CHAPTER

15 The Urinary System

Metabolism of nutrients by body cells produces various wastes such as carbon dioxide and nitrogenous wastes (creatinine, 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.

_____ 1.
_____ 2.
_____ 3.
_____ 4.
_____ 5.
_____ 6.
_____ 7.
_____ 8.
_____ 9.
_____ 10.

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

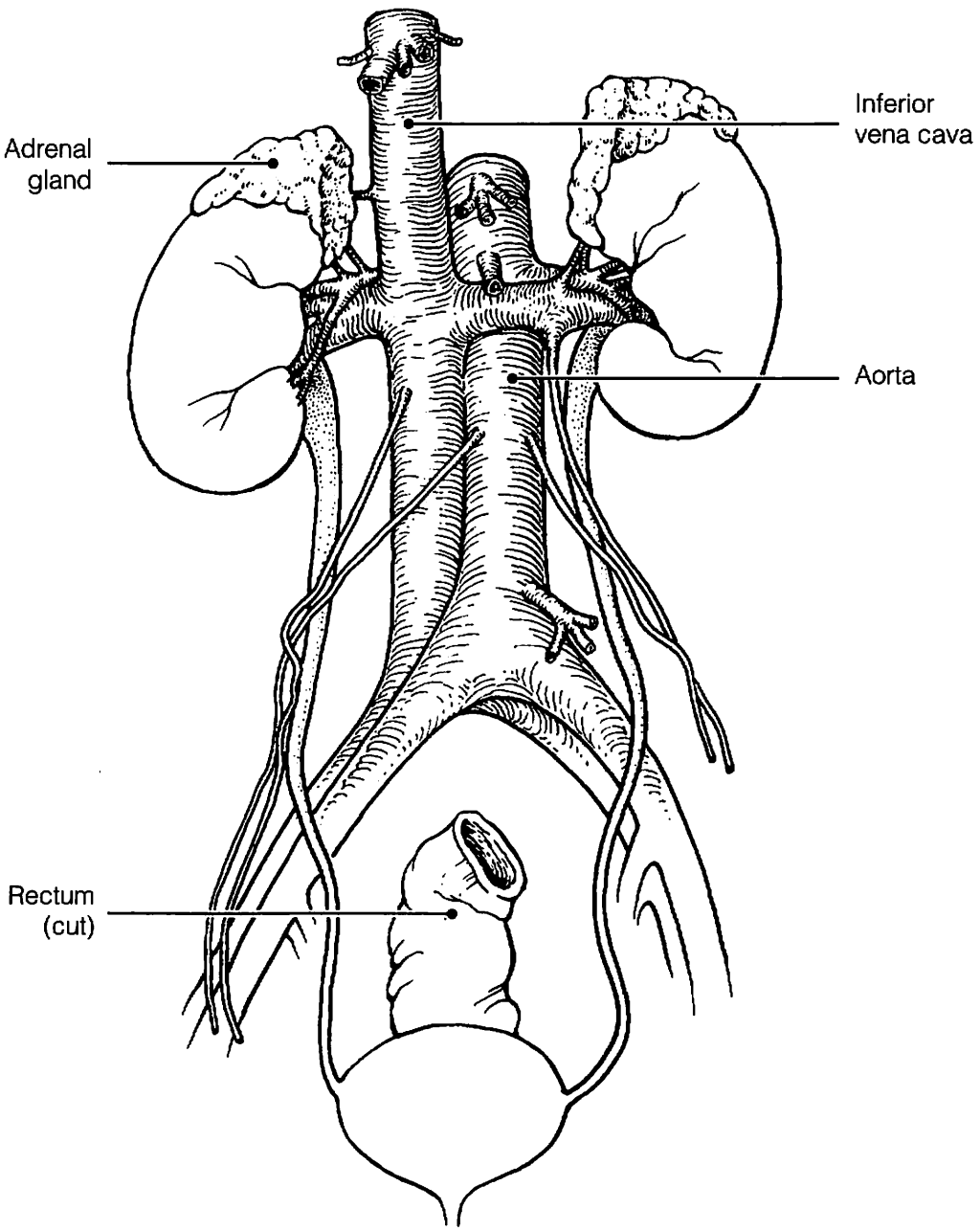

Figure 15–1

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.

