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Lab Manual
Introductory Anatomy & Physiology

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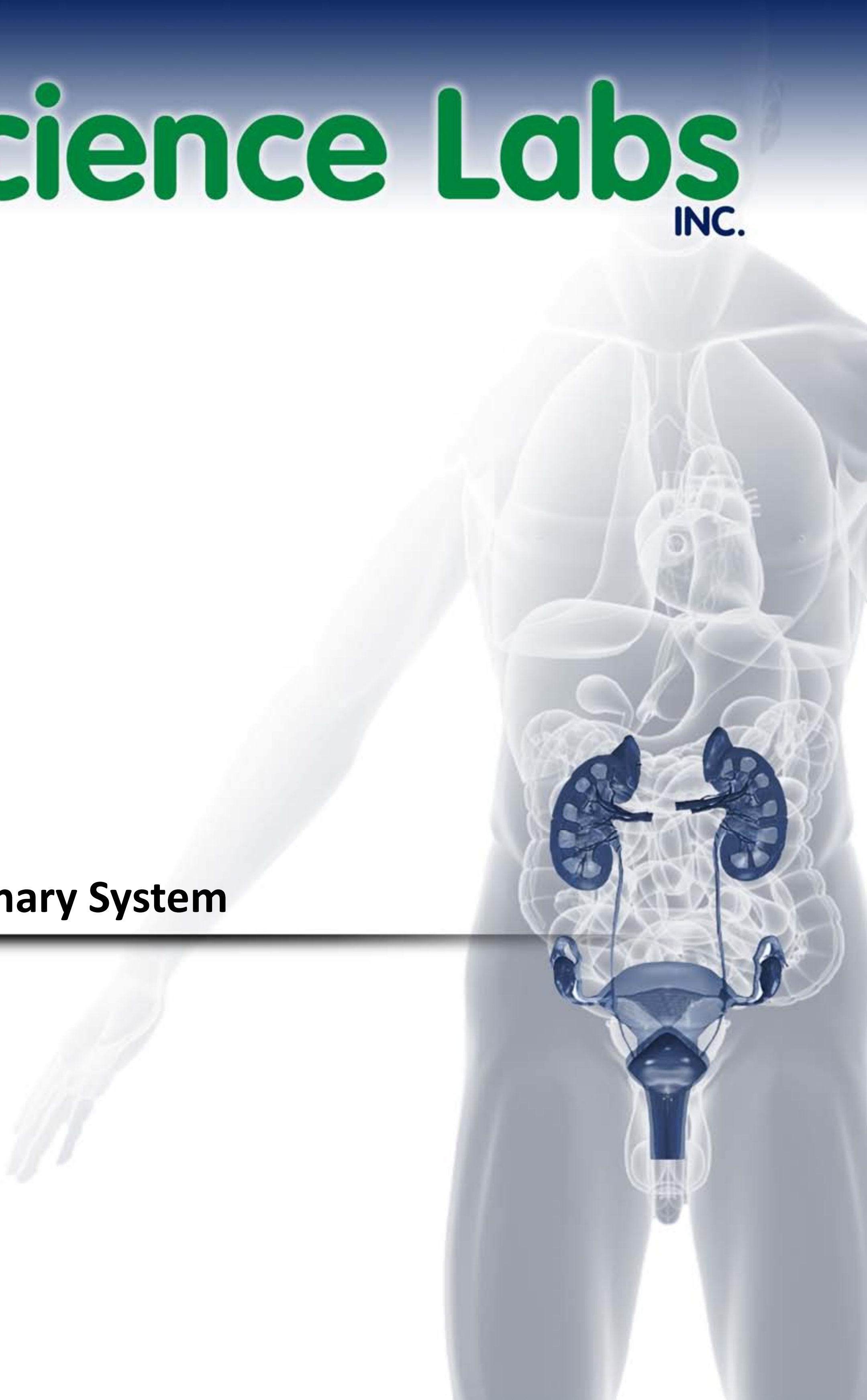
Anatomy and Physiology
Version 3

Lab 14: The Urinary System



The Urinary System

The organs, tubes, muscles, and nerves that work together to create, store, and carry urine are the urinary system. The primary function of the urinary system is to maintain the volume and composition of body fluids. Normal cell metabolism leads to the accumulation of waste products, including carbon dioxide, nitrogenous wastes, ammonia, etc., throughout the body. The urinary system help to remove these byproducts from the body in order for normal function to continue. This role leads to the alternate name for this system—the excretory system.

While the urinary system is the major player in excreting toxic wastes, it is not the only system involved in these processes. The lungs in the respiratory system excrete carbon dioxide and water; the skin rids the body of wastes through sweat glands; the liver and intestines secrete bile pigments that result from the destruction of hemoglobin.

The urinary system maintains the appropriate fluid volume in the body by regulating the amount of water that is excreted in urine. In doing so, the concentrations of various electrolytes and normal pH of the blood is also controlled. The major organs of the urinary system are the kidneys (2), ureters (2), urinary bladder, sphincter muscles (2), and the urethra (Figure 14.1). Together, these components of the urinary system maintain the fluid homeostasis of the body.

