Urinary System Structure and Function

Objectives

After completing this exercise, you should be able to:

1. Locate and identify the organs of the urinary system on models or charts
2. Describe the structure of urinary system organs
3. Describe the structure of the nephron and trace the path of filtrate through the nephron
4. Trace the path of urine from the collecting ducts to the exterior of the body
5. Describe the blood supply to the kidneys and trace the pathway of blood from the renal artery to the renal vein
6. Identify main urinary organs in the cat or fetal pig

Materials

- male and female urogenital models or charts
- human kidney and nephron models
- disposable gloves, dissection equipment, safety glasses, fresh or preserved sheep or pig kidney
- preserved cat or fetal pig, accompanying cat or fetal pig dissection manual

Urinary system organs include the kidneys, ureters, urinary bladder, and urethra. Urine is formed in the kidneys and flows through the ureters to the urinary bladder, which stores urine until it is eliminated from the body through the urethra.

A. Location and Gross Anatomy of Urinary System Organs

1. Kidneys

Kidneys are bean-shaped structures that are retroperitoneal (retro = behind), located between the abdominal wall and the peritoneum. They are found at waist level between the 12th thoracic vertebra and the 3rd lumbar vertebra. The concave surface of each kidney faces the vertebral column and contains a vertical fissure, the renal hilus. The ureter, renal arteries and veins, nerves, and lymphatics pass through the renal hilus.

The kidney is attached to the abdominal wall by the renal fascia, an outer layer of dense irregular connective tissue. The renal capsule, a thin fibrous membrane, covers the outer surface of the kidney. Between the renal fascia and the renal capsule is adipose tissue which forms the adipose capsule for protection and padding.

Within the kidney are three main regions: the cortex, medulla, and sinus. The renal cortex, a smooth area, is the most superficial region, whereas the renal medulla is deeper. The medulla contains cone-shaped renal pyramids
that have extensions of the cortex, renal columns, that are between each pyramid. The base of each pyramid faces the cortex, and the renal papilla is the apex that is pointed toward the renal sinus. The cortex and medulla contain nephrons, the structural and functional units of the kidney that form urine. Urine drains into papillary ducts that exit through the openings in the renal papilla. The renal sinus is a space or cavity that is adjacent to the medulla and extends to the renal hilus. Within the renal sinus are minor and major calyces and the renal pelvis which collect urine from the papillary ducts and deliver it to the ureters. The minor calyces are cup-like structures adjacent to the renal papillae which receive urine from the papillary ducts. Several minor calyces drain into a major calyx. Each kidney has 8 to 18 minor calyces and 2 to 3 major calyces. The major calyces drain into the renal pelvis, which is continuous with the ureter. Blood vessels, lymphatics, and nerves also travel through the renal sinus. Adipose tissue fills the remaining space within the renal sinus.

**ACTIVITY 1 Location and Structure of Kidneys**

1. Label the structures in Figures 36.1, 36.2, and 36.3.
2. Locate the kidneys on a human torso.
3. Identify the structures from Figure 36.3 on a dissectible kidney model.

**DISCUSSION QUESTIONS: LOCATION AND GROSS ANATOMY OF THE KIDNEY**

1. Use an articulated skeleton to identify which ribs help protect the kidneys.
2. Observe the kidneys in a dissectible human torso model.
   a. Which kidney is lower?
   b. Identify the organ that forces this kidney into a lower position.

**FIGURE 36.1 Organs of the female urinary system.**
FIGURE 36.2  Location and coverings of the kidneys.

1. adipose capsule
2. left kidney
3. peritoneum
4. renal capsule
5. renal fascia
6. renal hilus (HIGH-lus)
7. right kidney

Transverse section through the body (lying down and viewed from the feet)

FIGURE 36.3  Internal structure of the kidney.

1. (region) 2
2. major calyx (KAY-likes)
3. minor calyx
4. renal artery
5. renal capsule
6. renal column
7. renal cortex
8. renal hilus
9. renal medulla
10. renal papilla
11. renal pelvis in renal sinus
12. renal pyramid
13. renal vein

Adipose tissue
2. Ureters, Urinary Bladder, and Urethra

The ureters are narrow, 25- to 30-cm long muscular tubes located behind the peritoneum (retroperitoneal). The diameter of the ureters varies from 1 to 10 mm. The ureters descend toward the urinary bladder, curving medially as they approach the inferior portion of the bladder and enter the posterior wall of the bladder at an oblique angle. Urine is propelled through the ureters by peristalsis, hydrostatic pressure, and gravity.