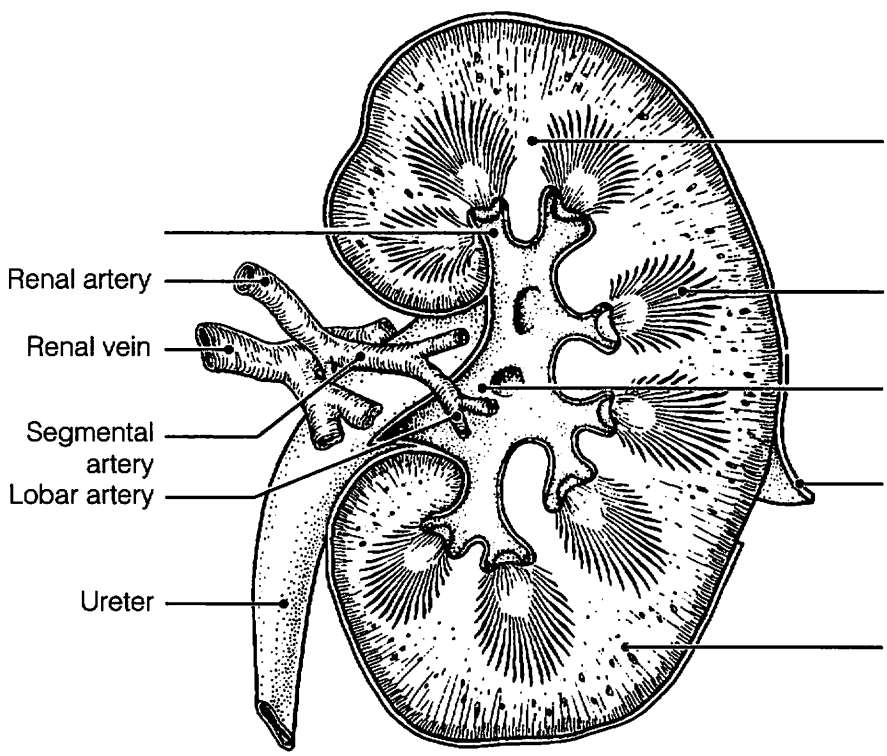

Figure 15–2

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.

_____ 1.
_____ 2.
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_____ 8.
_____ 9.
_____ 10.
_____ 11.
_____ 12.
_____ 13.
_____ 14.
_____ 15.

