

## **INTRODUCTION- RENAL SYSTEM- NOTES 1**

The urinary system has roles you may be well aware of: cleansing the blood and ridding the body of wastes probably come to mind. However, there are additional, equally important functions played by the system. Take for example, regulation of pH, a function shared with the lungs and the buffers in the blood. Additionally, the regulation of blood pressure is a role shared with the heart and blood vessels. What about regulating the concentration of solutes in the blood? Did you know that the kidney is important in determining the concentration of red blood cells? Eighty-five percent of the erythropoietin (EPO) produced to stimulate red blood cell production is produced in the kidneys. The kidneys also perform the final synthesis step of vitamin D production, converting calcidiol to calcitriol, the active form of vitamin D.

If the kidneys fail, these functions are compromised or lost altogether, with devastating effects on homeostasis. The affected individual might experience weakness, lethargy, shortness of breath, anemia, widespread edema (swelling), metabolic acidosis, rising potassium levels, heart arrhythmias, and more. Each of these functions is vital to your well-being and survival. The urinary system, controlled by the nervous system, also stores urine until a convenient time for disposal and then provides the anatomical structures to transport this waste liquid to the outside of the body. Failure of nervous control or the anatomical structures leading to a loss of control of urination results in a condition called incontinence.

This chapter will help you to understand the anatomy of the urinary system and how it enables the physiologic functions critical to homeostasis. It is best to think of the kidney as a regulator of plasma makeup rather than simply a urine producer. As you read each section, ask yourself this question: “What happens if this does not work?” This question will help you to understand how the urinary system maintains homeostasis and affects all the other systems of the body and the quality of one’s life.

### **Learning Objectives**

By the end of this section, you will be able to:

- Describe the external structure of the kidney, including its location, support structures, and covering
- Identify the major internal divisions and structures of the kidney

- Identify the major blood vessels associated with the kidney and trace the path of blood through the kidney
- Compare and contrast the cortical and juxtamedullary nephrons
- Name structures found in the cortex and medulla
- Describe the physiological characteristics of the cortex and medulla

Location- The kidneys lie on either side of the spine in the retroperitoneal space between the parietal peritoneum and the posterior abdominal wall, well protected by muscle, fat, and ribs. They are roughly the size of your fist, and the male kidney is typically a bit larger than the female kidney. The kidneys are well vascularized, receiving about 25 percent of the cardiac output at rest.

### EXTERNAL ANATOMY

The left kidney is located at about the T12 to L3 vertebrae, whereas the right is lower due to slight displacement by the liver. Upper portions of the kidneys are somewhat protected by the eleventh and twelfth ribs ([Figure 1](#)). Each kidney weighs about 125–175 g in males and 115–155 g in females. They are about 11–14 cm in length, 6 cm wide, and 4 cm thick, and are directly covered by a fibrous capsule composed of dense, irregular connective tissue that helps to hold their shape and protect them. This capsule is covered by a shock-absorbing layer of adipose tissue called the **renal fat pad**, which in turn is encompassed by a tough renal fascia. The fascia and, to a lesser extent, the overlying peritoneum serve to firmly anchor the kidneys to the posterior abdominal wall in a retroperitoneal position.

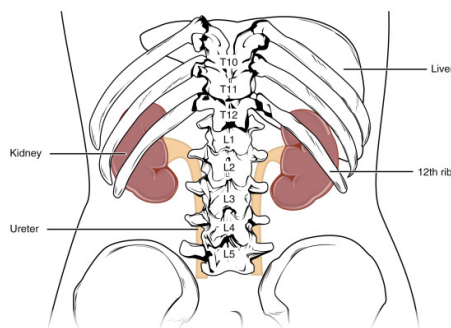


Figure 1. Kidneys. The kidneys are slightly protected by the ribs and are surrounded by fat for protection (not shown).

On the superior aspect of each kidney is the adrenal gland. The adrenal cortex directly influences renal function through the production of the hormone aldosterone to stimulate sodium reabsorption.

## INTERNAL ANATOMY

A frontal section through the kidney reveals an outer region called the **renal cortex** and an inner region called the **medulla** (Figure 2). The **renal columns** are connective tissue extensions that radiate downward from the cortex through the medulla to separate the most characteristic features of the medulla, the **renal pyramids** and **renal papillae**. The papillae are bundles of collecting ducts that transport urine made by nephrons to the **calyces** of the kidney for excretion. The renal columns also serve to divide the kidney into 6–8 lobes and provide a supportive framework for vessels that enter and exit the cortex. The pyramids and renal columns taken together constitute the kidney lobes.