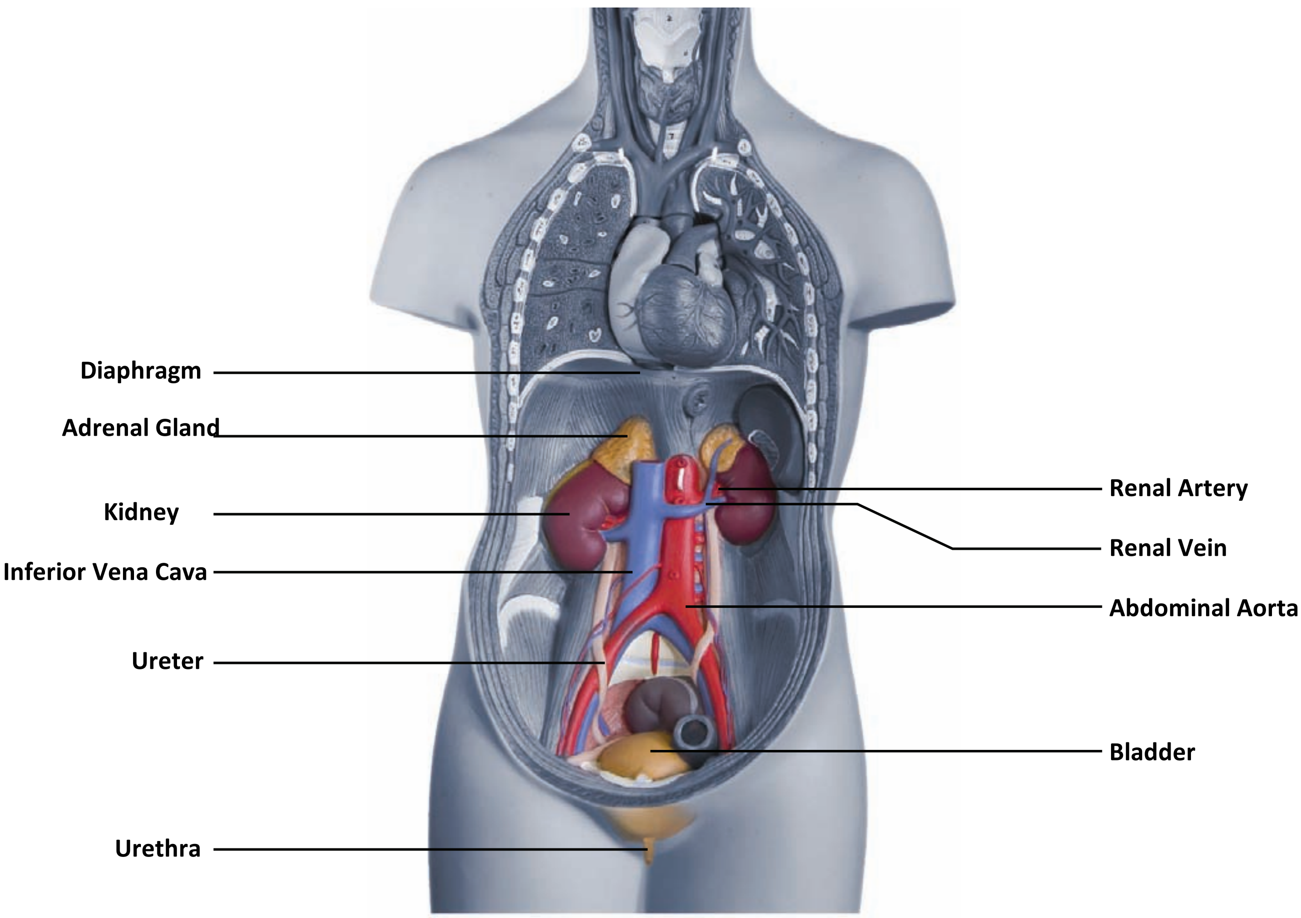


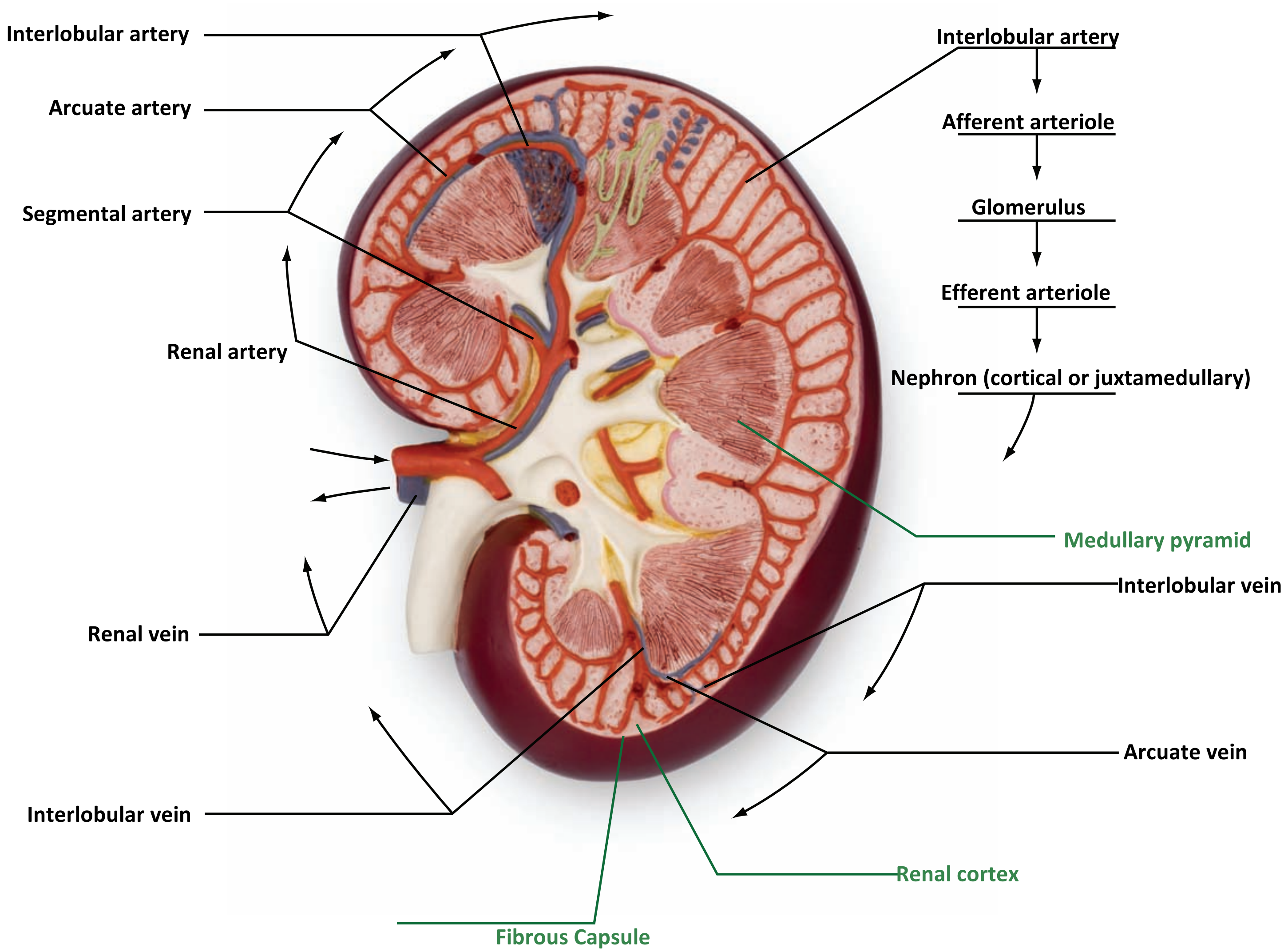
Figure 14.1: The urinary system consists of paired kidneys and ureters, a urinary bladder, sphincter muscles and a urethra. Nearly a quarter of the total blood flow is delivered to the kidneys each minute via the renal arteries which enters at the hilum of each organ.

The urinary system can be subdivided into two functional groups: kidneys and the excretory passage. The kidney is the site of urine manufacture, the waste products eliminated from the bloodstream by the filtration processes that occur within these organs. The ureter, bladder, and urethra are structures for collecting urine and transporting it from the body.

