

A tiny sparrow hops across snow drifts on a subfreezing day, searching for food. How is it able to remain alive, even active, in such a hostile environment? Despite the cold, the sparrow's internal environment, the fluid that bathes its cells, remains remarkably constant. Numerous mechanisms keep it that way despite external fluctuations in temperature. Rapid cell metabolism allows the bird to generate its own body heat. Its feathers, circulatory system, and behavior control heat loss. It needs to keep eating to keep its temperature up, but metabolism of food alters body chemistry. To compensate, the sparrow's liver makes minute-to-minute adjustments in blood nutrient content and sweeps the blood for toxins. The kidneys actively sort the blood's chemical constituents, helping to maintain optimum solute content, adjust pH, get rid of waste products, and save water at the same time. This chapter discusses three processes that help maintain a constant internal environment—thermoregulation, osmoregulation, and excretion of wastes.

Organizing Your Knowledge

Exercise 1 (Introduction)

The polar bear has many adaptations that help in thermoregulation—maintenance of its internal body temperature within narrow limits. Bears are endotherms, animals that derive most of their body heat from metabolism. Many other animals are ectotherms, which absorb heat from their surroundings. Which of the following are endotherms, and which are ectotherms?

- _____ 1. Most fishes
- _____ 2. A squirrel
- _____ 3. Most invertebrates
- _____ 4. A frog
- _____ 5. Some insects
- _____ 6. Some fishes
- _____ 7. An eagle
- _____ 8. A lizard

Exercise 2 (Modules 25.1 – 25.4)

Does the room temperature where you are right now feel comfortable? Do you feel a bit chilly? Or are you sweating because it is hot and humid? These modules discuss thermoregulation, and they provide numerous examples of methods animals use to regulate their internal temperatures. Animals regulate temperatures two ways: (1) by changing rate of heat production and (2) by adjusting rate of heat gain or loss. State whether each of the following is

- A. a method of warming or cooling the body by regulating heat production
- B. a method of warming the body by reducing heat loss
- C. a method of warming the body by increasing heat gain
- D. a method of cooling the body by increasing heat loss
- E. a method of cooling the body by decreasing heat gain

- _____ 1. Moisture evaporates from a lizard's nostrils.
- _____ 2. A robin fluffs up its feathers to trap more air near the skin.
- _____ 3. A rabbit grows a thicker coat in the winter.
- _____ 4. A lizard comes out of its burrow and turns broadside to the sun.
- _____ 5. An elephant sprays itself with cold water.
- _____ 6. Bees shiver.
- _____ 7. Blood vessels dilate in a jackrabbit's ears.
- _____ 8. You jump up and down and swing your arms to warm up on a cold day.
- _____ 9. A kangaroo rat presses itself against the cool wall of its burrow.
- _____ 10. A countercurrent heat exchanger cools the blood flowing to a duck's feet.
- _____ 11. Hormones increase a mouse's metabolic rate.
- _____ 12. A polar bear's transparent hairs beam sunlight to its black skin.
- _____ 13. A cat licks itself, and saliva evaporates from its skin.
- _____ 14. A bee seeks flowers that focus sunlight on its body.
- _____ 15. A snake moves out of the sun and into the shade.

Exercise 3 (Modules 25.5 – 25.7)

Animals must maintain a correct balance of water and solutes in body fluids to stay alive. The concentration of seawater is good enough for many marine animals, so they are osmoconformers, simply matching the osmotic concentration of their environment. Other marine creatures, as well as freshwater and land animals, are osmoregulators. They actively move solutes and water in and out of their cells to maintain body fluid compositions different from their environments. Land animals have particular problems with loss of water and solutes. Use the information in the modules to complete this chart comparing osmoconformers and various osmoregulators.

	<i>Marine Worm</i>	<i>Freshwater Fish</i>	<i>Saltwater Fish</i>	<i>Land Animal</i>
Osmoregulator or osmoconformer?	1.	2.	3.	4.
Tends to gain or lose water?	5.	6.	7.	8.
Tends to gain or lose solutes (ions)?	9.	10.	11.	12.
Method of compensating for gain or loss?	13.	14.	15.	16.