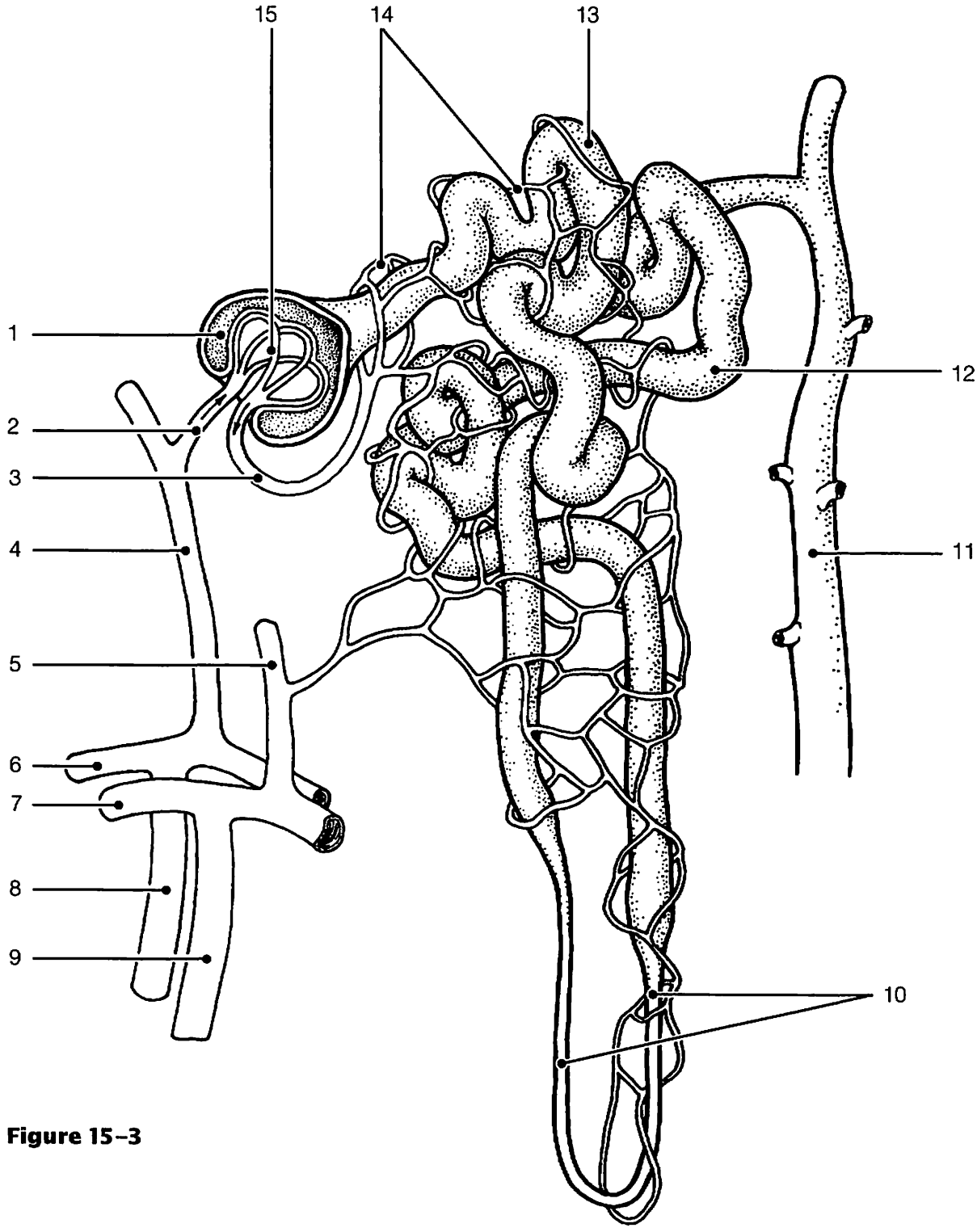


Figure 15–3

Afferent arteriole	Distal convoluted tubule	Interlobular artery
Arcuate artery	Efferent arteriole	Interlobular vein
Arcuate vein	Glomerulus	Loop of Henle
Glomerular capsule	Interlobar artery	Proximal convoluted tubule
Collecting duct	Interlobar vein	Peritubular capillaries

6. Figure 15–4 is a diagram of a nephron. Add colored arrows on the figure as instructed to show the location and direction of the following processes. Add **black arrows** at the site of filtrate formation; **red arrows** at the major site of amino acid and glucose reabsorption; **green arrows** at the sites most responsive to action of ADH (show direction of water movement); **yellow arrows** at the sites most responsive to the action of aldosterone (show direction of Na^+ movement); and **blue arrows** at the site of tubular secretion.

   Then, label the proximal convoluted tubule (PCT), distal convoluted tubule (DCT), loop of Henle, glomerular capsule, and glomerulus on the figure. Also label the collecting duct (not part of the nephron) on the figure.