Kidneys

The main role of the kidneys is to filter water soluble waste products from the blood resulting from bodily functions. Thus, it is able to control the flux of ions out of the body and conserve water. The renal arteries are supplied by the Abdominal aorta, delivering 1.25L/min of blood to the kidneys for purification. Within these organs, urine is concentrated as the kidney excretes and reabsorbs electrolytes, amino acids, glucose, and other small molecules under the influence of local and systemic hormones. The pH of the blood is regulated by bound acids and ammonium ions. Furthermore, kidneys remove urea from the blood, which is a nitrogenous waste resulting from the metabolism of amino acids. The product of these waste products is urine, which is stored in the bladder before excreted from the body.

Figure 14.2: The flow through a kidney



The kidneys are bean-shaped reddish colored organs which lie in the abdomen, retroperitoneal to the organs of digestions and around or just below the ribcage. The left kidney lies slightly superior to the right kidney (which sits under the liver) ,and is also slightly longer. Each organ in the human body is roughly the size of a fist, measuring 10-12cm in length, 5-7cm wide, and 2-5cm thick. The blood supply, nerves and lymphatic vessels enter and exit at the hilum (the indented region). Each kidney is sur-

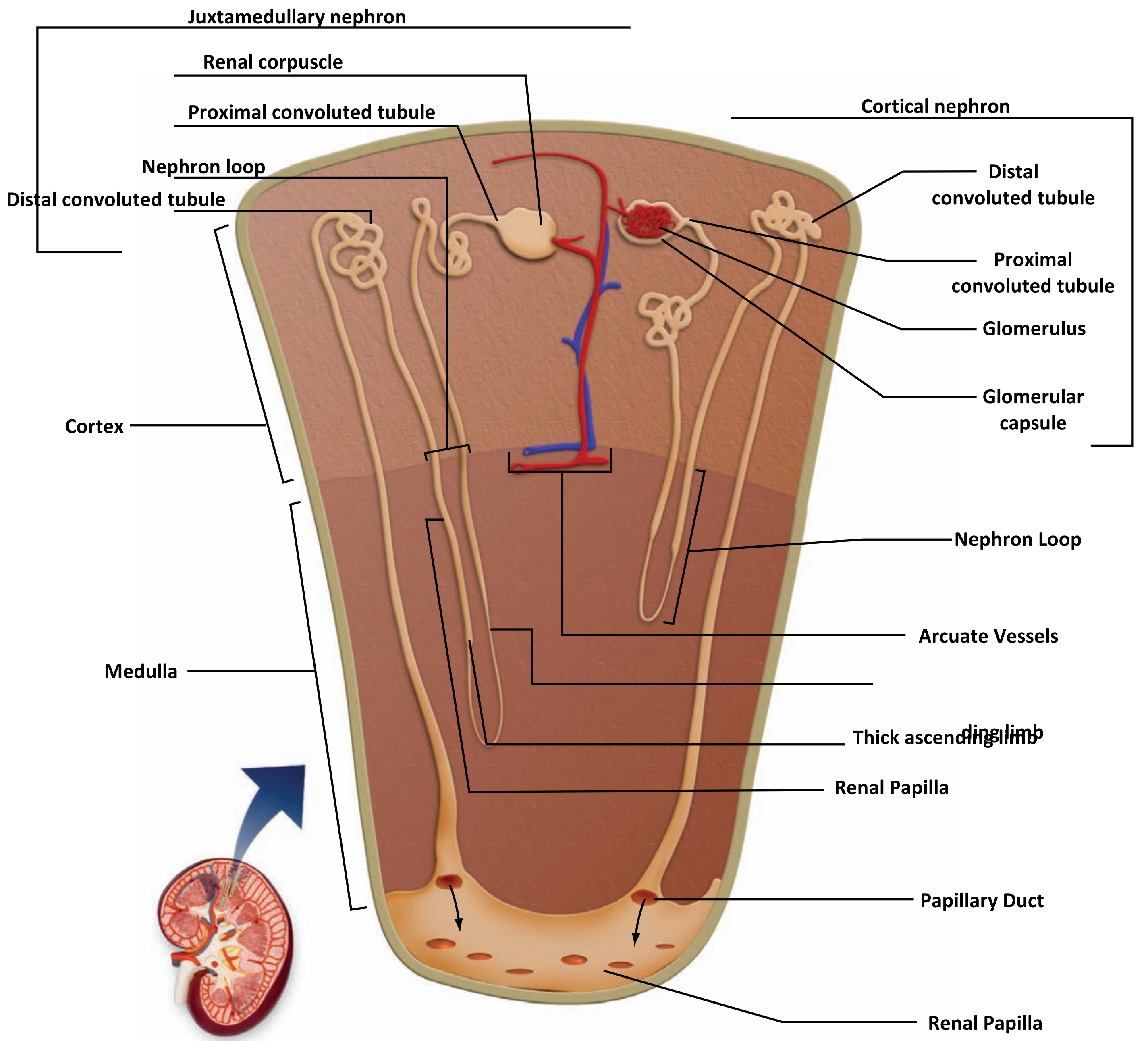


Figure 14.3: The kidney has millions of nephrons actins together to achieve its function. The composition of blood is adjusted by glomerular filtration, tubular reabsorption, and tubular secretion. The filtrate emerges from the glomerular capsule, and travels through the highly coiled and twisted tubules before reaching the nephron loop (a hairpin loop in the tubules called the loop of Henle), again travels through coiled and twisted loops before exiting through a collection duct.

rounded by the renal capsule, a layer of collagen fibers that covers the outer surface of the organ, and peri-nephratic fat which stabilizes the organ. Adrenal glands cap the kidneys on the superior pole.

The kidney itself is constructed of two layers. The cortex is the outer layer and the medulla is the inner layer (Figure 14.2). The superficial cortex is lighter in color compared to the medulla. Within the medulla are a number of conical structures called the medullary pyramids. The base of these triangular regions faces toward the cortex while the papilla (apex) points inward. Renal columns segregate the pyramids.

Each pyramid of medullary tissue and the cortical tissue immediately above it is defined as a kidney lobe. Medial to the hilum, the renal pelvis forms a basin-like structure with radial projections , called major calyces which are further subdivided into the minor calyces, penetrate the medulla. This duct system collects urine from the pyramids and drains the fluid into the ureters.

