
    • *Inner mucosa*
    • *Middle muscular layer* (consisting of longitudinal and circular muscles)
    • *Adventitia* (this is continuous with the fibrous capsule)
A ureter seen in transverse section. Note the thick layer of smooth muscle surrounding the lumen. (See also Figure 3.22c.)
Structures for Urine Transport, Storage, and Elimination

• The Urinary Bladder
  • Males
    • The base of the urinary bladder is between the rectum and the symphysis pubis
  • Females
    • The base of the urinary bladder is inferior to the uterus and anterior to the vagina
Figure 26.11a Organs Responsible for the Conduction and Storage of Urine

Peritoneum

Urinary bladder

Pubic symphysis

Prostate gland

External urethral sphincter

Spongy urethra

External urethral orifice

Left ureter

Rectum

Urethra [see part c]

Urogenital diaphragm

Position of the ureter, urinary bladder, and urethra in the male
Figure 26.11b Organs Responsible for the Conduction and Storage of Urine

- Rectum
- Right ureter
- Uterus
- Peritoneum
- Urinary bladder
- Internal urethral sphincter
- Pubic symphysis
- Urethra
- External urethral sphincter (in urogenital diaphragm)
- Vagina
- Vestibule

Position of the ureter, urinary bladder, and urethra in the female
Structures for Urine Transport, Storage, and Elimination

• The Urinary Bladder
  • There are peritoneal folds that assist in maintaining the position of the urinary bladder
    • **Median umbilical ligament**
      • Extends from the anterior/superior border to the umbilical region
    • **Lateral umbilical ligament**
      • Extends from the lateral edges to the umbilical region
Figure 26.11c Organs Responsible for the Conduction and Storage of Urine

- Median umbilical ligament (urachus)
- Ureter
- Lateral umbilical ligament
- Detrusor muscle
- Rugae
- Ureteral openings
- Internal urethral sphincter
- Prostatic urethra
- External urethral sphincter (in urogenital diaphragm)
- Trigone
- Center of trigone
- Neck of urinary bladder
- Prostate gland
- Membranous urethra

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Structures for Urine Transport, Storage, and Elimination

• Histology of the Urinary Bladder
  • The muscular layer of the urinary bladder is called the **detrusor muscle**
  • At the exit of the urinary bladder and entrance to the urethra is a smooth muscle that makes up the **internal urethral sphincter**
    • This is under involuntary control
Figure 26.11c Organs Responsible for the Conduction and Storage of Urine

Anatomy of the urinary bladder in a male

- Median umbilical ligament (urachus)
- Ureter
- Lateral umbilical ligament
- Detrusor muscle
- Rugae
- Ureteral openings
- Internal urethral sphincter
- Prostatic urethra
- External urethral sphincter (in urogenital diaphragm)
- Membranous urethra
- Trigone
- Center of trigone
- Neck of urinary bladder
- Prostate gland
- Prostatic urethra
Structures for Urine Transport, Storage, and Elimination

• The Urethra
  • Female
    • 3 to 5 cm in length
    • The external urethral orifice is near the anterior wall of the vagina
  • Male
    • 18 to 20 cm in length
    • Subdivided to form the prostatic urethra, membranous urethra, and spongy urethra
Structures for Urine Transport, Storage, and Elimination

• The Urethra
  • Male (continued)
    • Prostatic urethra
      • Passes through the prostate gland
    • Membranous urethra
      • Short segment that goes through the urogenital diaphragm
    • Spongy urethra (penile urethra)
      • Extends through the penis to the external urethral orifice
Figure 26.11a Organs Responsible for the Conduction and Storage of Urine

- Peritoneum
- Urinary bladder
- Pubic symphysis
- Prostate gland
- External urethral sphincter
- Spongy urethra
- External urethral orifice
- Left ureter
- Rectum
- Urethra [see part c]
- Urogenital diaphragm

Position of the ureter, urinary bladder, and urethra in the male

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Figure 26.11b Organs Responsible for the Conduction and Storage of Urine

- Rectum
- Right ureter
- Uterus
- Peritoneum
- Urinary bladder
- Internal urethral sphincter
- Pubic symphysis
- Urethra
- External urethral sphincter (in urogenital diaphragm)
- Vagina
- Vestibule

**b** Position of the ureter, urinary bladder, and urethra in the female

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Structures for Urine Transport, Storage, and Elimination

• The Urethra
  • As the urethra passes through the urogenital diaphragm there is a skeletal muscle that makes up the external urethral sphincter
    • This is under voluntary control – this is the sphincter we learned to control as an infant
    • We lose control as we age
    • We lose control due to some spinal cord injuries
Figure 26.11c Organs Responsible for the Conduction and Storage of Urine

- Median umbilical ligament (urachus)
- Ureter
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- Center of trigone
- Neck of urinary bladder
- Prostate gland

Anatomy of the urinary bladder in a male
Structures for Urine Transport, Storage, and Elimination

• The Micturition Reflex and Urination
  • The first urge to urinate is when the urinary bladder fills to about **200 ml**
  • Voluntary effort is needed to relax (and therefore open) the external urethral sphincter
  • When the urinary bladder nears capacity, both urethral sphincters will open based on pressure
  • Upon “complete void,” approximately 10 ml of urine still remains
Aging and the Urinary System

• Age-related problems include:
  • Nephrons decrease in number
  • Glomerular filtration rate declines
  • Reduced sensitivity to antidiuretic hormone (ADH) resulting in frequent urination
  • Micturition problems
Aging and the Urinary System

• Age-related problems (continued)
  • Nephrons decline by 30–40 percent
  • Micturition problems
    • Urethral sphincters lose muscle tone leading to incontinence
    • The ability to control micturition
      • Due to stroke / Alzheimer’s, etc.
  • Urinary retention leading to infections
    • Enlarged prostate reduces urine flow