Metabolism of nutrients by body cells produces various wastes such as carbon dioxide and nitrogenous wastes (creatine, urea, and ammonia), as well as imbalances of water and essential ions. The metabolic wastes and excesses must be eliminated from the body. Essential substances are retained to ensure internal homeostasis and proper body functioning. Although several organ systems are involved in excretory processes, the urinary system bears the primary responsibility for removing nitrogenous wastes from the blood. In addition to this purely excretory function, the kidneys maintain the electrolyte, acid-base, and fluid balances of the blood. Thus, kidneys are major homeostatic organs of the body. Malfunction of the kidneys leads to a failure of homeostasis, resulting (unless corrected) in death.

Student activities in this chapter are concerned with identification of urinary system structures, and with examining urine composition and physiological processes involved in urine formation.

1. Complete the following statements by inserting your answers in the answer blanks.

   The kidney is referred to as an excretory organ because it excretes _1_ wastes. It is also a major homeostatic organ because it maintains the electrolyte, _2_, and _3_ balance of the blood. Urine is continuously formed by the _4_ and is routed down the _5_ by the mechanism of _6_ to a storage organ called the _7_. Eventually the urine is conducted to the body exterior by the _8_. In males, this tube-like structure is about _9_ inches long; in females, it is approximately _10_ inches long.
KIDNEYS

Location and Structure

2. Figure 15–1 is an anterior view of the entire urinary system. Identify and select different colors for the following organs. Use them to color the coding circles and the corresponding organs on the figure.

- **Kidney**
- **Bladder**
- **Ureters**
- **Urethra**

![Figure 15–1](image-url)
3. Figure 15–2 is a longitudinal section of a kidney. First, using the correct anatomical terminology, label the following regions/structures indicated by leader lines on the figure.

- Fibrous membrane, surrounding the kidney
- Basinlike area of the kidney that is continuous with the ureter
- Cuplike extension of the pelvis that drains the apex of a pyramid
- Area of cortical tissue running through the medulla

Then, excluding the color red, select different colors to identify the following areas and structures. Then color in the coding circles and the corresponding area/structures on the figure; label these regions using the correct anatomical terms.

- Area of the kidney that contains the greatest proportion of nephron structures
- Striped-appearing structures formed primarily of collecting ducts

Finally, beginning with the renal artery, draw in the vascular supply to the cortex on the figure. Include and label the interlobar artery, arcuate artery, and interlobular artery. Color the vessels bright red.
4. Circle the term that does not belong in each of the following groupings.

1. Intraperitoneal  Kidney  Retroperitoneal  Superior lumbar region
2. Drains kidney  Ureter  Urethra  Renal pelvis
3. Peritubular capillaries  Reabsorption  Glomerulus  Low-pressure vessels
4. Juxtaglomerular apparatus  Distal tubule  Glomerulus  Afferent arteriole
5. Glomerulus  Peritubular capillaries  Blood vessels  Collecting duct
6. Cortical nephrons  Juxtamedullary nephrons  Cortex/medulla junction  Long loops of Henle

7. Nephron  Proximal convoluted tubule  Distal convoluted tubule  Collecting duct
8. Medullary pyramids  Glomeruli  Renal pyramids  Collecting ducts

Nephrons, Urine Formation, and Control of Blood Composition

5. Figure 15–3 is a diagram of the nephron and associated blood supply. First, match each of the numbered structures on the figure to one of the terms below the figure. Place the terms in the numbered spaces provided below. Then color the structure on the figure that contains podocytes green; the filtering apparatus red; the capillary bed that directly receives the reabsorbed substances from the tubule cells blue; the structure into which the nephron empties its urine product yellow; and the tubule area that is the primary site of tubular reabsorption orange.

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Glomerular capsule  1.  Interlobar vein  9.
Afferent arteriole  2.  Loop of Henle  10.
Efferent arteriole  3.  Collecting duct  11.
Interlobular artery  4.  Distal convoluted tubule  12.
Interlobular artery  8.
Figure 15-3

1. Glomerular capsule
2. Afferent arteriole
3. Efferent arteriole
4. Interlobular artery
5. Interlobular vein
6. Arcuate artery
7. Arcuate vein
8. Interlobar artery
9. Interlobar vein
10. Loop of Henle
11. Collecting duct
12. Distal convoluted tubule
13. Proximal convoluted tubule
14. Peritubular capillaries
15. Glomerulus
7. Complete the following statements by inserting your answers in the answer blanks.

