Urinary System Anatomy

This is the first of two units on the urinary system. Although the focus here is urinary anatomy, we do introduce the functional significance of the structures discussed. Note that this unit uses the most current terminology recommended by anatomists for the parts of the nephron: proximal tubule, nephron loop, and distal tubule. These terms might differ somewhat from what is in your students’ textbooks, so you may want to remind them of this at the start of lab to prevent any confusion.

Pre-Lab Exercises

Pre-Lab Exercise 25-1  Key Terms

Estimated Total Completion Time: 40 min.

Estimated Completion Time: 10 min.

Gross Structures of the Kidney

Renal cortex  The most superficial region of the kidney; contains many blood vessels that serve the nephrons

Renal medulla  The kidney’s middle region; consists of medullary pyramids and renal columns

Renal pyramid  Wedge-shaped structure of the renal medulla that contains nephron loops and parts of the collecting system

Renal column  Extensions of the renal cortex into the renal medulla that contain blood vessels

Renal pelvis  The kidney’s innermost region; serves as a basin for collecting urine

Major and minor calyces  Structures that drain urine; minor calyces drain urine from papillary ducts into major calyces, which drain into the renal pelvis

Other Structures of the Urinary System

Ureter  Muscular hollow organ that contracts via peristalsis to propel urine from the renal pelvis to the urinary bladder

Urinary bladder  Distensible organ that stores urine and contracts to expel it during micturition

Urethra  Hollow organ that drains urine from the urinary bladder to outside the body during micturition

Microanatomy of the Kidney

Nephron  Functional unit of the kidney responsible for filtering and removing waste products from the blood

Glomerulus  A ball-shaped capillary bed that is the site of blood filtration in the kidneys
Peritubular capillaries   Blood vessels surrounding most of the renal tubule and collecting system; receive reabsorbed water and solutes and provide the cells with oxygen and nutrients

Proximal tubule   Initial segment of the renal tubule

Nephron loop   Segment of the renal tubule that consists of a descending limb that dives into the renal medulla and an ascending limb that travels back to the renal cortex

Distal tubule   Final segment of the renal tubule

Cortical collecting duct   The first part of the collecting system located in the renal cortex that receives filtrate from distal tubules

Medullary collecting duct   The next part of the collecting system located in the renal medulla

Papillary duct   The final part of the collecting system that drains into a minor calyx

Pre-Lab Exercise 25-2  Structures of the Urinary System

Estimated Completion Time: 15 min.
FIGURE 25.2 Organs of the urinary system: (A) anterior view; (B) posterior view.
Pre-Lab Exercise 25.3 Microanatomy of the Kidney

Estimated Completion Time: 15 min.

FIGURE 25.3 Microanatomy of the kidney: (A) structure of the nephron and collecting system; (B) structure of the renal corpuscle and filtration.
Materials and Prep Notes

Exercise 25-1  Urinary System Anatomy

In this exercise, your students learn about the structures of the urinary system with a model inventory, two new drawing activities, and a kidney dissection. For the dissection, I recommend using the double-color-injected kidneys so that students can easily see the blood vessels. I prefer these to the triple-color-injected kidneys because the yellow dye tends to spill over into the surrounding tissues.

Procedure 1  Model Inventory for the Urinary System

MATERIALS
- Anatomical models, including models of the kidney in various sections, models of the nephron, models of the abdomen and pelvis, and human torso models

Procedure 2  Time to Draw the Urinary System

MATERIALS
- An anatomical model of the kidney for students to draw
- Colored pencils

Procedure 3  Time to Draw a Nephron

MATERIALS
- An anatomical model of the nephron for students to draw
- Colored pencils

Procedure 4  Kidney Dissection

MATERIALS
- Preserved kidneys, color injected (Carolina Biological #228573); one kidney per lab group
- Dissection trays and equipment, one set per lab group

Exercise 25-2  Urinary Organ Histology

Students examine the microscopic structure of several urinary system organs, including the urinary bladder, the ureter, and the kidney. In the kidney, students are asked to examine both the renal cortex and the renal medulla. You can generally find both of these on the same slide and shouldn’t have to purchase them separately. The kidney slide is actually Carolina Biological’s simple cuboidal epithelium slide, which happens to be of the kidney. However, do double-check and make sure the simple cuboidal epithelium is from the kidney before ordering, in case they choose to switch to a different source organ. I have found that the staining used for this particular slide makes it much easier to see the glomeruli and renal tubule sections than on their actual kidney slide.

Procedure 1  Microscopy

MATERIALS
- Microscope slides: urinary bladder, ureter (Carolina Biological #312462), and kidney section (Carolina Biological #312366); one set per lab group
- Light microscope with three objectives
- Colored pencils
1. Label the following parts of the kidney on Figure 25.17.

