30.4 The Excretory System

Key Questions

- ***What is the principal role of the structures of the excretory system?***
- ***How do the kidneys clean the blood?***
- ***How do the kidneys help maintain homeostasis?***

Vocabulary

excretion
ureter
urinary bladder
urethra
nephron
filtration
glomerulus
Bowman's capsule
reabsorption
loop of Henle

Taking Notes

Preview Visuals Examine **Figure 30–19.** What does this Figure reveal about the important functions of the kidneys?

THINK ABOUT IT It's a hot day, and you've been getting thirsty for hours. Finally, you get the chance to go inside, and you gulp down more than a liter of water. The water tastes great, but as you drink, you begin to wonder. Where's all that water going? Will it just dilute your blood, or is something in your body making sure that everything stays in balance?

Structures of the Excretory System

What is the principal role of the structures of the excretory system?

The chemistry of the human body is a marvelous thing. An intricate system of checks and balances controls everything from your blood pressure to your body temperature. Nutrients are absorbed, stored, and carefully released when they are needed. However, every living system, including the human body, produces chemical waste products, some of which are so toxic that they will cause death if they are not eliminated.

For example, as a normal consequence of being alive, every cell in the body produces waste compounds, including excess salts and carbon dioxide. Ammonia, one of the most toxic of these waste compounds, is produced when the amino acids from proteins are used for energy. Ammonia is converted to a less toxic compound called urea, but it, too, must be eliminated from the body. The process by which these metabolic wastes are eliminated to maintain homeostasis is called **excretion.** Excretion is one part of the many processes that maintain homeostasis.

The excretory system, which includes the skin, lungs, liver, and kidneys, excretes metabolic wastes from the body. The ureters, urinary bladder, and urethra are also involved in excretion. **Figure 30–18** shows the major organs of excretion.

In Your Notebook *Make a two-column table that lists the organs of excretion in the first column and their function in the second column.*

The Skin The skin excretes excess water, salts, and a small amount of urea in sweat. By releasing sweat in very small amounts, this process eliminates wastes even when you may not think you're sweating.

The Lungs The blood transports carbon dioxide, a waste product of cellular respiration, from the body cells to the lungs. When you exhale, your lungs excrete carbon dioxide and small amounts of water vapor.

The Liver The liver plays many important roles in excretion. As we have seen, one of its principal activities is the conversion of potentially dangerous nitrogen wastes, a product of protein breakdown, into less toxic urea. Urea, which is highly soluble, is then transported through the blood to the kidneys for elimination from the body.

The Kidneys The major organs of excretion are the kidneys, a pair of fist-sized organs located on either side of the spinal column near the lower back. Through a complex filtering process, the kidneys remove excess water, urea, and metabolic wastes from the blood. The kidneys produce and excrete a waste product known as urine. **Ureters** transport urine from the kidneys to the **urinary bladder,** where the urine is stored until it is released through the **urethra.**