1. The glomerulus is a unique high-pressure capillary bed, because the \( (1) \) arteriole feeding it is larger in diameter than the \( (2) \) arteriole draining the bed. Glomerular filtrate is very similar to \( (3) \), but it has fewer proteins. Mechanisms of tubular reabsorption include \( (4) \) and \( (5) \). As an aid for the reabsorption process, the cells of the proximal convoluted tubule have dense \( (6) \) on their luminal surface, which increase the surface area dramatically. Other than reabsorption, an important tubule function is \( (7) \), which is important for ridding the body of substances not already in the filtrate. Blood composition depends on \( (8) \), \( (9) \), and \( (10) \). In a day’s time, 180 liters of blood plasma are filtered into the kidney tubules, but only about \( (11) \) liters of urine are actually produced. \( (12) \) is responsible for the normal yellow color of urine. The three major nitrogenous wastes found in the blood, which must be disposed of, are \( (13) \), \( (14) \), and \( (15) \). The kidneys are the final “judges” of how much water is to be lost from the body. When water loss via vaporization from the \( (16) \) or \( (17) \) from the skin is excessive, urine output \( (18) \). If the kidneys become nonfunctional, \( (19) \) is used to cleanse the blood of impurities.

8. Circle the term that does not belong in each of the following groupings.

(BP = Blood pressure.)

1. Hypothalamus  ADH  Aldosterone  Osmoreceptors
2. Glomerulus  Secretion  Filtration  \( \uparrow \) BP
3. Aldosterone  \( \uparrow \) Na\(^+\) reabsorption  \( \uparrow \) K\(^+\) reabsorption  \( \uparrow \) BP
4. ADH  \( \downarrow \) BP  \( \uparrow \) Blood volume  \( \uparrow \) Water reabsorption
5. \( \downarrow \) Aldosterone  Edema  \( \downarrow \) Blood volume  \( \downarrow \) K\(^+\) retention
6. \( \downarrow \) Urine pH  \( \uparrow \) H\(^+\) in urine  \( \uparrow \) HCO\(_3\)\(^-\) in urine  \( \uparrow \) Ketones
9. Decide whether the following conditions would cause urine to become more acidic or more basic. If more acidic, insert an A in the blank; if more basic, insert a B in the blank.

   A  1. Protein-rich diet        A  4. Diabetes mellitus
   B  2. Bacterial infection     B  5. Vegetarian diet
   A  3. Starvation

10. Decide whether the following conditions would result in an increase or decrease in urine specific gravity. Insert I in the answer blank to indicate an increase and D to indicate a decrease.

   D  1. Drinking excessive fluids        D  4. Using diuretics
   D  2. Chronic renal failure            I  5. Limited fluid intake
   I  3. Pyelonephritis                   I  6. Fever

11. Assuming normal conditions, note whether each of the following substances would be (G) in greater concentration in the urine than in the glomerular filtrate, (L) in lesser concentration in the urine than in the glomerular filtrate, or (A) absent in both urine and glomerular filtrate. Place the correct letter in the answer blanks.


12. Several specific terms are used to indicate the presence of abnormal urine constituents. Identify each of the following abnormalities by inserting the term that names the condition in the spaces provided. Then for each condition, provide one possible cause of the condition in the remaining spaces.

5. Presence of bile: bilirubinuria. Cause: liver disease
6. Presence of "sand": no official term. Cause: kidney stones
13. Glucose and albumin are both normally absent from urine, but the reason for their exclusion differs. Respond to the following questions in the spaces provided.

1. Explain the reason for the absence of glucose in urine. **All glucose is normally reabsorbed by tubule cells.**

2. Explain the reason for the absence of albumin in urine. **Normally, albumin is too large to pass through glomelular fenestrations.**

15. By what three methods is H⁺ concentration in body fluids regulated? Also give the approximate time for each method to respond to pH changes.

1. 

2. 

3. 

16. Circle the term that does not belong in each of the following groupings. (ECF = Extracellular fluid compartment)

1. Female adult  Male adult  About 50% water  Less muscle
2. Obese adult  Lean adult  Less body water  More adipose tissue
3. ECF  Interstitial fluid  Intracellular fluid  Plasma
4. Electric charge  Nonelectrolyte  Ions  Conducts a current
5. ↑ Water output  ↓ Na⁺ concentration  ↑ ADH  ↓ ADH
6. Aldosterone  ↑ Na⁺ reabsorption  ↑ K⁺ reabsorption  ↑ BP

**URETERS, URINARY BLADDER, AND URETHRA**

16. Circle the term that does not belong in each of the following groupings.

1. Bladder  Kidney  Transitional epithelium  Detrusor muscle
2. Trigone  Ureter openings  Urethral opening  Bladder  Forms urine
3. Surrounded by prostate gland  Contains internal and external sphincters
   **Continuous with renal pelvis**  Urethra
17. Using the key choices, identify the structures that best fit the following descriptions. Insert the correct term(s) or corresponding letter(s) in the answer blanks.