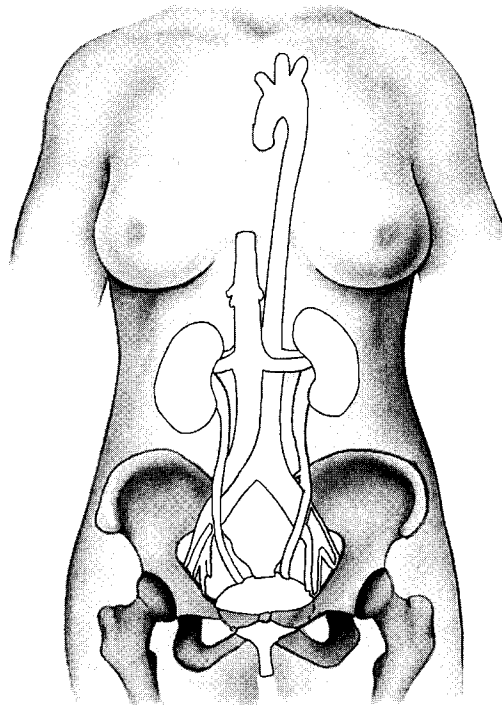
Exercise 4 (Module 25.8)

Breakdown of proteins and nucleic acids produces nitrogen-containing waste products. Different animals dispose of nitrogen in different ways. Summarize the kinds of animals that excrete each of the following nitrogenous wastes, and discuss the advantages and disadvantages of each.

	<i>Ammonia</i>	<i>Urea</i>	<i>Uric Acid</i>
Animals excreting this compound	1.	2.	3.
Advantages of excreting this compound	4.	5.	6.
Disadvantages of excreting this compound	7.	8.	9.

Exercise 5 (Module 25.9)Web/CD Activity 25A *Structure of the Human Excretory System*

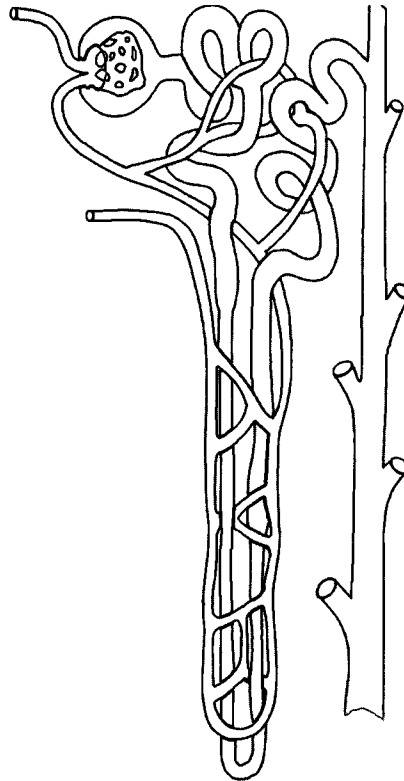
The human excretory system performs important functions in fluid homeostasis. This exercise and the next will help you to become familiar with the kidneys and nephrons, their functional units. First, complete this diagram of the excretory system. Label the **renal artery**, and color it red. Label the **renal vein**, and color it blue. Label the **kidneys**, and color them brown. Then label and color the **ureters** (light brown), the **bladder** (yellow), and the **urethra** (green).



Exercise 6 (Module 25.9)

Web/CD Activity 25A *Structure of the Human Excretory System*

Note in Figure 25.9 in the text how many tiny nephrons are arranged in each kidney. Label and color the following diagram of a nephron. Color arterioles and arterial capillaries red; color venous capillaries and the renal vein blue; and color the entire renal tubule, from Bowman's capsule through the collecting duct, yellow. Label **arteriole from renal artery**, **glomerulus**, **arteriole from glomerulus**, **capillaries**, **Bowman's capsule**, **proximal tubule**, **loop of Henle**, **distal tubule**, and **collecting duct**.