The smallest function unit of the kidney is the nephron (Figure 14.3), and is where urine is formed and the composition of the blood is regulated. Nephrons consist of a glomerular capsule (renal corpuscle) and a tubule system. The glomerular capsule (specifically, the Bowman's capsule) surrounds a tight twisted knot of capillaries called the glomerulus. The Bowman's capsule is lined on the inside by visceral epithelial cells called podocytes. These cells have long processes that cling to the capillary walls to establish size selectivity and offer a huge surface area for exchange between the blood vessel and nephron. Most nephrons are located within the cortex, and are thus names cortical nephrons. However, others called juxtamedullary nephrons, are positioned partially in the medulla. These nephrons have additional capillaries called the vasa recta that facilitate both reabsorption and secretion.

The tubule system of the nephron (Figure 14.3) carries plasma filtrate from the glomerular capsule to a collection duct, and is the site of reabsorption and secretion. The tubular structure is lined by a single layer of simple cells and surrounded by peritubular capillaries. These lining cells facilitate the reabsorption of water and small molecules from the filtrate into the blood (through the capillaries), and the secretion of wastes from the blood into the urine (the filtrate). This is the only place in the body where a capillary network is both supplied (afferent artery) and drained by (efferent artery) an artery. These high-resistance vessels facilitate the filtration process. The diameter of both arteries can by regulated in order to control the blood hydrostatic pressure in the glomerular capillaries, thus adjusting the filtration rate within the kidneys.

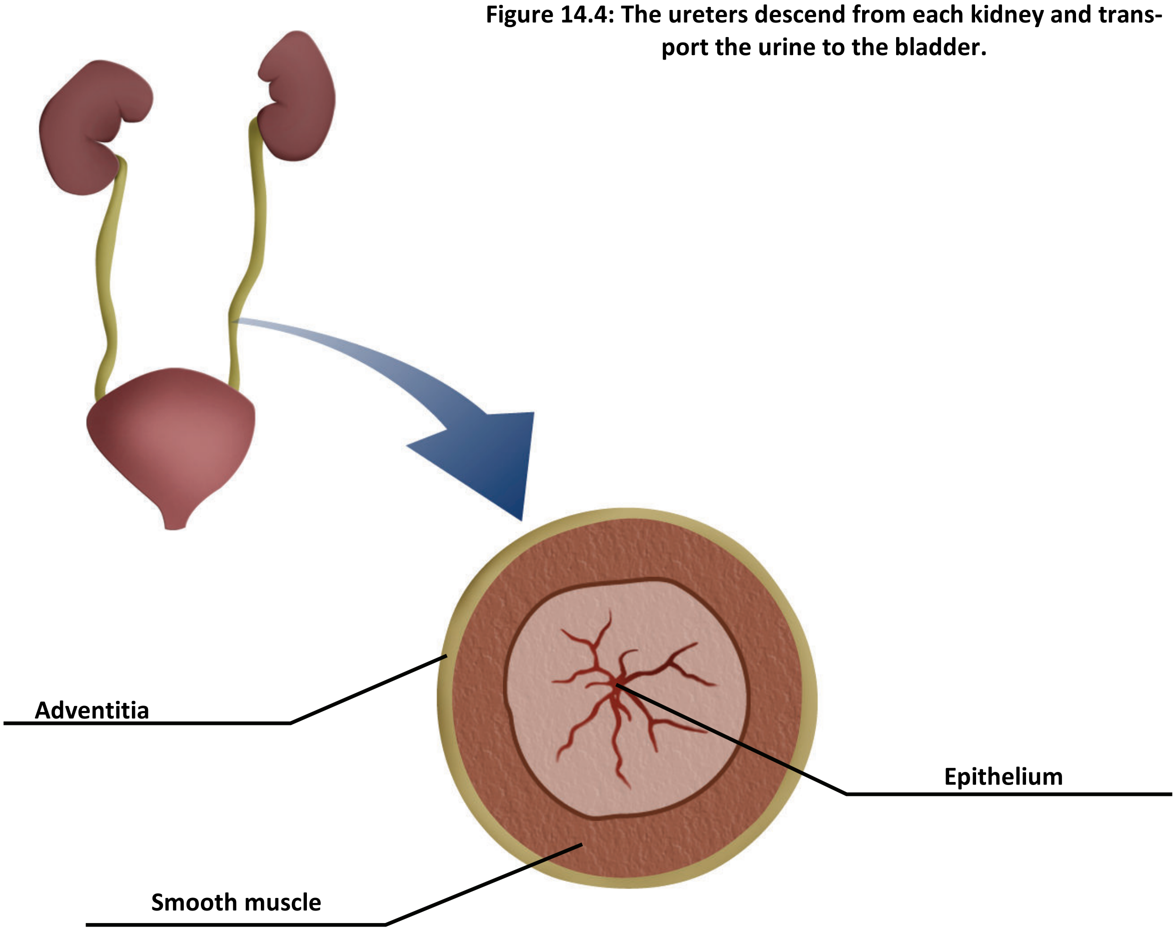
Depending on what substances are needed by the body to maintain proper pH and electrolyte concentration, the reabsorption of filtrate components will vary. Water is reabsorbed by osmosis, but most substances depend on active transport to select what will re-enter the bloodstream.

The highly vascularized renal cortex and the pyramids together make up the parenchyma. The medullary pyramids appear striated, due to the parallel alignment of the loops of Henle and collecting tubules. Collecting tubules are not considered part of the nephron as they are the duct system of the kidney. The bulk of the medullary pyramid is composed of collecting tubules. The collecting tubules are lined with simple cuboidal epithelium. They meet at the apex, merging together to form large ducts, called the ducts of Bellini, which empty into the renal pelvis. From here, the filtrate exits the kidney through the ureter and is collected in the bladder awaiting urination.

Excretory Passage

The ureters are muscular tubules that link the kidneys to the bladder (Figure 14.4) . They measure about 30cm in length and 3mm in diameter. This tubule is composed of an outer layer of connective tissue (adventitia), a middle layer of smooth muscle cells, and an inner layer of epithelium (mucosa). There are slight differences in the ureters of males and females to accommodate reproductive organs. The mechanism transporting urine from the kidneys to the bladder is peristaltic action, the rhythmic contraction of the smooth muscle cells.

Figure 14.4: The ureters descend from each kidney and transport the urine to the bladder.



The bladder is composed of bands of three layers of interlaced smooth muscle, collectively called the detrusor muscle (Figure 14.5). Voiding the bladder, also called micturition, is controlled by two sphincter muscles—the internal urethral sphincter and the external urethral sphincter. When the bladder reaches a volume of roughly 200mL, the stretch receptors in the bladder wall transmit signals to the CNS. The parasympathetic nervous system produces reflex contractions of the bladder, and the liquid is forced past the involuntary internal sphincter muscle into the superior part of the urethra. At this point, a person feels the need to urinate. The voluntary external sphincter muscle can be relaxed and the bladder emptied.