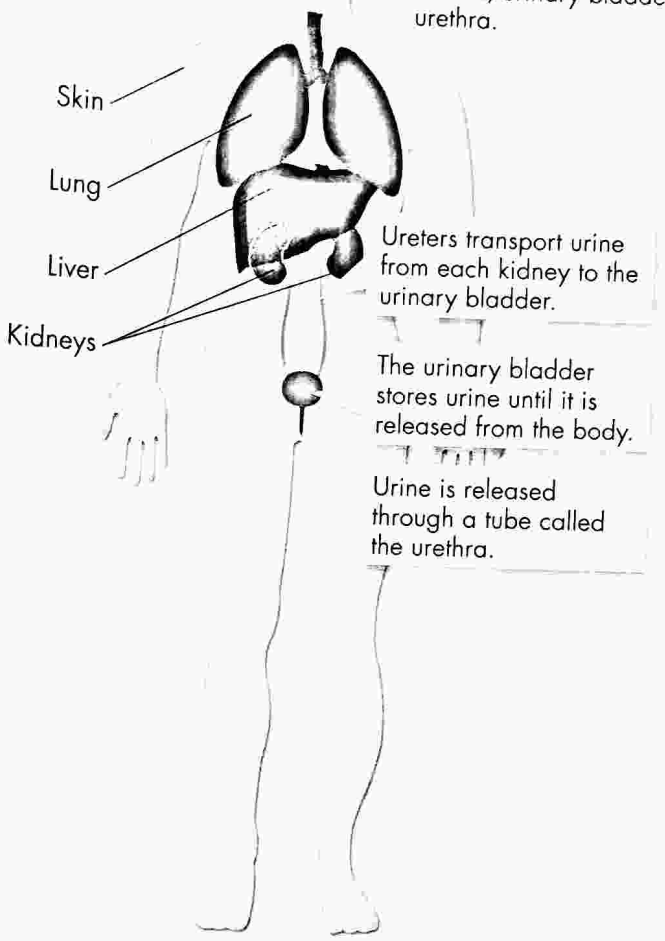


FIGURE 30–18 The Excretory System The organs of the excretory system include the skin, lungs, liver, kidneys, ureters, urinary bladder, and urethra.

Analyzing Data

The Composition of Urine

The kidneys are selective filters. As blood passes through them, urea, other impurities, and excess salts are removed from the blood. But important substances such as water, protein, and glucose remain in circulation. The collected waste products are excreted in urine. The concentrations of certain substances in the blood compared to their concentration in urine reveal the important work of the kidneys.

Concentrations of Selected Substances in Blood and Urine

Substance	Average Concentration in Blood (g/mL)	Average Concentration in Urine (g/mL)
Calcium	0.01	0.02
Glucose	0.10	0.00
Potassium	0.02	0.20
Sodium	0.32	0.60
Urea	0.03	2.00

1. Interpret Data Which substances listed have the highest and lowest concentrations in the blood? Which substances have the highest and lowest concentrations in the urine?

2. Calculate Approximately how many times more concentrated is urea in urine than in the blood? MATH

3. Infer Recall that urea is a byproduct of amino acid breakdown. How might the urea concentration vary in the blood and urine as the result of high protein diets? Explain.

Excretion and the Kidneys

How do the kidneys clean the blood?

What does a kidney do? **As waste-laden blood enters the kidney through the renal artery, the kidney removes urea, excess water and minerals, and other waste products.** The clean, filtered blood leaves the kidney through the renal vein and returns to circulation.

Each kidney contains nearly a million individual processing units called **nephrons.** These nephrons are where most of the work of the kidney takes place—impurities are filtered out, wastes are collected, and purified blood is returned to circulation. Blood purification in the kidneys is complex and involves two distinct processes: filtration and reabsorption.

BUILD Vocabulary

WORD ORIGINS The word **glomerulus** derives from the Latin words *glomus,* which means "ball of yarn," and *glomerare,* which means "to form into a ball." The twisted capillaries of a glomerulus resemble a ball of yarn.

Filtration Passing a liquid or gas through a filter to remove wastes is called **filtration.** The filtration of blood mainly takes place in the **glomerulus** (gloh MUR yoo lus). A glomerulus is a small but dense network of capillaries (very small blood vessels) encased in the upper end of each nephron by a hollow, cup-shaped structure called **Bowman's capsule.** A glomerulus is shown in **Figure 30–19.**

Because the blood is under pressure and the walls of the capillaries and Bowman's capsule are permeable, much of the fluid from the capillaries flows into Bowman's capsule. The material that is filtered from the blood is called the filtrate. The filtrate contains water, urea, glucose, salts, amino acids, and some vitamins. Large substances in the blood, such as proteins and blood cells, are too large to pass through the capillary walls.

Reabsorption Nearly 180 liters of filtrate pass from the blood into nephron tubules every day. That's the equivalent of 90 2-liter bottles of soft drink. Thank goodness, not all of those 180 liters are excreted. In fact, nearly all of the material that moves into Bowman's capsule makes its way back into the blood. The process by which water and dissolved substances are taken back into the blood is called **reabsorption.**

A number of materials, including salts, vitamins, amino acids, fats, and glucose, are removed from the filtrate by active transport and reabsorbed by the capillaries. Because water follows these materials by osmosis, almost 99 percent of the water that enters Bowman's capsule is actually reabsorbed into the blood. In effect, the kidney first throws away nearly everything and then takes back only what the body needs. This is how the kidney is able to remove drugs and toxic compounds from the blood—even chemicals the body has never seen before.

A section of the nephron tubule called the **loop of Henle** is responsible for conserving water and minimizing the volume of the filtrate. The waste material—now called urine—that remains in the tubule is emptied into a collecting duct.

Urine Excretion From the collecting ducts, urine flows to the ureter of each kidney. The ureters carry urine to the urinary bladder for storage until the urine leaves the body through the urethra.