The urinary bladder is a hollow, muscular organ that distends to store urine. It is covered by visceral peritoneum and is secured to the pelvic wall by parietal peritoneal folds. The smooth muscle within the wall of the urinary bladder is called the detrusor muscle, and the epithelial lining of the bladder forms folds or rugae. The inferior surface of the urinary bladder contains three openings that form a triangle called the trigone. The two posterior openings are the ureteral openings, whereas the anterior opening is the opening into the urethra, the internal urethral orifice. In males, the urinary bladder is anterior to the rectum and posterior to the pubic symphysis. In females, the urinary bladder is anterior to the vagina, inferior to the uterus, and posterior to the pubic symphysis.

The tube-like urethra carries urine from the internal urethral orifice to the external urethral orifice, the opening through which urine exits the body. The internal urethral sphincter is a layer of circular, involuntary smooth muscle that controls passage of urine into the urethra from the urinary bladder. Voluntary skeletal muscle within the urogenital diaphragm (deep muscles of perineum) forms the external urethral sphincter that permits the passage of urine to the external urethral orifice. During micturition, the detrusor muscle contracts and forces urine out of the urinary bladder, and the internal and external urethral sphincters relax to allow the passage of urine. In females, the urethra is short (4 cm), whereas the urethra in males is longer (15–20 cm). The male urethra has three regions: the prostatic urethra that passes through the prostate gland, the membranous urethra that passes through the urogenital diaphragm, and the spongy (penile) urethra that passes through the penis.

**CLINICAL NOTE:** BPH, or benign prostatic hypertrophy, is a noncancerous enlargement of the prostate gland that restricts the prostatic urethra and inhibits urine flow, causing urinary retention.

**ACTIVITY 2 Location and Gross Anatomy of the Ureters, Urinary Bladder, and Urethra**

1. Label the urinary system structures in Figures 36.4 and 36.5.
2. Identify the structures from Figures 36.4 and 36.5 on urogenital models or charts.

**DISCUSSION QUESTION: URINARY BLADDER**

1. Is the urinary bladder retroperitoneal? Explain your answer.
B. Structure of the Nephron

The 1 million nephrons in each kidney filter the blood and form urine. Each nephron is composed of a renal corpuscle that filters blood, and a renal tubule that modifies the filtrate to form urine. The renal corpuscle, which is located in the renal cortex, consists of a glomerulus (capillary network) and a glomerular (Bowman’s) capsule, a cup-shaped epithelial membrane surrounding the glomerulus. Blood is filtered across a filtration membrane formed by the walls of the glomerulus and the glomerular capsule into the capsular space (glomerular cavity). The liquid, now called filtrate, drains into the renal tubule.

Each renal tubule is subdivided into three structural and functional sections. Starting at the glomerular capsule, these sections are: proximal convoluted tubule, loop of Henle, and distal convoluted tubule. The proximal convoluted tubule is located in the renal cortex and connects to the loop of Henle (nephron loop), which dips down into the renal medulla. The third portion is the distal convoluted tubule, which is located in the cortex.

Distal convoluted tubules from several nephrons drain the liquid (now called urine) into collecting ducts that descend through the renal pyramids and merge to form larger papillary ducts. These ducts connect to renal papillae, which immediately drain urine into minor calyces, and then into major calyces, the renal pelvis, ureters, and finally into the urinary bladder for storage.

The vasculature of the nephron is important to the formation of urine. The glomerulus is located between two arterioles—a larger diameter afferent arteriole that delivers systemic blood to the glomerulus, and a smaller diameter efferent arteriole that receives blood from the glomerulus. The efferent arteriole then delivers blood to a second capillary bed, the peritubular capillary network that entwines the renal tubule.

There are two types of nephrons: cortical nephrons and juxtamedullary nephrons. Cortical nephrons have short loops of Henle that descend slightly into the medulla, whereas juxtamedullary nephrons have long loops of Henle that extend deep into the medulla. In addition to peritubular capillaries, the loops of Henle of juxtamedullary nephrons are supplied by vasa recta, long capillary loops that extend from the efferent arteriole.