The urethra extends from the neck of the bladder to the exterior of the body, and is the final passageway that urine travels through before exiting the body. The final passageway for the flow of urine is the urethra. This thin-walled tube is composed of smooth muscle, connective tissue, and is lined with transitional epithelium.

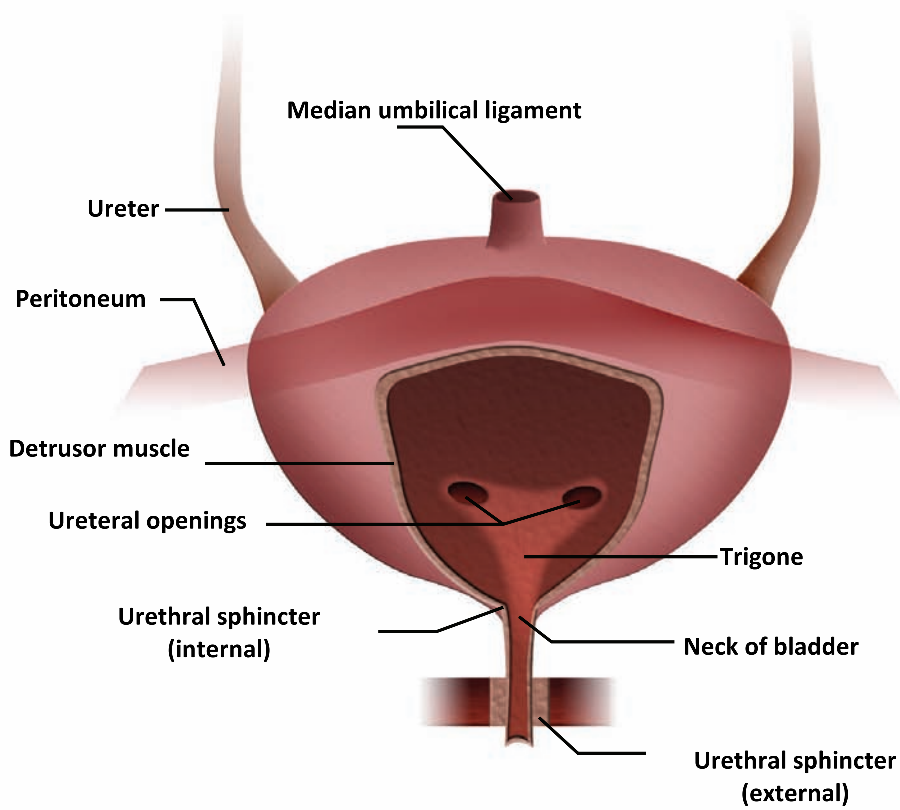


Figure 14.5: The urinary bladder is a muscle that stores urine until it is released from the body through urination

Experiment 14.1: Kidney Filtration

The kidneys function to filter the blood in the body, removing waste, therefore cleansing the blood. In this experiment, the dialysis bag will act as a part of the kidney. When the solution containing the Congo Red, Yellow Food Coloring and Water is made, this symbolizes blood as it is entering the kidney via the renal artery . As the experiment progresses, notice the filtration occurring with the kidney (dialysis tubing) and the resulting substances.

Materials
1 ft Dialysis Tubing
Small Rubber Band
Pipette
3ml Congo Red
3ml Yellow Food Coloring
(2) 250 ml beaker
10 ml Graduated Cylinder
*water
** you must provide*

Procedure

1. Begin by placing a small rubber band around the bottom of the dialysis tubing to close it off. Wrap the rubber band as many times as possible. Test that the dialysis tubing will not leak out of the bottom by placing a few drops of water into the tubing. If it leaks out the bottom, the rubber band has not been fastened tight enough. If it does not leak, pour the water out of the tubing into the sink. Set the tubing aside.

2. Grab one 250 ml beaker and fill it with 200 ml of water. Set this aside for now.

3. With the 10 ml graduated cylinder, measure out 3 ml of Congo Red. Pour it into the empty 250 ml Beaker. Wash out the cylinder.

4. With the 10 ml graduated cylinder, measure out 3 ml of Yellow Food Coloring. Pour it into the same 250 ml beaker as you poured the Congo Red. Wash out the cylinder.

5. With the 10 ml graduated cylinder, measure out 5 ml of water. Pour the water into the same 250 ml beaker that contains the Congo Red and Yellow Food Coloring.

6. Now, take a pipette and mix the solutions in the 250 ml beaker. To do this, place the pipette in the solution and squeeze and release the bulb of the pipette while moving the pipette throughout the solution.

7. Once the solution has been thoroughly mixed, pipette 10 ml into the dialysis tubing. Fill out Table 14.1 below indicating whether the solution was present before the experiment.

8. When all 10 ml have been placed into the dialysis tubing, gently place a rubber band around the top of the dialysis tubing to close it off, similarly to the bottom of the tubing.

9. When the dialysis tubing is securely closed off on both ends, place the dialysis tubing into the 250 ml beaker with 200 ml of water.

10. Let the dialysis tubing sit for 60 minutes. Notice the diffusion through the dialysis tubing. Indicate in Table 14.2 below whether the solution was present after the experiment.

Table 14.1—Before the experiment

Solution	Dialysis Tubing	Beaker
Congo Red		
Yellow Food Coloring		

Table 14.2—After the experiment

Solution	Dialysis Tubing	Beaker
Congo Red		
Yellow Food Coloring		

Questions

1. What specific part of the kidney does the dialysis tubing represent? What is this parts function?

2. What does the Yellow Food Coloring represent at the end of the experiment? What does the Congo Red represent?

3. Why is it important that the kidney filters the blood?

Experiment 14.2: Urinalysis

As was seen in Experiment 14.1, urine is the waste product filtered within the kidney. The urine is made up of many waste products as well as excess water. Urine is also a very helpful tool for doctors when diagnosing different conditions in patients. In this experiment, you will perform a urinalysis on four different samples of urine, testing a variety of different components. When all components have been tested, you will determine which of the urine samples are "abnormal" using Table 14.3 below.