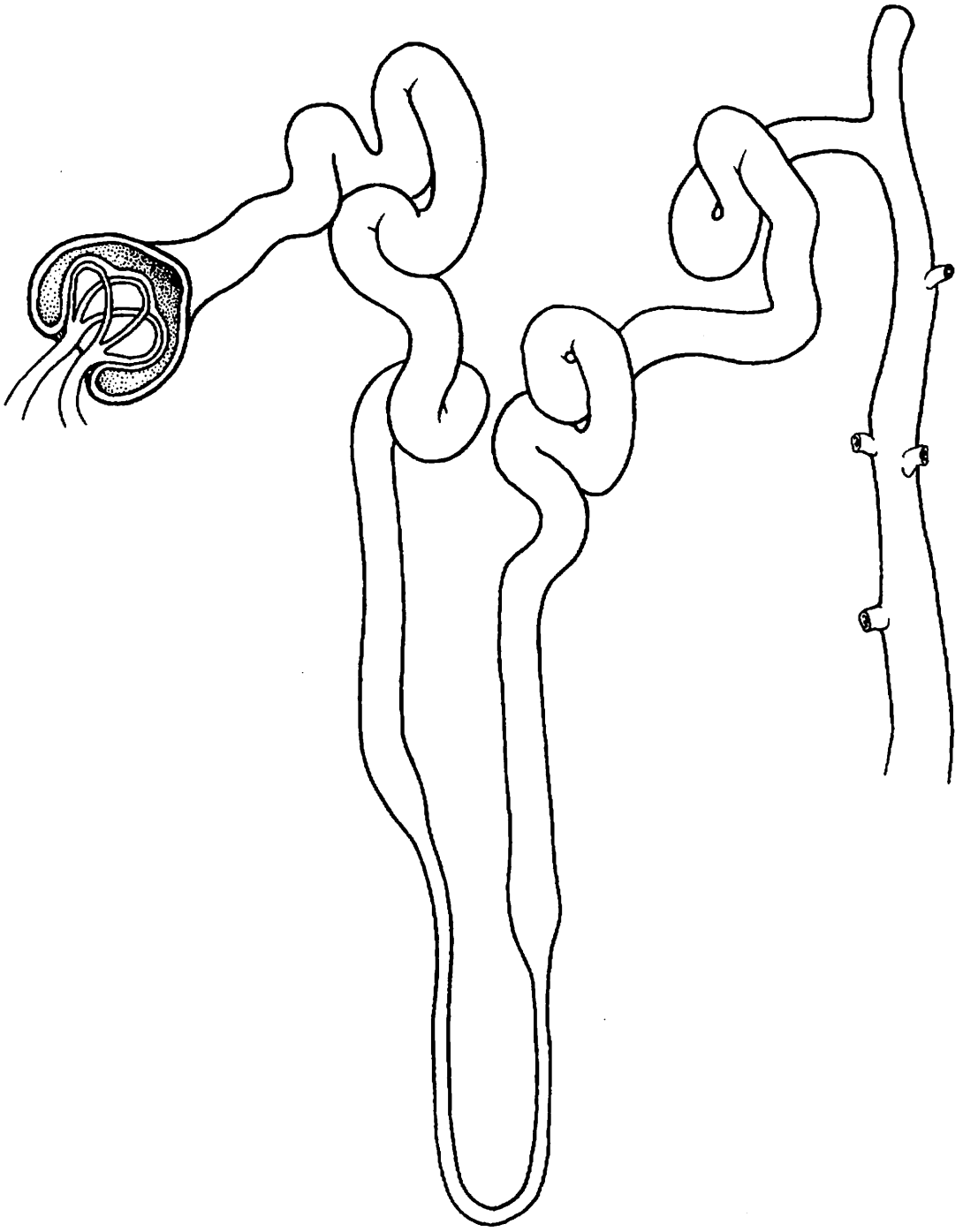


Figure 15–4

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

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.

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____
9. _____
10. _____
11. _____
12. _____
13. _____
14. _____
15. _____
16. _____
17. _____
18. _____
19. _____

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 ↑ BP
3. Aldosterone ↑ Na^+ reabsorption ↑ K^+ reabsorption ↑ BP
4. ADH ↓ BP ↑ Blood volume ↑ Water reabsorption
5. ↓ Aldosterone Edema ↓ Blood volume ↓ K^+ retention
6. ↓ Urine pH ↑ H^+ in urine ↑ HCO_3^- in urine ↑ 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.

_____ 1. Protein-rich diet

_____ 2. Bacterial infection

_____ 3. Starvation

_____ 4. Diabetes mellitus

_____ 5. Vegetarian diet

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.

_____ 1. Drinking excessive fluids

_____ 2. Chronic renal failure

_____ 3. Pyelonephritis

_____ 4. Using diuretics

_____ 5. Limited fluid intake

_____ 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.

_____ 1. Water

_____ 2. Urea

_____ 3. Uric acid

_____ 4. Pus (white blood cells)

_____ 5. Glucose

_____ 6. Albumin

_____ 7. Creatinine

_____ 8. Hydrogen ions

_____ 9. Potassium ions

_____ 10. Red blood cells

_____ 11. Sodium ions

_____ 12. Amino acids

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.

1. Presence of red blood cells: _____. Cause: _____.
2. Presence of ketones: _____. Cause: _____.
3. Presence of albumin: _____. Cause: _____.
4. Presence of pus: _____. Cause: _____.
5. Presence of bile: _____. Cause: _____.
6. Presence of "sand": _____. Cause: _____.
7. Presence of glucose: _____. Cause: _____.

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. _____

_____

2. Explain the reason for the absence of albumin in urine. _____

_____

14. 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. _____

15. 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

_____ 2. Storage area for urine

_____ 3. Contains the trigone

_____ 4. In males has prostatic, membranous, and spongy parts

_____ 5. Conducts urine by peristalsis

_____ 6. Substantially longer in males than in females

_____ 7. A common site of "trapped" renal calculi

_____ 8. Contains transitional epithelium

_____ 9. Also transports sperm in males

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

_____ 1.
_____ 2.
_____ 3.
_____ 4.
_____ 5.
_____ 6.
_____ 7.
_____ 8.
_____ 9.
_____ 10.
_____ 11.
_____ 12.

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.

_____ 13.

19. Match the terms in Column B with the appropriate descriptions provided in Column A. Insert the correct term or letter in the answer blanks.