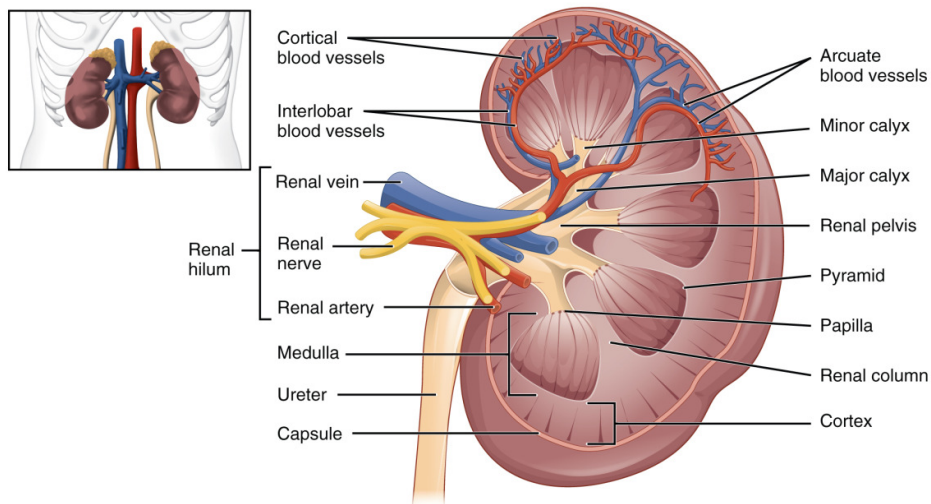


Figure 2. Left Kidney.

## RENAL HILUM

The **renal hilum** is the entry and exit site for structures servicing the kidneys: vessels, nerves, lymphatics, and ureters. The medial-facing hila are tucked into the sweeping convex outline of the cortex. Emerging from the hilum is the renal pelvis, which is formed from the major and minor calyces in the kidney. The smooth muscle in the renal pelvis funnels urine via

peristalsis into the ureter. The renal arteries form directly from the descending aorta, whereas the renal veins return cleansed blood directly to the inferior vena cava. The artery, vein, and renal pelvis are arranged in an anterior-to-posterior order.

## NEPHRONS AND VESSELS

The renal artery first divides into segmental arteries, followed by further branching to form interlobar arteries that pass through the renal columns to reach the cortex ([Figure 3](#)). The interlobar arteries, in turn, branch into arcuate arteries, cortical radiate arteries, and then into afferent arterioles. The afferent arterioles service about 1.3 million nephrons in each kidney.

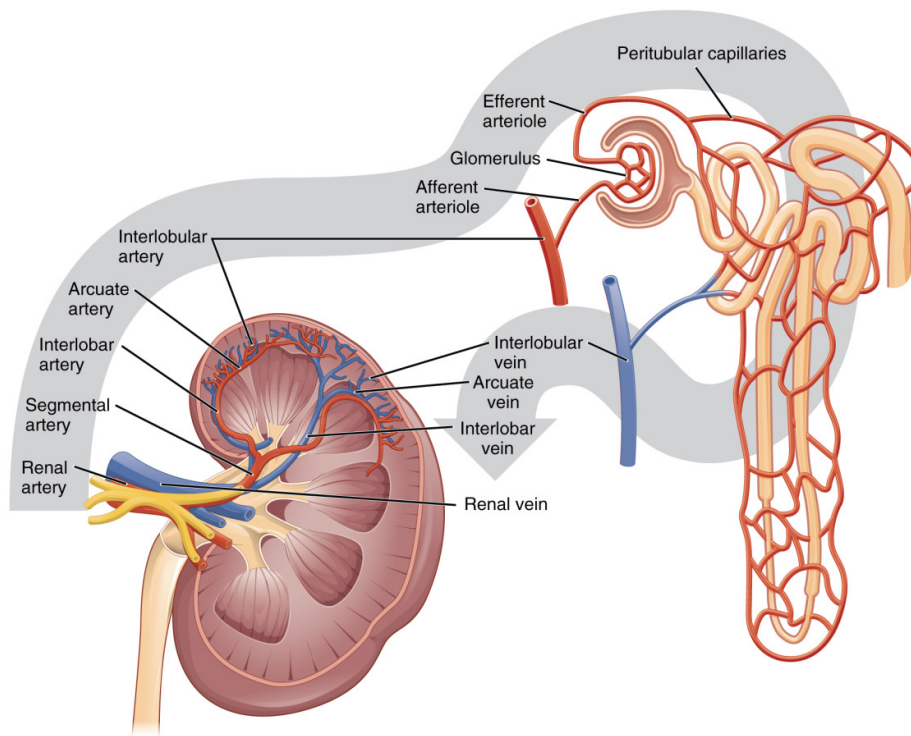


Figure 3. Blood Flow in the Kidney.