Table 14.3: Urine Tests

Test	Normal	Abnormal
pH	4.5—7.5	Below 4.5, above 7.5
Glucose	None	Glucose present (red or green color after test)
Albumin	None	Albumin present (violet color after test)
Yeast	None	Yeast present (bubbles form after test)
Ketones	Little or None	Large amount of Ketones present (sweet smell of urine)

Materials

Safety Glasses
Gloves
4 glass test tubes
Simulated Urine Sample A
Simulated Urine Sample B
Simulated Urine Sample C
Simulated Urine Sample D
10 ml Graduated Cylinder
Pipettes
Test Tube Rack
Benedicts Solution
Sharpie
4 pH test strips
Hydrogen Peroxide
Buiret Solution
* Hot Water Bath (warm water in a deep bowl will work)
** you will provide*

Procedure

pH

1. Before beginning this lab, be sure you are wearing your safety glasses and gloves.

2. Begin by marking one test tube A, one test tube B, one test tube C and one test tube D.

3. Place these four test tubes into the test tube rack.

4. Add 5 ml of the simulated urine to the corresponding test tube (ex. Add 5 ml of simulated urine A to the test tube labeled A).

5. Then, grab the pH test strip. Dip one test strip into each tube. Wait approximately 45 seconds and then compare the test strip to the pH color chart below.

6. Record the pH of each of the samples in Table 14.4.

Table 14.4—Simulated Urine pH Test

Simulated Urine Sample	pH
A	
B	
C	
D	

Glucose Test

1. Before beginning this lab, be sure you are wearing your safety glasses and gloves.

2. Begin by marking one test tube A, one test tube B, one test tube C and one test tube D.

3. Place these four test tubes into the test tube rack.

4. Add 5 ml of the simulated urine to the corresponding test tube (ex. Add 5 ml of simulated urine A to the test tube labeled A).

5. Then, place all four tubes into a hot water bath. Let them sit for 3 minutes. Record their color change in Table 14.5.

Table 14.5—Simulated Urine Glucose Test

Simulated Urine Sample	Color Before Hot Water Bath	Color After Hot Water Bath
A		
B		
C		
D		

Albumin Test

1. Before beginning this lab, be sure you are wearing your safety glasses and gloves.
2. Begin by marking one test tube A, one test tube B, one test tube C and one test tube D.
3. Place these four test tubes into the test tube rack.
4. Add 5 ml of the simulated urine to the corresponding test tube (ex. Add 5 ml of simulated urine A to the test tube labeled A).
5. Then, add 25 drops of buiret solution into each of the 4 tubes. Grab each tube, one at a time, out of the test tube rack and swirl it around to mix up the buiret solution into the specimen. Record the color change in Table 14.6.

Table 14.6—Simluated Urine Albumin Test

Simulated Urine Sample	Color Before Buiret Solution	Color After Buiret Solution
A		
B		
C		
D		

Yeast Test

1. Before beginning this lab, be sure you are wearing your safety glasses and gloves.
2. Begin by marking one test tube A, one test tube B, one test tube C and one test tube D.
3. Place these four test tubes into the test tube rack.
4. Add 5 ml of the simulated urine to the corresponding test tube (ex. Add 5 ml of simulated urine A to the test tube labeled A).
5. Then, add 2 ml of Hydrogen Peroxide into each tube and note any bubbles in table 14.7.

Table 14.7—Simluated Urine Yeast Test

Simulated Urine Sample	Bubbles before Hydrogen Peroxide?	Bubbles After Hydrogen Peroxide?
A		
B		
C		
D		

Ketone Test

1. Before beginning this lab, be sure you are wearing your safety glasses and gloves.

2. Begin by marking one test tube A, one test tube B, one test tube C and one test tube D.

3. Place these four test tubes into the test tube rack.

4. Add 5 ml of the simulated urine to the corresponding test tube (ex. Add 5 ml of simulated urine A to the test tube labeled A).

5. Then, using a wafting motion (pulling your hand over the tube without bringing the tube directly to your nose), notice the order of each of the samples. Record your observations in Table 14.8.

Table 14.8—Simluated Urine Ketone Test

Simulated Urine Sample	Odor Observation
A	
B	
C	
D	

Questions

1. Fill in the following charts for each urine sample. State whether they showed normal or abnormal results for each urine test. If abnormal, write in their test result (i.e., pH of 3.2, glucose present, etc.).

Table 14.9—Sample A

Simulated Urine Sample A	Test Results
pH	
Glucose	
Albumin	
Yeast	
Ketones	

Table 14.10—Sample B

Simulated Urine Sample B	Test Results
pH	
Glucose	
Albumin	
Yeast	
Ketones	

Table 14.11—Sample C

Simulated Urine Sample C	Test Results
pH	
Glucose	
Albumin	
Yeast	
Ketones	

Table 14.12—Sample D

Simulated Urine Sample D	Test Results
pH	
Glucose	
Albumin	
Yeast	
Ketones	

2. Using the test results from each of the urine samples, along with the following table, diagnosis the condition(s) that each of the sample patients is experiencing.

Table14.13—Abnormal Conditions

Test	Abnormal Conditions
pH	Acidic urine (below4.5)— diabetes, starvation, dehydration, respiratory acidosis Alkaline urine (above 7.5) - kidney disease, kidney failure, urinary tract infection, respiratory alkalosis
Glucose	Diabetes mellitus
Albumin	Kidney disease
Yeast	Yeast infection in urinary tract
Ketones	Starvation, prolonged vomiting, diabetes, hyperthyroidism and other metabolic disorders

1. If you were a doctor and a patient's urinalysis came back with high level of glucose, ketones and an acidic pH, what diagnosis would you immediately look into?

2. If you were a doctor and a patient's urinalysis came back with an alkaline pH and high levels of albumin, what diagnosis would you immediately look into?

3. What other things can urine be used to test for?

Lab 14.3: Fetal Pig Dissection of the Urinary System

Studying the urinary system of a pig provides a representation of the urinary system of a human.

Materials

Fetal Pig
Dissection Tray
Scalpel
Pins
Scissors
Blunt Probe
Forceps
Goggles
Gloves
Apron