**Exercise 7 (Modules 25.9 – 25.11)**

Web/CD Activity 25A *Structure of the Human Excretory System*

Web/CD Activity 25B *Nephron Function*

Web/CD Activity 25C *Control of Water Reabsorption*

Nephrons regulate the water and solute content of blood in a four-step process: filtration, reabsorption, secretion, and excretion. The next two exercises review nephron function, which is the heart of this chapter. After studying the modules, match each of the following parts of a nephron with its function.

- | | |
|--|--------------------------------------|
| A. Mainly functions in water reabsorption | _____ 1. Loop of Henle |
| B. "Refine" filtrate by reabsorption and secretion | _____ 2. Bowman's capsule |
| C. Delivers blood to glomerulus | _____ 3. Proximal and distal tubules |
| D. Carries urine to central "pelvis" of kidney; also functions in water reabsorption | _____ 4. Glomerulus |
| E. Porous ball of capillaries where filtration occurs | _____ 5. Collecting duct |
| F. Collects filtrate from glomerulus | _____ 6. Renal artery |

Exercise 8 (Modules 25.10 – 25.11)Web/CD Activity 25B *Nephron Function*Web/CD Activity 25C *Control of Water Reabsorption*

After studying kidney function, match each of the following components of blood with what happens to it in a nephron. Hint: Ask yourself, "Is this something the body wants to keep, or something it wants to get rid of?" (Answers may be used more than once.)

- | | |
|--|--------------------------|
| A. Not filtered | _____ 1. Glucose |
| B. Filtered and mostly reabsorbed | _____ 2. Water |
| C. Filtered, then mostly <i>not</i> reabsorbed, and finally excreted in urine | _____ 3. Urea |
| | _____ 4. H ⁺ |
| D. Filtered, mostly <i>not</i> reabsorbed, <i>also</i> secreted, and finally excreted in urine | _____ 5. Plasma protein |
| | _____ 6. Amino acid |
| | _____ 7. Red blood cell |
| | _____ 8. Nicotine (drug) |
| | _____ 9. Salt (NaCl) |

Exercise 9 (Module 25.12)

Kidney dialysis has saved many lives, often as a stopgap until a kidney transplant can be arranged.

1. What are some advantages and disadvantages of dialysis, compared with a transplanted kidney?
2. What do you think would be some advantages and disadvantages of a kidney transplant, compared with dialysis?

Exercise 10 (Module 25.13 and Summary)

The liver complements the kidneys in regulating body fluid composition. Unlike the kidneys, the liver can chemically alter substances in the blood and store useful substances for later use. The liver releases its waste products into the blood, and they are excreted by the kidneys. Fill in the blanks in the following scenario summarizing the roles of the liver and kidneys in dealing with some substances in food.

Tom finished his breakfast with a cup of coffee (with milk and sugar) and dashed off to work. Digestion of milk proteins began immediately. The resulting amino acids were absorbed through the intestinal lining into Tom's blood. At the same time, enzymes split the sucrose (sugar) molecules, forming glucose and fructose, which also entered the blood. Caffeine molecules entered the blood immediately, without digestion.

Blood from Tom's intestine was carried via the ¹_____ to the liver. Liver cells absorbed some of the amino acids, sugars, fats, and caffeine. The fructose was immediately converted into glucose. The blood carried some of the glucose through the liver and into general circulation, where it was distributed to nourish body cells. The rest of the glucose was converted to ²_____ and stored in the liver. It would later be turned back into ³_____, as Tom's blood sugar dropped between

breakfast and lunch. Meanwhile, the liver packaged some of the milk fats as lipoproteins and shipped them out to body tissues.

Some of the caffeine from the coffee made it through the liver and had the intended “wake-up” effect on Tom’s brain as he was driving to work. Like other potentially harmful chemicals, the rest of the caffeine was ⁴ _____ by liver cells and the resulting less-toxic products were released back into the blood. All the caffeine would eventually be disposed of in this manner.