**Nephrons** are the “functional units” of the kidney; they cleanse the blood and balance the constituents of the circulation. The afferent arterioles form a tuft of high-pressure capillaries about 200  $\mu\text{m}$  in diameter, the **glomerulus**. The rest of the nephron consists of a continuous sophisticated tubule whose proximal end surrounds the glomerulus in an intimate embrace—this is **Bowman’s capsule**. The glomerulus and Bowman’s capsule together form the **renal corpuscle**. As mentioned earlier, these glomerular capillaries filter the blood based on particle size. After passing through the renal corpuscle, the capillaries form a second

arteriole, the **efferent arteriole** (Figure 4). These will next form a capillary network around the more distal portions of the nephron tubule, the **peritubular capillaries** and **vasa recta**, before returning to the venous system. As the glomerular filtrate progresses through the nephron, these capillary networks recover most of the solutes and water, and return them to the circulation. Since a capillary bed (the glomerulus) drains into a vessel that in turn forms a second capillary bed, the definition of a portal system is met. This is the only portal system in which an arteriole is found between the first and second capillary beds. (Portal systems also link the hypothalamus to the anterior pituitary, and the blood vessels of the digestive viscera to the liver.)

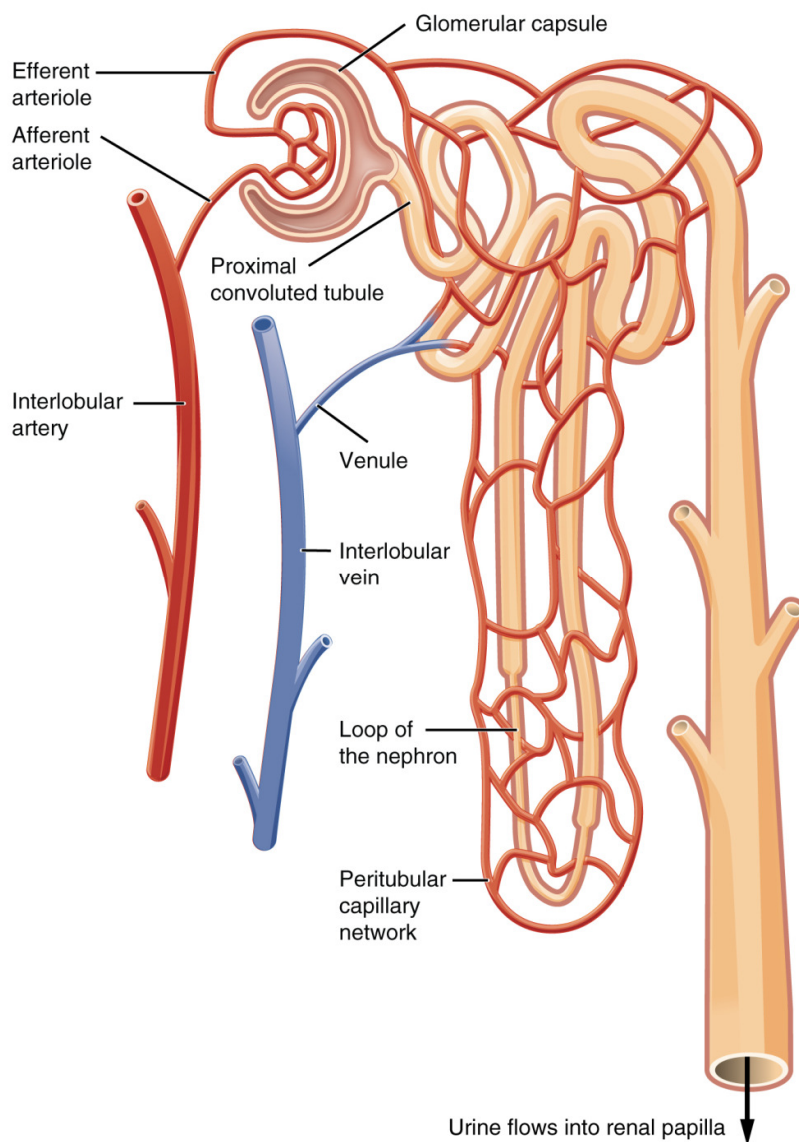


Figure 4. Blood Flow in the Nephron. The two capillary beds are clearly shown in this figure. The efferent arteriole is the connecting vessel between the glomerulus and the peritubular capillaries and vasa recta.

## **CORTEX**

In a dissected kidney, it is easy to identify the cortex; it appears lighter in color compared to the rest of the kidney. All of the renal corpuscles as well as both the **proximal convoluted tubules (PCTs)** and **distal convoluted tubules** are found here. Some nephrons have a short **loop of Henle** that does not dip beyond the cortex. These nephrons are called **cortical nephrons**. About 15 percent of nephrons have long loops of Henle that extend deep into the medulla and are called **juxtamedullary nephrons**.