Procedure

1. Before beginning, be sure you have your safety glasses, gloves and apron on.

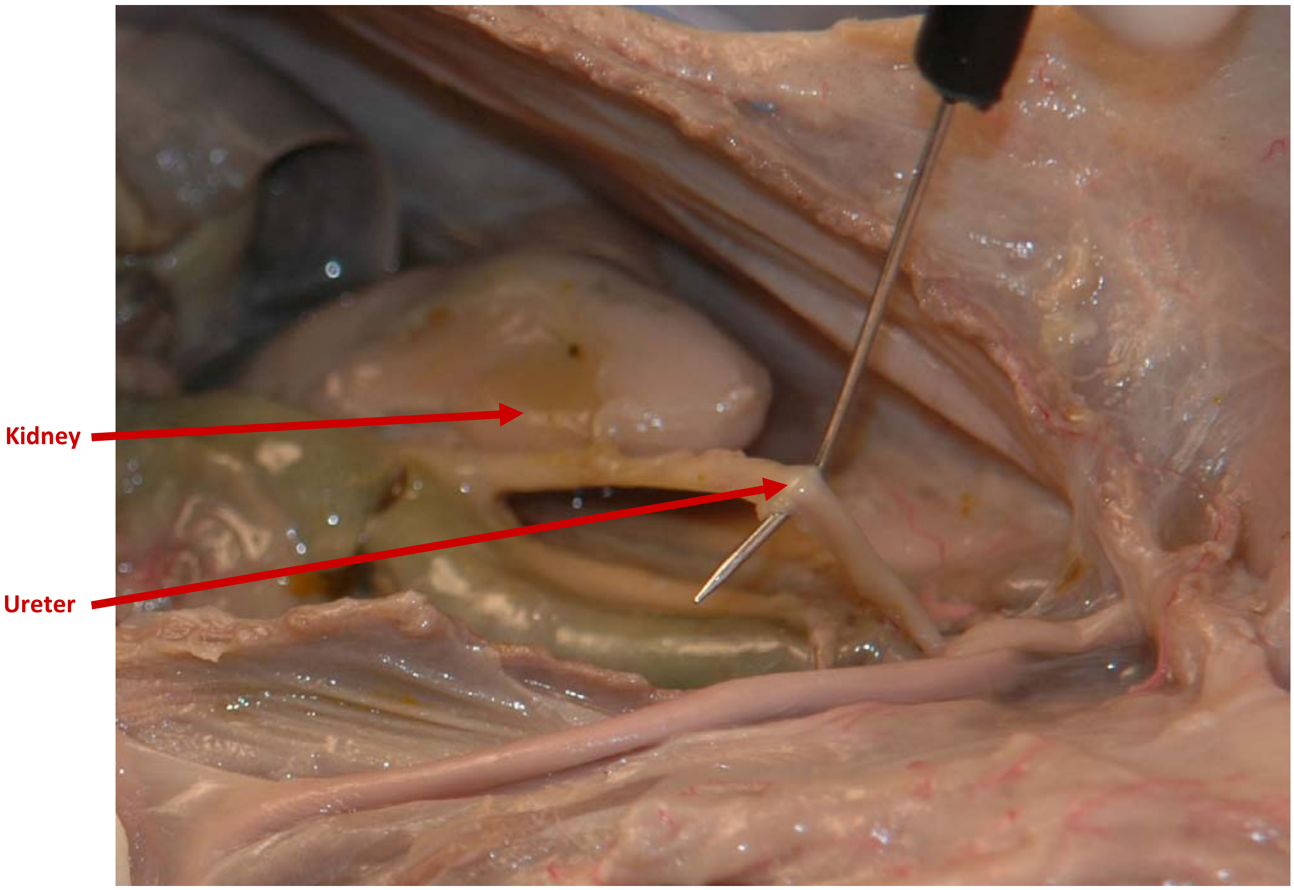
2. Remove the pig from the bag. Again, be sure to keep all the preserving fluid within the bag.

3. Lay the pig once again on its dorsal side with the ventral side facing upwards. Using the incisions made previously, open up the pig, exposing the intestines. Pin the excess skin and tissue down if necessary.

4. Gently remove the intestines, leaving a portion of the large intestine (this will be used to locate the rectum).

5. Locate the kidneys. These look like small, bean shaped organs against the dorsal wall of the body.

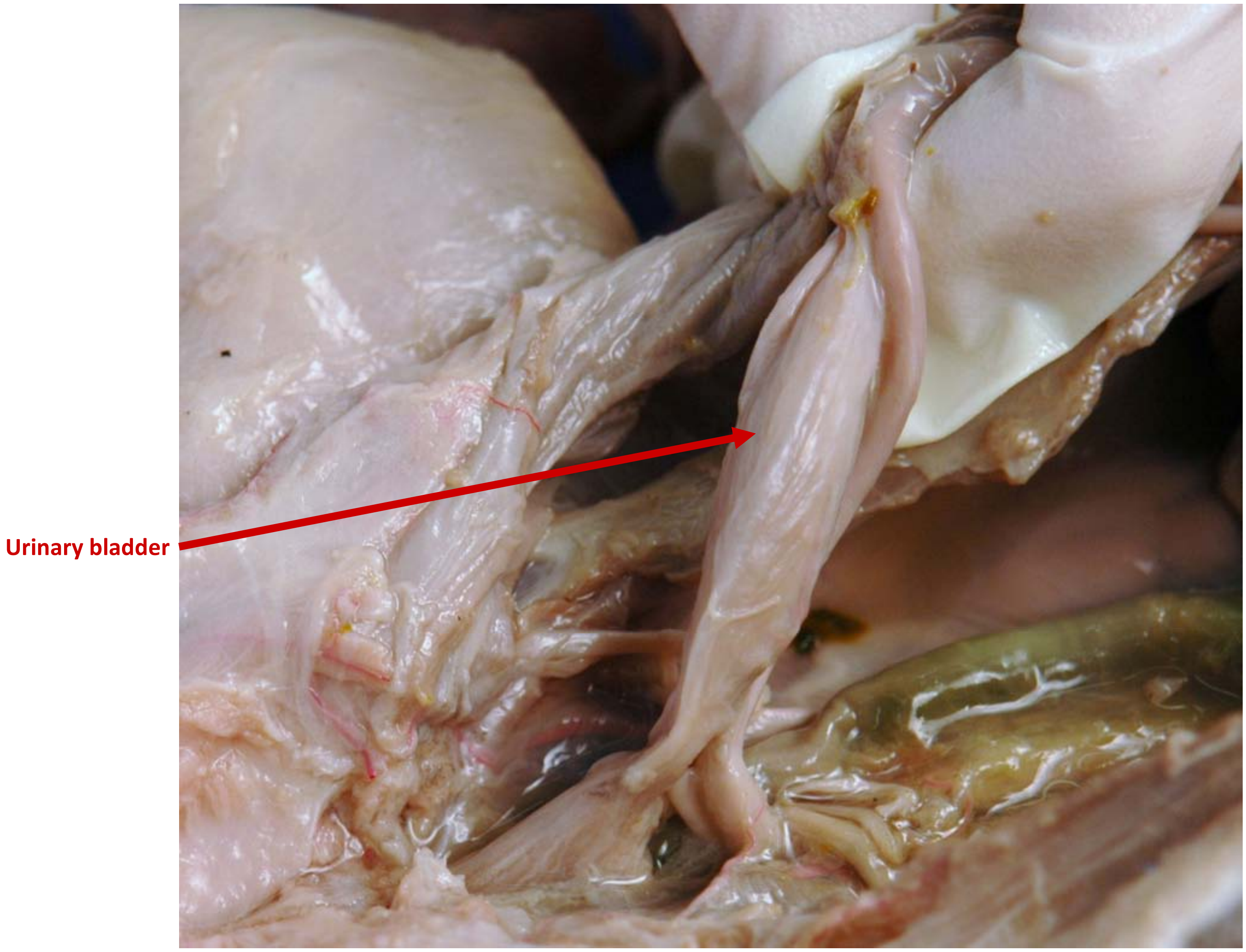
6. Looking at the kidney, locate the adrenal gland. This sits near the anterior surface of the kidney.