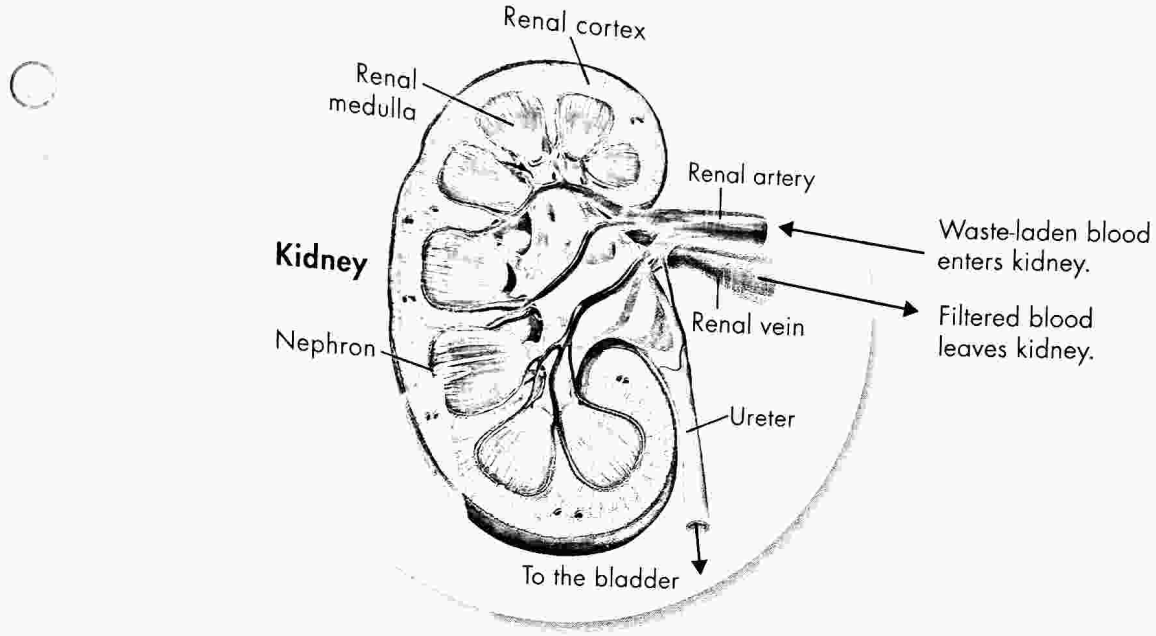
MYSTERY CLUE

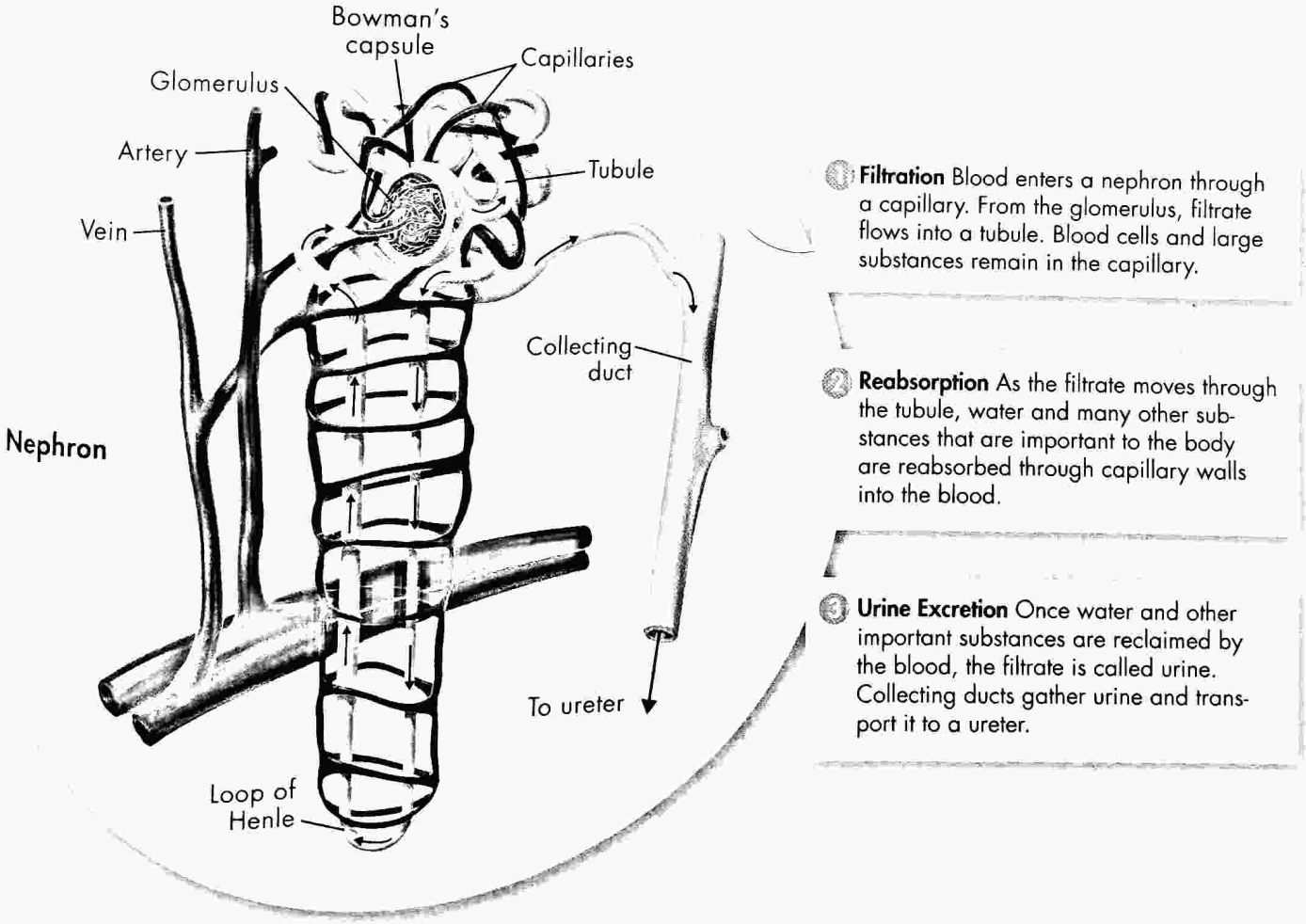
The illegal drug taken by one of the athletes contained a synthetic compound never found in nature. How did his body remove the compound from his blood and eliminate it in urine?

ZOOMING IN

STRUCTURE AND FUNCTION OF THE KIDNEYS

FIGURE 30–19 Kidneys are made up of nephrons. Blood enters the nephron, where impurities are filtered out and emptied into the collecting duct. Purified blood leaves a nephron through a vein. **Interpret Visuals** *List in order the structures that blood flows through in a kidney.*





1. **Filtration** Blood enters a nephron through a capillary. From the glomerulus, filtrate flows into a tubule. Blood cells and large substances remain in the capillary.

2. **Reabsorption** As the filtrate moves through the tubule, water and many other substances that are important to the body are reabsorbed through capillary walls into the blood.

3. **Urine Excretion** Once water and other important substances are reclaimed by the blood, the filtrate is called urine. Collecting ducts gather urine and transport it to a ureter.

The Kidneys and Homeostasis

How do the kidneys help maintain homeostasis?

The kidneys play an important role in maintaining homeostasis. Besides removing wastes, the kidneys also maintain blood pH and regulate the water content of the blood. **The kidneys respond directly to the composition of the blood. They are also influenced by the endocrine system. Disruption of proper kidney function can lead to serious health problems.**

Control of Kidney Function To a large extent, the activity of the kidneys is controlled by the composition of the blood itself. For example, if you eat salty food, the kidneys will respond to the excess salt in your blood by returning less salt to your blood during reabsorption. If the blood is too acidic, then the kidneys excrete more hydrogen ions in the urine. If your blood glucose levels rise past a certain point, the kidneys will even excrete glucose into the urine. This is one of the danger signals of diabetes, a disease caused by the body's inability to control the concentration of glucose in the blood.

Glands release hormones that also influence kidney function. For example, if you have not consumed enough fluids or if you have sweat excessively, your pituitary gland releases antidiuretic hormone (ADH) into your blood. This hormone causes the kidneys to reabsorb more water and to excrete less water in the urine. If the blood contains excess water, ADH secretion stops and more water is excreted.

Did you know that the color of your urine is an indicator of how hydrated you are? A pale yellow color indicates that you are well hydrated because your kidneys are releasing a good amount of water. A darker color indicates that the water level in your blood is low, causing your kidneys to conserve water.