## **CHAPTER REVIEW**

As noted previously, the structure of the kidney is divided into two principle regions—the peripheral rim of cortex and the central medulla. The two kidneys receive about 25 percent of cardiac output. They are protected in the retroperitoneal space by the renal fat pad and overlying ribs and muscle. Ureters, blood vessels, lymph vessels, and nerves enter and leave at the renal hilum. The renal arteries arise directly from the aorta, and the renal veins drain directly into the inferior vena cava. Kidney function is derived from the actions of about 1.3 million nephrons per kidney; these are the “functional units.” A capillary bed, the glomerulus, filters blood and the filtrate is captured by Bowman’s capsule. A portal system is formed when the blood flows through a second capillary bed surrounding the proximal and distal convoluted tubules and the loop of Henle. Most water and solutes are recovered by this second capillary bed. This filtrate is processed and finally gathered by collecting ducts that drain into the minor calyces, which merge to form major calyces; the filtrate then proceeds to the renal pelvis and finally the ureters.

### **Review Questions**

1. The renal pyramids are separated from each other by extensions of the renal cortex called \_\_\_\_\_.

- A. renal medulla
- B. minor calyces
- C. medullary cortices
- D. renal columns

2. The primary structure found within the medulla is the \_\_\_\_\_.

- A. loop of Henle
- B. minor calyces
- C. portal system
- D. ureter

3. The right kidney is slightly lower because \_\_\_\_\_.

- A. it is displaced by the liver
- B. it is displaced by the heart
- C. it is slightly smaller
- D. it needs protection of the lower ribs

### **Critical Thinking Questions**

1. What anatomical structures provide protection to the kidney?
2. How does the renal portal system differ from the hypothalamo–hypophyseal and digestive portal systems?
3. Name the structures found in the renal hilum.

### **GLOSSARY**

#### **Bowman's capsule**

cup-shaped sack lined by a simple squamous epithelium (parietal surface) and specialized cells called podocytes (visceral surface) that participate in the filtration process; receives the filtrate which then passes on to the PCTs

#### **calyces**

cup-like structures receiving urine from the collecting ducts where it passes on to the renal pelvis and ureter

**cortical nephrons**

nephrons with loops of Henle that do not extend into the renal medulla

**distal convoluted tubules**

portions of the nephron distal to the loop of Henle that receive hyposmotic filtrate from the loop of Henle and empty into collecting ducts

**efferent arteriole**

arteriole carrying blood from the glomerulus to the capillary beds around the convoluted tubules and loop of Henle; portion of the portal system

**glomerulus**

tuft of capillaries surrounded by Bowman's capsule; filters the blood based on size

**juxtamedullary nephrons**

nephrons adjacent to the border of the cortex and medulla with loops of Henle that extend into the renal medulla

**loop of Henle**

descending and ascending portions between the proximal and distal convoluted tubules; those of cortical nephrons do not extend into the medulla, whereas those of juxtamedullary nephrons do extend into the medulla

**nephrons**

functional units of the kidney that carry out all filtration and modification to produce urine; consist of renal corpuscles, proximal and distal convoluted tubules, and descending and ascending loops of Henle; drain into collecting ducts

**medulla**

inner region of kidney containing the renal pyramids

**peritubular capillaries**

second capillary bed of the renal portal system; surround the proximal and distal convoluted tubules; associated with the vasa recta

**proximal convoluted tubules (PCTs)**

tortuous tubules receiving filtrate from Bowman's capsule; most active part of the nephron in reabsorption and secretion

**renal columns**

extensions of the renal cortex into the renal medulla; separates the renal pyramids; contains blood vessels and connective tissues



**renal corpuscle**

consists of the glomerulus and Bowman's capsule

**renal cortex**

outer part of kidney containing all of the nephrons; some nephrons have loops of Henle extending into the medulla

**renal fat pad**

adipose tissue between the renal fascia and the renal capsule that provides protective cushioning to the kidney

**renal hilum**

recessed medial area of the kidney through which the renal artery, renal vein, ureters, lymphatics, and nerves pass

**renal papillae**

medullary area of the renal pyramids where collecting ducts empty urine into the minor calyces

**renal pyramids**

six to eight cone-shaped tissues in the medulla of the kidney containing collecting ducts and the loops of Henle of juxtamedullary nephrons

**vasa recta**

branches of the efferent arterioles that parallel the course of the loops of Henle and are continuous with the peritubular capillaries; with the glomerulus, form a portal system

**Solutions****Answers for Review Questions**

1. D
2. A
3. A

**Answers for Critical Thinking Questions**

1. Retroperitoneal anchoring, renal fat pads, and ribs provide protection to the kidney.
2. The renal portal system has an artery between the first and second capillary bed. The others have a vein.

3. The structures found in the renal hilum are arteries, veins, ureters, lymphatics, and nerves.