Some of the amino acids from the milk were carried by the blood to cells that could use them to make proteins. Other amino acids were broken down for energy or converted to other nutrients. Leftover amino groups were first changed into highly toxic ⁵ _____, but the liver cells quickly converted this into ⁶ _____, a much safer nitrogenous waste. This was also dumped into the blood exiting the liver.

The blood processed by the liver, with its cargo of glucose, amino acids, caffeine by-products, urea, and H^+ ions from the acid in the coffee, flowed through the hepatic vein to the ⁷ _____. This vessel carried the blood to the heart. The heart pumped the blood to the lungs and back, and then out through the aorta, whose branches distributed the blood to body tissues. About one-fifth of the blood pumped by each heartbeat flowed through the ⁸ _____ arteries to the kidneys.

In each of Tom’s kidneys, branches of the renal artery delivered blood to a million ⁹ _____, the kidney’s tiny working units. As a drop of blood passed through a ¹⁰ _____, a porous knot of capillaries, blood pressure filtered some of the blood through the pores into a funnel-like structure called ¹¹ _____. Blood cells and large protein molecules were left behind in the blood, while smaller molecules were filtered. The fluid that collected in Bowman’s capsule, called ¹² _____, contained some of the water, glucose, H^+ , and amino acids from Tom’s morning coffee, plus urea and caffeine by-products from the liver. But filtration was just the beginning of the work of the nephron. The processes of ¹³ _____ and ¹⁴ _____ had to occur before the blood could leave the kidney and waste products could be ¹⁵ _____ from the body in urine.

As Tom exited from the freeway, the walls of the proximal tubules were beginning to reabsorb the glucose and amino acids in the filtrate via the process of ¹⁶ _____. Uptake of these substances, and others like salt, caused ¹⁷ _____ to be reabsorbed by osmosis, especially in the long ¹⁸ _____ of Henle and the collecting duct. These materials, valuable to the body, would reenter the blood and leave the kidneys through the ¹⁹ _____.

Filtration is not usually enough to get rid of all the acid the body needs to excrete, so Tom’s kidneys actually removed some H^+ from the blood and added it to the filtrate, a process known as ²⁰ _____. Although some of the urea was reabsorbed, most of it, along with the caffeine by-products, remained in the refined filtrate, which is called ²¹ _____ when it leaves the kidney.

Because the caffeine in Tom’s coffee is a stimulant that raises blood pressure, Tom’s kidneys were filtering his blood at a slightly higher than normal rate as he drove into the company parking lot. Urine left the kidneys through the ²² _____ and accumulated in the ²³ _____. Tom had just enough time to stop at the restroom on his way to his office.