**Key Choices**

A. Bladder  
B. Urethra  
C. Ureter

1. Drains the bladder  
**B. Urethra**  

2. Storage area for urine  
**A. Bladder**  

3. Contains the trigone  
**A. Bladder**  

4. In males has prostatic, membranous, and spongy parts  
**B. Urethra**  

5. Conducts urine by peristalsis  
**C. Ureter**  

6. Substantially longer in males than in females  
**B. Urethra**  

7. A common site of "trapped" renal calculi  
**C. Ureter**  

8. Contains transitional epithelium  
**A. Bladder**  

9. Also transports sperm in males  
**B. Urethra**

18. Complete the following statements by inserting your answers in the answer blanks.

**micturition**  
1. Another term that means voiding or emptying of the bladder is **(1)**. Voiding has both voluntary and involuntary aspects. As urine accumulates in the bladder, **(2)** are activated. This results in a reflex that causes the muscular wall of the bladder to **(3)**, and urine is forced past the **(4)** sphincter. The more distal **(5)** sphincter is controlled **(6)**; thus an individual can temporarily postpone emptying the bladder until it has accumulated **(7)** ml of urine. **(8)** is a condition in which voiding cannot be voluntarily controlled. It is normal in **(9)**, because nervous control of the voluntary sphincter has not been achieved. Other conditions that might result in an inability to control the sphincter include **(10)** and **(11)**. **(12)** is essentially the opposite of incontinence and often is a problem in elderly men due to **(13)** enlargement.
A Visualization Exercise for the Urinary System

You see the kidney looming brownish red through the artery wall.

21. Where necessary, complete statements by inserting the missing word(s) in the answer blanks.

1. capsule
2. renal
3. afferent
4. glomerulus
5. glomerular capsule
6. blood plasma
7. proteins
8. loop of Henle
9. microvilli
10. reabsorption

For your journey through the urinary system, you must be made small enough to filter through the filtration membrane from the bloodstream into a renal (1). You will be injected into the subclavian vein and must pass through the heart before entering the arterial circulation. As you travel through the systemic circulation, you have at least two minutes to relax before reaching the (2) artery, feeding a kidney. You see the kidney looming brownish red through the artery wall.

Once you have entered the kidney, the blood vessel conduits become increasingly smaller until you finally reach the (3) arteriole, feeding into the filtering device, or (4). Once in the filter, you maneuver yourself so that you are directly in front of a pore. Within a fraction of a second, you are swept across the filtration membrane into the (5) part of the nephron. Drifting along, you lower the specimen cup to gather your first filtrate sample for testing. You study the readout from the sample and note that it is very similar in composition to (6) with one exception: There are essentially no (7). Your next sample doesn’t have to be collected until you reach the “hairpin,” or, using the proper terminology, the (8) part of the tubule. As you continue your journey, you notice that the tubule cells have dense fingerlike projections extending from their surfaces into the lumen of the tubule. These are (9), which increase the surface area of tubules because this portion of the tubule is very active in the process of (10). Soon you collect your second sample, and then later, in the distal convoluted tubule, your third sample. When you read the computer’s summary of the third sample, you make the following notes in your register.
glucose 11.  • Virtually no nutrients such as (11) and (12) are left in the filtrate.

amino acids 12.  • The pH is acid, 6.0. This is quite a change from the pH of (13) recorded for the newly formed filtrate.

\( \sim 7.4 \) 13.  • There is a much higher concentration of (14) wastes here.

nitrogenous 14.  • There are many fewer (15) ions but more of the (16) ions noted.

sodium 15.  • Color of the filtrate is yellow, indicating a high relative concentration of the pigment (17).

potassium 16.  Gradually you become aware that you are moving along much more quickly. You see that the water level has dropped dramatically and that the stream is turbulent and rushing. As you notice this, you realize that the hormone (18) must have been released recently to cause this water drop. You take an abrupt right turn and then drop straight downward. You realize that you must be in a (19). Within a few seconds, you are in what appears to be a large tranquil sea with an ebbing tide toward a darkened area at the far shore. You drift toward the darkened area, confident that you are in the kidney (20). As you reach and enter the dark tubelike structure seen from the opposite shore, your progress becomes rhythmic—something like being squeezed through a sausage skin. Then you realize that your progress is being regulated by the process of (21). Suddenly, you free-fall and land in the previously stored (22) in the bladder, where the air is very close. Soon the walls of the bladder begin to gyrate, and you realize you are witnessing a (23) reflex. In a moment, you are propelled out of the bladder and through the (24) to exit from your host.

22. A man was admitted to the hospital after being trampled by his horse. He received crushing blows to his lower back, on both sides. He is in considerable pain, and his chart shows a urine output of 70 ml in the last 24 hours. What is this specific symptom called? What will be required if the renal effects of his trauma persist?