MYSTERY CLUE

Would Seth's and Philip's blood contain a high level or low level of ADH?

Urine Testing Medical professionals can learn a lot about a person's health from a simple urine sample. The presence of protein or glucose in urine can be indicators of diseases such as dangerously high blood pressure or diabetes. Although many filtered substances are reabsorbed into the blood, drugs generally remain in the filtrate and are eliminated in urine. This is why the effects of many drugs wear off over time and why urine tests are often used to detect the use of illegal drugs.

In Your Notebook *Explain in your own words why urine can reveal a lot about a person's health.*

Kidney Disorders The kidneys are the master chemists of the blood supply. If anything goes wrong with the kidneys, serious medical problems will likely follow. Three of these problems are kidney stones, kidney damage, and kidney failure.

▶ ***Kidney Stones*** Sometimes substances such as calcium, magnesium, or uric acid salts in the urine crystallize and form kidney stones. When kidney stones block a ureter, they cause great pain. Kidney stones are often treated using ultrasound waves. The sound waves pulverize the stones into smaller fragments, which are eliminated with the urine.

▸ ***Kidney Damage*** Many diseases, injuries, and exposure to hazardous substances can lead to impaired kidney function. But most cases of kidney damage in the United States are related to high blood pressure and diabetes. Excessive blood pressure damages the delicate filtering mechanism, and high blood sugar levels cause the kidneys to filter more blood than normal. Over time, the tubules weaken, and the kidneys may fail to keep up with the demands placed upon them.

▸ ***Kidney Failure*** When kidneys can no longer cleanse the blood and maintain a state of homeostasis in the body, a person is said to be in kidney failure. A patient with kidney failure must receive dialysis or undergo a kidney transplant as shown in **Figure 30–20.**

During dialysis, a machine performs the role of the kidneys. The patient's blood is pumped through the machine, cleansed, and pumped back into the body. Although the procedure is painless, it is very time-consuming. Most patients receive dialysis treatments three times a week for about four hours each time. To prevent the buildup of fluid and harmful materials between treatments, patients must restrict their fluid intake and eat foods low in potassium, phosphorus, and salt.

In transplantation, a patient receives a kidney and ureter from a compatible donor. Fortunately for the donor, a person can survive with just one healthy kidney.

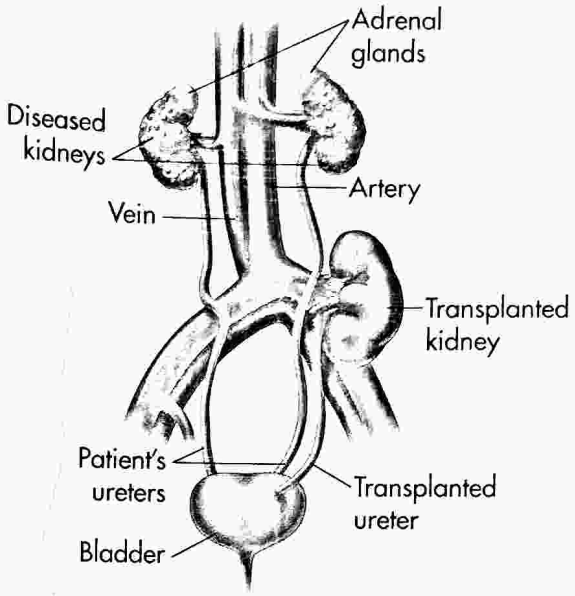


FIGURE 30–20 Kidney Transplantation Unless the patient's diseased kidneys are causing infection or high blood pressure, they are left in place when a healthy kidney and ureter are transplanted from a donor.

30.4 Assessment

Review Key Concepts

1. a. Review List the organs that are involved in excretion.

b. Classify Why is excretion important for homeostasis?

2. a. Review What substances do the kidneys remove from blood?

b. Sequence Explain what happens during filtration, reabsorption, and urine excretion.

3. a. Review Describe how the kidneys help maintain water balance.

b. Apply Concepts Why do you think protein and glucose in the urine are signs of kidney damage?

BUILD VOCABULARY

4. Two words that are often used interchangeably are *excretion* and *secretion*. They have two distinct meanings, however. An excretion is usually a waste product of metabolism that is expelled from an organism. A secretion is a useful substance that is released inside or outside an organism. Name one example each of an excretion and a secretion from this lesson.