- Major calyx
- Minor calyx
- Renal artery
- Renal capsule
- Renal column
- Renal cortex
- Renal medulla
- Renal pelvis
- Renal pyramid
- Renal vein
- Ureter

**FIGURE 25.17** Right kidney, frontal section.
Label the following parts of the nephron on Figure 25.18:

- Afferent arteriole
- Cortical collecting duct
- Distal tubule
- Efferent arteriole
- Glomerular capsule
- Glomerulus
- Nephron loop
- Proximal tubule

**FIGURE 25.18** Structure of the nephron.
3 Label the following parts of the urinary system on Figure 25.19.

- External urethral orifice
- Membranous urethra
- Pelvic (urogenital diaphragm)
- Prostatic urethra
- Spongy urethra
- Ureter
- Urinary bladder

![Figure 25.19 Organs of the male and female urinary systems, sagittal sections: (A) male; (B) female.](image)

4 True/False: Mark the following statements as true (T) or false (F). If the statement is false, correct it to make it a true statement.

- F a. The kidneys regulate erythrocyte formation through the production of the hormone glucagon erythropoietin.
- F b. Renal corpuscles are confined to the renal medulla cortex.
- T c. Renal columns are extensions of the renal cortex into the renal medulla.
- F d. The renal tubule consists of the proximal tubule, nephron loop, and the distal tubule and collecting system.

5 The blood flow through the kidney is special because

a. its first capillary beds drain into arterioles.
b. its second capillary beds drain into arterioles.
c. it is supplied by three renal arteries.
d. it contains no capillary beds.
6 Number the following from the point the filtrate is first formed (with a number 1) to the point it drains into the renal pelvis (with a number 10).

- **10** Major calyx
- **9** Minor calyx
- **2** Proximal tubule
- **6** Cortical collecting duct
- **1** Capsular space
- **3** Nephron loop—descending limb
- **7** Medullary collecting duct
- **4** Nephron loop—ascending limb
- **8** Papillary duct
- **5** Distal tubule

7 Urine drains from the urinary bladder via the
   a. ureteral orifices.
   b. papillary calyces.
   c. ureters.
   d. urethra.

8 Glomeruli are located in the
   a. renal cortex.
   b. renal medulla.
   c. renal pelvis.
   d. Both a and b are correct.

9 The smooth muscle layer of the urinary bladder is also called the ____________ muscle.
   a. trigone
   b. detrusor
   c. levator ani
   d. rugae

10 The urinary bladder and ureters are lined by
   a. simple squamous epithelium.
   b. **transitional epithelium.**
   c. pseudostratified columnar epithelium.
   d. stratified cuboidal epithelium.
1. Extreme starvation can lead to a loss of fat from the adipose capsule of the kidney. This leads to drooping of the affected kidney, a condition called nephroptosis. Explain why a loss of the adipose capsule can lead to nephroptosis.

   The adipose capsule helps to wedge the kidneys against the body wall, holding it in place. When the adipose capsule shrinks, there is insufficient adipose tissue to hold the kidney against the posterior body wall. This causes the kidney to drop.

2. Ana has advanced kidney disease. As part of her routine lab work, her physician monitors her complete blood count to check the number of erythrocytes in her blood. The most recent test demonstrated that Ana had a much lower erythrocyte count than normal, leading her physician to diagnose her with anemia. What is the relationship between Ana’s kidney disease and her anemia?

   The kidneys produce the hormone erythropoietin, which stimulates the production and maturation of erythrocytes. When the kidneys are failing, erythropoietin production declines, which can result in anemia.

3. Your lab partner wonders how the cells of the renal tubules and ducts of the collecting system obtain oxygen and nutrients when their capillary bed is located only in the renal corpuscle. What is your lab partner misunderstanding about the blood flow in the kidney? Explain his mistake to him.

   The kidneys have two capillary beds, the glomerulus and the peritubular capillaries. Filtration occurs in the glomerulus, and reabsorption, secretion, and gas/nutrient exchange take place in the peritubular capillaries.

4. Female patients suffer urinary tract infections, or bacterial infections of the urethra and urinary bladder, more frequently than do male patients. Why do you think this is so, considering the anatomy of the female and male urinary tracts?

   The female urethra is much shorter than the male urethra, which makes it easier for bacteria to gain access to the urinary bladder. The female urethra is also anatomically closer to the anus, where a large number of bacteria reside.

5. The condition interstitial cystitis is characterized by insufficient mucus production by the mucosa and submucosa of the urinary bladder. What signs and symptoms would you expect to see with interstitial cystitis? Why?

   The mucus produced by these tissue layers helps protect the underlying cells from damage as a result of the solutes in urine. Insufficient mucus production could lead to ulceration of the mucosa and submucosa, leading to pain and difficulty with urination.
6 Would the renal tubule and ducts of the collecting system be able to perform their functions if their epithelium were stratified rather than simple? Why or why not?

Large volumes of water and solutes must be rapidly reabsorbed (and some solutes secreted) across the epithelium of the renal tubule and collecting system. Thick stratified epithelium would make this happen too slowly, and so would prevent the epithelium from performing its function.

7 Predict how the functioning of the kidney might be affected if the microvilli in the proximal and distal tubules were destroyed. Explain your reasoning.

A huge amount of reabsorption takes place in the renal tubule, especially in the proximal tubule. Microvilli are needed to increase surface area so that this reabsorption takes place efficiently. If microvilli were absent, far fewer solutes and far less water would be reabsorbed, leading to fluid, electrolyte, and acid-base imbalances.