Testing Your Knowledge

Multiple Choice

- Which of the following is an endotherm?
 - mouse
 - iguana
 - frog
 - trout
 - all of the above except a
- Which of the following describes the route of urine out of the body after it leaves the kidney?
 - renal vein, bladder, urethra, ureter
 - urethra, bladder, ureter
 - renal vein, ureter, bladder, urethra
 - ureter, bladder, urethra
 - ureter, urethra, bladder
- Blood flows through the hepatic portal vessel
 - from the aorta to the kidney.
 - from the intestine to the liver.
 - from the kidney to the inferior vena cava.
 - from the liver to the inferior vena cava.
 - from the liver to the intestine.
- As your kidneys regulate your body fluid composition, which of the following is the largest?
 - the volume of filtrate formed by the nephrons
 - the volume of urine excreted
 - the volume of blood flowing through the nephrons
 - the volume of solutes added to the filtrate by secretion
 - the volume of filtrate reabsorbed
- A countercurrent heat exchanger enables an animal to
 - produce more heat when needed.
 - reduce loss of heat to the environment.
 - slow metabolism when food is not available.
 - increase heat loss by evaporation.
 - absorb heat from the environment.
- Uric acid is the nitrogenous waste excreted by birds, insects, and many reptiles. An advantage of excreting uric acid is that it _____, but a disadvantage is that it _____.
 - saves water . . . costs energy
 - saves energy . . . is highly toxic
 - is not very toxic . . . wastes a lot of water
 - is much more soluble in water than other wastes . . . costs energy
 - saves water . . . is highly toxic
- Which of the following is the most accurate and comprehensive description of the function of the kidneys?
 - breaking down body wastes
 - excreting wastes
 - regulating body fluid composition
 - filtering the blood
 - producing urine
- Which of the following happens first as a nephron processes blood?
 - excretion
 - osmosis
 - secretion
 - reabsorption
 - filtration
- On a cold day, blood vessels in the skin
 - dilate, allowing blood to keep the skin warm.
 - constrict, forcing blood to flow through vessels in the skin.
 - constrict, reducing heat loss from blood at the surface.
 - dilate, causing blood to pass through the cold skin more quickly.
 - dilate, preventing blood flow to the surface.
- The animals in which of these pairs have similar problems regulating water balance?
 - freshwater fish—saltwater fish
 - land animal—freshwater fish
 - osmoconformer—freshwater fish
 - salmon in fresh water—salmon in salt water
 - saltwater fish—land animal
- The filtrate formed by the nephrons in the kidney is not the same as urine. The filtrate is first refined and concentrated by the processes of _____, forming the urine that leaves the body.
 - filtration and secretion
 - reabsorption and secretion
 - reabsorption and excretion
 - filtration and reabsorption
 - secretion and excretion
- Nitrogenous waste products are made from by-products of the breakdown of
 - fats.
 - starch.
 - glucose.
 - urea.
 - proteins.

13. By definition, an ectotherm
 - a. is "cold-blooded."
 - b. is "warm-blooded."
 - c. obtains most of its heat from its environment.
 - d. derives most of its heat from its own metabolism.
 - e. is none of the above.
14. Most aquatic animals excrete ammonia, while land animals excrete urea or uric acid. What is the most likely explanation for this difference?
 - a. They have different diets.
 - b. Land animals can get the energy needed to make urea or uric acid.
 - c. Ammonia is very toxic, and it takes lots of water to dilute it.
 - d. Land animals cannot afford the energy needed to make ammonia.
 - e. Fish need to get rid of ammonia, but land animals need it to live.
15. A freshwater fish tends to _____ water by osmosis. As a consequence, its kidneys excrete _____.
 - a. gain . . . large amounts of dilute urine
 - b. lose . . . small amounts of concentrated urine
 - c. gain . . . large amounts of concentrated urine
 - d. lose . . . large amounts of dilute urine
 - e. gain . . . small amounts of concentrated urine

Essay

1. Describe how the skin can make adjustments that cool the body on a hot day and warm it on a cold day.
2. Explain how a goose can stand barefoot on ice without losing large amounts of body heat.
3. Compare the problems that freshwater and saltwater fish face in maintaining the water and solute balances of their body fluids. How does each kind of fish solve these problems?
4. Describe five behaviors by which animals control their body temperatures.
5. The kidneys regulate body fluid composition by means of filtration, reabsorption, secretion, and excretion. Where does each of these processes occur? How does each contribute to the formation of filtrate and urine?

Applying Your Knowledge

Multiple Choice

1. Which of the following primarily involves heat transfer by convection?
 - a. You roll down the car window to let the cool breeze blow through.
 - b. The water in a lake is so cold that your legs become numb.
 - c. You sweat profusely as you mow the lawn on a hot summer day.
 - d. After sunset, you can feel heat from the warm pavement.
 - e. As you lie on the sand, you can feel the sun's warm rays on your skin.
2. Which needs to drink the smallest amount of water to maintain its water balance?
 - a. a sparrow
 - b. a saltwater fish
 - c. a freshwater fish
 - d. a dog
 - e. both a and b drink very small amounts
3. Humid weather makes you feel warmer because humid air
 - a. interferes with heat loss by conduction.
 - b. holds warm water vapor.
 - c. interferes with heat loss by evaporation.
 - d. prevents countercurrent heat exchange from occurring.
 - e. increases metabolic heat production.
4. Pound for pound, a kidney uses as much energy as the heart. What do you think the energy is used for?
 - a. to produce pressure for filtration
 - b. for water reabsorption
 - c. for the breakdown and detoxification of harmful substances
 - d. to pump urine to the bladder
 - e. for reabsorption and secretion of solutes by active transport
5. Look at the diagram of kidney dialysis, Figure 25.12, in the text. For kidney dialysis to work properly, the dialyzing solution should contain
 - a. a higher solute concentration than blood.
 - b. a higher concentration of urea than blood.
 - c. a lower glucose concentration than blood.
 - d. a lower concentration of urea than blood.
 - e. a much smaller volume of fluid than the blood passing through it.