	Column A	**Column B**
_____	1. Inflammatory condition common in women with poor toileting habits	A. Cystitis
_____	2. Backup of urine into the kidney; often a result of a blockage in the urinary tract	B. Diabetes insipidus
_____	3. Toxic condition due to renal failure	C. Hydronephrosis
_____	4. Inflammation of a kidney	D. Ptosis
_____	5. A condition in which excessive amounts of urine are produced because of a deficiency of antidiuretic hormone (ADH)	E. Pyelonephritis
_____	6. Dropping of the kidney to a more inferior position in the abdomen; may result from a rapid weight loss that decreases the fatty cushion surrounding the kidney	F. Uremia

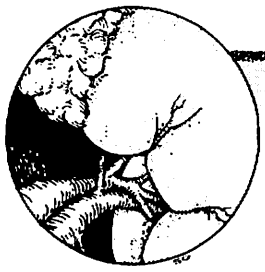
DEVELOPMENTAL ASPECTS OF THE URINARY SYSTEM

20. Complete the following statements by inserting your responses in the answer blanks.

_____ 1.
_____ 2.
_____ 3.
_____ 4.
_____ 5.
_____ 6.
_____ 7.
_____ 8.
_____ 9.
_____ 10.
_____ 11.
_____ 12.

Three separate sets of renal tubules develop in the embryo; however, embryonic nitrogenous wastes are actually disposed of by the __(1)__. A congenital condition typified by blisterlike sacs in the kidneys is __(2)__. __(3)__ is a congenital condition seen in __(4)__, when the urethral opening is located ventrally on the penis. A newborn baby voids frequently, which reflects its small __(5)__. Daytime control of the voluntary urethral sphincter is usually achieved by approximately __(6)__ months. Urinary tract infections are fairly common and not usually severe with proper medical treatment. A particularly problematic condition, called __(7)__, may result later in life as a sequel to childhood streptococcus infection. In this disease, the renal filters become clogged with __(8)__ complexes, urine output decreases, and __(9)__ and __(10)__ begin to appear in the urine. In old age, progressive __(11)__ of the renal blood vessels results in the death of __(12)__ cells. The loss of bladder tone leads to __(13)__ and __(14)__ and is particularly troublesome to elderly people.

_____ 13.
_____ 14.



INCREDIBLE JOURNEY

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.
_____ 2.
_____ 3.
_____ 4.
_____ 5.
_____ 6.
_____ 7.
_____ 8.
_____ 9.
_____ 10.

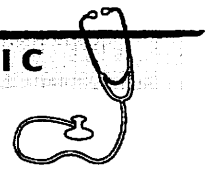
For your journey through the urinary system, you must be made small enough to filter through the filtration membrane from the bloodstream into a renal __(1)__. You will be injected into the subclavian vein and must pass through the heart before entering the arterial circulation. As you travel through 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.

_____ 11.
_____ 12.
_____ 13.
_____ 14.
_____ 15.
_____ 16.
_____ 17.
_____ 18.
_____ 19.
_____ 20.
_____ 21.
_____ 22.
_____ 23.
_____ 24.

- Virtually no nutrients such as (11) and (12) are left in the filtrate.
- The pH is acid, 6.0. This is quite a change from the pH of (13) recorded for the newly formed filtrate.
- There is a much higher concentration of (14) wastes here.
- There are many fewer (15) ions but more of the (16) ions noted.
- Color of the filtrate is yellow, indicating a high relative concentration of the pigment (17).

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.

AT THE CLINIC



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?

23. Four-year-old Eddie is a chronic bedwetter. He wets the bed nearly every night. What might explain his problem?

24. If a tumor of the glucocorticoid-secreting cells of the adrenal cortex crowds out the cells that produce aldosterone, what is the likely effect on urine composition and volume?

25. Jimmy has been stressed out lately as he has been juggling two jobs while taking classes at a local college. He appears at the clinic complaining of a pounding headache. Tests show that he has high blood pressure and his cortiscosteroid levels are elevated. What is the relationship between his stress and his signs and symptoms?

26. Mr. O'Toole is very drunk when he is brought to the emergency room after falling down City Hall steps during a political rally. He is complaining about his "cotton mouth." Knowing that alcohol inhibits ADH's action, you explain to him why his mouth is so dry. What do you tell him?

27. Mrs. Rodriques is breathing rapidly and is slurring her speech when her husband calls the clinic in a panic. Shortly after, she becomes comatose. Tests show that her blood glucose and ketone levels are high and her husband said that she was urinating every few minutes before she became lethargic. What is Mrs. Rodriques's problem? Would you expect her blood pH to be acidic or alkaline? What is the significance of her rapid breathing? Are her kidneys reabsorbing or secreting bicarbonate ions during this crisis?