ACTIVITY 3 Structure of the Nephron

1. Label the renal tubule in Figure 36.6(a), and the blood vessels and renal tubule in Figure 36.6(b).
2. Identify the structures in Figure 36.6(a) and (b) on a nephron model or chart.
(a) Renal tubule of cortical nephron

- ascending limb of loop of Henle
- collecting duct
- descending limb of loop of Henle
- distal convoluted tubule
- glomerular (glow-MER-u-lar) capsule
- papillary duct
- proximal convoluted tubule

(b) Renal corpuscle and vasculature of the renal tubule

- afferent arteriole
- efferent arteriole
- glomerular capsule
- glomerulus
- peritubular capillary
- renal corpuscle

FIGURE 36.6 Structure and vascular supply of a cortical nephron.
C. Blood Flow Through the Kidneys

During rest, the renal arteries carry 20 to 25% of the cardiac output to the kidneys, and the renal veins return blood to the inferior vena cava. The pathway of blood through the kidneys is outlined below.

Renal artery

Segmental arteries

Interlobar arteries

Arcuate arteries

Interlobular (cortical radiate) arteries

Afferent arteriole

Glomerular capillaries

Efferent arterioles → Peritubular capillaries and/or vasa recta → Interlobular (cortical radiate) veins

Renal vein

Interlobar veins

Arcuate veins

1. Label the blood vessels in Figure 36.7. Find the renal artery and label it first to follow the blood flow.
2. Identify the blood vessels on a model or chart.

**FIGURE 36.7** Blood supply of the kidney.
D. Dissection of a Pig (or Sheep) Kidney

Pig and sheep kidneys are very similar to human kidneys. This dissection will illustrate the location of the calyces and pelvis within the renal sinus.

**SAFETY NOTE:** Wear gloves and safety glasses when using preserved or fresh tissue. Wash hands thoroughly with soap and water when you are done.

**ACTIVITY 5** Kidney Dissection

1. Identify the bolded structures listed below on a pig or sheep kidney, using Figure 36.8 as a reference.
2. Protect your hands with disposable gloves.
3. Obtain a fresh or preserved kidney, dissecting tray, and scalpel or knife.
4. If you have a fresh kidney, carefully remove any fat on its exterior. If you are lucky, the adrenal glands may still be located on the superior surface. Adrenal glands are usually not present on preserved kidneys.
5. Locate the renal hilus on the concave surface. Identify the ureter, renal artery, and renal vein that travel through the hilus. The renal artery will have a thicker wall than the renal vein.
6. Using a scalpel or knife, carefully cut along the frontal plane to separate the kidney into anterior and posterior sections.
7. Observe the cut surface. Using a needle probe, pull the thin renal capsule away from the surface of the kidney. The outer region of the kidney, the cortex, will be a slightly lighter color than the deeper medulla.

**FIGURE 36.8** Frontal section of preserved pig kidney.
8 Glomeruli may be observed in preserved kidneys that are injected with red and blue latex. The glomeruli will appear as red and blue dots within the cortex.

9 Within the medulla, extensions of light-colored cortical tissue, renal columns, are found between the darker, cone-shaped renal pyramids. Identify the renal papillae located at the apices of the renal pyramids.

10 Between the medulla and the renal hilus is a space called the renal sinus. Within the renal sinus are the minor and major calyces, and the renal pelvis. Adipose tissue, blood vessels, lymphatics, and nerves fill the remaining space within the renal sinus.

The epithelium lining the proximal convoluted tubule is simple cuboidal epithelium. The microvilli forming the brush border on the apical surface of these epithelial cells give a brush-like appearance.

The descending limb of the loop of Henle (nephron loop) is lined by simple squamous epithelium. The initial part of the ascending limb or thin section of the ascending limb is also lined by simple squamous epithelium, whereas the thick section of the ascending limb of the loop of Henle (nephron loop) is lined by simple cuboidal to low columnar cells.

The distal convoluted tubule is lined with simple cuboidal epithelium. These cells do not have a brush border and appear shorter than the simple cuboidal cells lining the proximal convoluted tubule. The final part of the distal convoluted tubule and the collecting ducts are lined with simple cuboidal epithelium.

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E. Animal Dissection of the Urinary System

The urinary system organs of the cat and fetal pig are similar to those of the human. This dissection will illustrate the retroperitoneal location of the urinary system organs, the relationship of urinary system organs to other organs, and how well these organs are secured by connective tissues. Refer to the appropriate accompanying cat or fetal pig dissection manual for dissection instructions and figures.