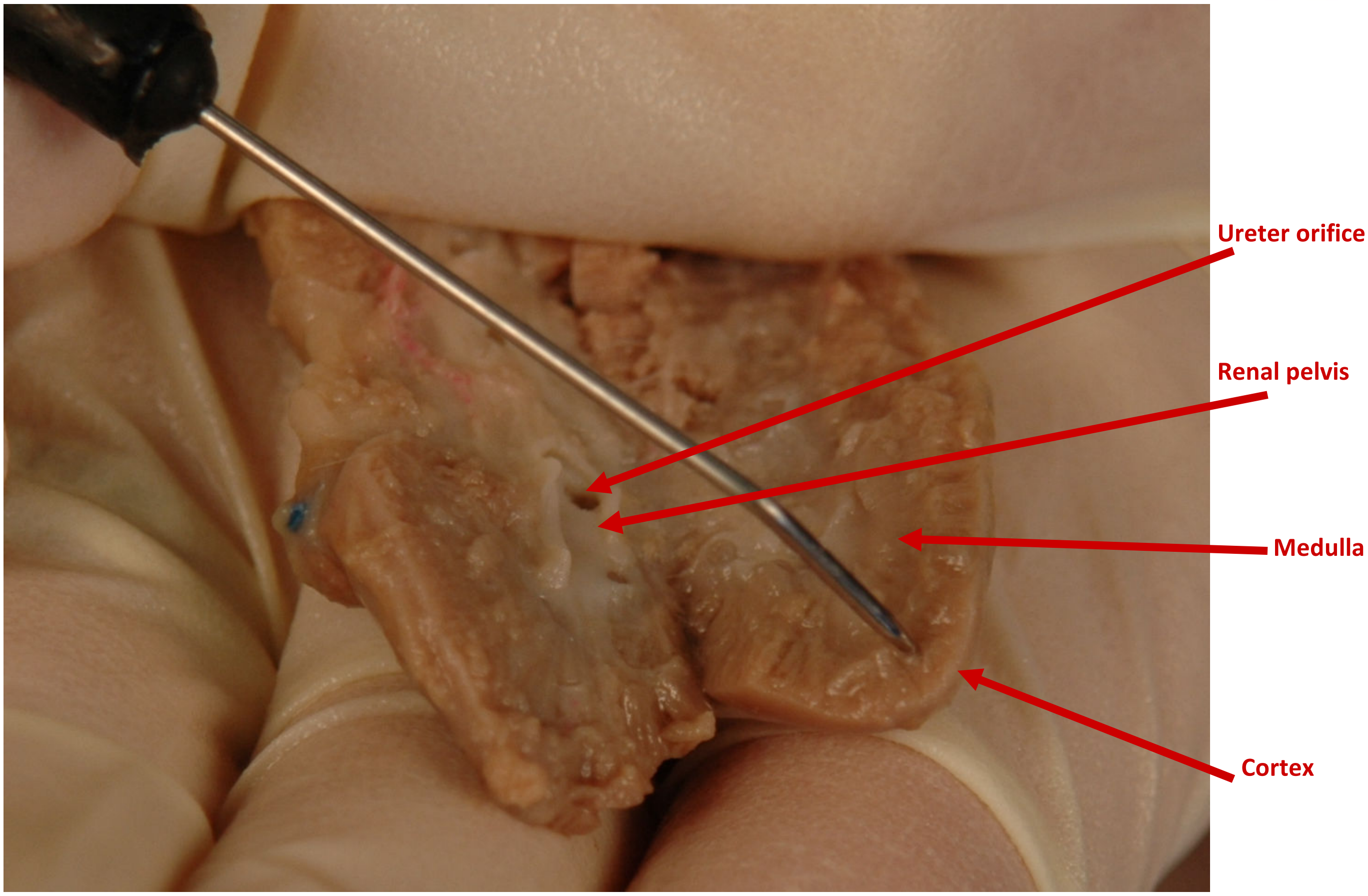


7. Locate the ureter (picture above). This stems from the medial surface of the kidney. Near the origination of the ureter, notice the renal vein and the renal artery.

8. Follow the ureters posteriorly until you locate the urinary bladder and the urethra (picture below). Notice the elongation of the urinary bladder in the fetal pig. This occurs because the urinary bladder is actually connected to the umbilical cord in a fetus. If the urine generated by the fetus were to pass to the urethra as it does in adults, the amniotic sac would become toxic to the fetus. Instead, the fetus transports its waste directly through the allantoic duct and through to the allantois, a small sac created specifically to handle toxic waste in a fetus, which then passes the waste onto the umbilical blood vessels. At birth, this process collapses and urine begins to flow from the

urinary bladder into the urethra.





9. Return to the kidney. Carefully make a longitudinal incision along the side of the kidney, as if you were cutting a bean in half. Gently lay the kidney open.

10. Inside, the kidney is made up of three different regions: the *inner renal pelvis* where the ureter begins. The darker tissue extending from the renal pelvis is known as the *middle medulla*. Within the middle medulla are the renal pyramids which look like triangular or cone-shaped masses. The outer portion of the kidney is called the *outer cortex*.

11. Notice the process in which waste is removed from the body. The process begins with blood flowing in from the renal arteries into the kidneys. As the blood flows through the kidneys, it passes through many small tubules that remove waste, water and other ions. The cleansed blood then flows out of the kidney via the renal veins. The waste removed is collected and then passes through the inner renal pelvis into the ureter, on its way to the urinary bladder. The waste again collects in the urinary bladder until it flows down the urethra and is expelled from the body.

12. Be sure that you can follow this process within the pig.

13. When you have finished with your dissection, gently place your pig back into the bag and place it in

a safe location for the next dissection.

14. Wash your work area thoroughly.

Questions

1. Draw a picture of the inside of a kidney. Be sure to label the three different regions, as well as the ureter, renal pyramids, renal artery and renal vein.

2. What is the function of the urinary bladder?

3. Why does the urinary bladder of the fetal pig bypass the urethra?

4. Would you think the kidneys are highly vascular? Why or why not?

5. What is the function of the renal pyramids?

6. What is the function of the adrenal glands?

7. Explain, in detail, the process by which urine is made.

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