6. Which would have the toughest time surviving over the long term in the environment given?
 - a. an osmoconformer in seawater
 - b. an endotherm in a warm environment
 - c. an ectotherm in a cold environment
 - d. an osmoregulator in seawater
 - e. an ectotherm in a warm environment
7. The loops of Henle in the kidneys of a desert kangaroo rat are much longer than those in a white laboratory rat because
 - a. the kangaroo rat lives in an environment where water is scarce.
 - b. the white rat's diet is much less varied than the kangaroo rat's.
 - c. the kangaroo rat cannot always find food.
 - d. the kangaroo rat produces more wastes.
 - e. the kangaroo rat has less stress and lower blood pressure.
8. How does the filtrate produced by the filtration process of the glomerulus differ from urine? The filtrate
 - a. contains very little water.
 - b. contains a higher concentration of glucose.
 - c. contains a much lower concentration of salt.
 - d. contains a lower concentration of proteins.
 - e. does all of the above.
9. The kidney's filtration process is nonselective, so
 - a. many valuable substances are lost in urine.
 - b. the proportions of substances in urine are the same as in blood.
 - c. urine is much less concentrated than blood.
 - d. it really has little control over body fluid composition.
 - e. useful substances must be selectively reabsorbed.
10. Which of the following would be filtered from the blood but not normally found in urine?
 - a. water
 - b. red blood cell
 - c. H^+ ions
 - d. amino acid
 - e. urea

Essay

1. In terms of heat loss, why is the windchill factor given in a weather report always a lower figure than the air temperature?
2. An animal behaviorist found that a large part of a horned lizard's daily routine consisted of behavior related to thermoregulation. Very little of the lizard's time was occupied by searching for food. A pocket mouse in the same environment spent most of its time seeking food but very little time thermoregulating. Explain this difference in behavior.
3. Many kinds of poisons cause liver damage. Sniffing the solvents in glue can quickly injure the liver. Poisonous *Amanita* mushrooms also kill by destroying the liver. Over a longer period, alcohol causes liver damage. Why do you think the liver ends up being a "lightning rod" for all these different poisons?
4. You may have noticed that you never see pictures of Antarctic crocodiles lying in ambush for unwary penguins or seals. Why are birds and mammals more successful in the polar regions than reptiles and amphibians?
5. Imagine that you are working with a team of physiologists sampling and comparing the blood entering and leaving the liver. How might the blood entering and leaving the liver differ in each of the following circumstances? After the subject eats a large candy bar. After the subject consumes two shots of whiskey. After a 4-hour period during which the subject consumed no food.

Extending Your Knowledge

1. For a patient with kidney failure, a kidney transplant is the key to an improved, more normal life. For an individual with liver failure, an immediate transplant is essential for survival. Why is a liver transplant so important? If this is the case, why are liver transplants performed much less often than kidney transplants?
2. Suppose a friend or relative needed a kidney transplant. Would you volunteer to donate a kidney if your tissue types were compatible? What might be some reasons for and against donating one of your kidneys?
3. Side effects of many medications include liver or kidney damage. Why? Have any of the prescription or over-the-counter medications you use been implicated in causing liver or kidney impairment? Try looking at some of the labels or package instructions. How else might you find out about this?