F. Histology of the Urinary System

1. Kidneys

The glomerular (Bowman's) capsule is composed of a visceral and parietal epithelial layer. The visceral layer, which forms part of the filtration membrane, is adjacent to the glomerulus, and the parietal layer forms a funnel-like structure that collects the filtrate within the capsular space (glomerular cavity). Both layers are simple squamous epithelium; however, the simple squamous epithelial cells of the visceral layer have foot-like projections that wrap around glomerular capillary walls and these cells are named podocytes (podo = foot).

The epithelium lining the proximal convoluted tubule is simple cuboidal epithelium. The microvilli forming the brush border on the apical surface of these epithelial cells give a brush-like appearance.

The descending limb of the loop of Henle (nephron loop) is lined by simple squamous epithelium. The initial part of the ascending limb or thin section of the ascending limb is also lined by simple squamous epithelium, whereas the thick section of the ascending limb of the loop of Henle (nephron loop) is lined by simple cuboidal to low columnar cells.

The distal convoluted tubule is lined with simple cuboidal epithelium. These cells do not have a brush border and appear shorter than the simple cuboidal cells lining the proximal convoluted tubule. The final part of the distal convoluted tubule and the collecting ducts are lined with simple cuboidal epithelium.
A. Interactive Anatomy Review

For an interactive anatomy review, go to www.wiley.com/college/allen. Click on the picture of your lab manual, then on Student Companion Site, Visual Anatomy, and Urinary System.

B. Renal Structures

Write the renal structure that the phrase describes.

1. Urine-forming structure of the kidney
2. Region of the kidney deep to cortex; contains collecting duct
3. Extensions of renal cortex found in between renal pyramids
4. Urine flowing through this structure drains into a minor calyx
5. Located between renal fascia and renal capsule
6. Apex of renal pyramid
7. Urine flowing through this structure drains into the renal pelvis
8. Vertical fissure in concave surface of kidney through which blood vessels and ureters pass
9. Covers outer surface of kidney
10. Dense irregular connective tissue that covers the adipose capsule and attaches the kidney to the abdominal wall
11. Receives urine from the major calyces
12. Space within kidney that is adjacent to renal medulla, contains calyces and renal pelvis
13. Cup-like structure that is located in renal sinus that receives urine from openings of papillary ducts
14. Cone-shaped structures located within the renal medulla
15. Outermost region of the kidney, contains renal corpuscles
C. Ureters, Urinary Bladder, and Urethra

Write the name of the structure that the phrase describes.

1. Detrusor muscle is the main muscle for this structure
2. Region of male urethra that passes through the prostate gland
3. Two openings in posterior urinary bladder wall
4. Region of male urethra that passes through penis
5. Area bounded by ureteral openings and internal urethral orifice
6. Voluntary skeletal muscle in urogenital diaphragm that allows passage of urine to exterior of body
7. Carries urine from renal pelvis to urinary bladder
8. Urine is excreted through this opening
9. Circular smooth muscle that involuntarily controls passage of urine from the urinary bladder to the urethra
10. Anterior opening in urinary bladder that leads into urethra
11. Region of male urethra that passes through urogenital diaphragm

D. The Nephron

Write the name of the structure the phrase describes.

1. Blood vessel that delivers blood to glomerulus
2. Blood from the efferent arteriole flows into this capillary bed
3. Structure that surrounds glomerulus and collects filtrate
4. Section of renal tubule that descends into medulla
5. Capillary network within the renal corpuscle
6. Structure composed of glomerulus and glomerular capsule
7. Blood vessel that drains blood from glomerulus
8. Capillary loops that extend from the efferent arteriole and run along loop of Henle (nephron loop) of juxtamedullary nephrons
E. Urine Formation and Flow

Trace the flow of filtrate and urine through the urinary system. Write the structures in order, starting with the glomerulus.

1. glomerulus
2. 
3. 
4. 
5. 
6. 
7. 
8. 
9. 
10. 
11. 
12. 
13. 
14. external urethral orifice

F. Blood Flow Through the Kidneys

Trace blood flow through the kidneys. Start at the renal artery and number the blood vessels in sequence.

afferent arteriole interlobular (cortical radiate) artery
arcuate artery interlobular (cortical radiate) vein
arcuate vein peritubular capillary
efferent arteriole renal artery
glomerulus renal vein
interlobar artery segmental artery
interlobar vein