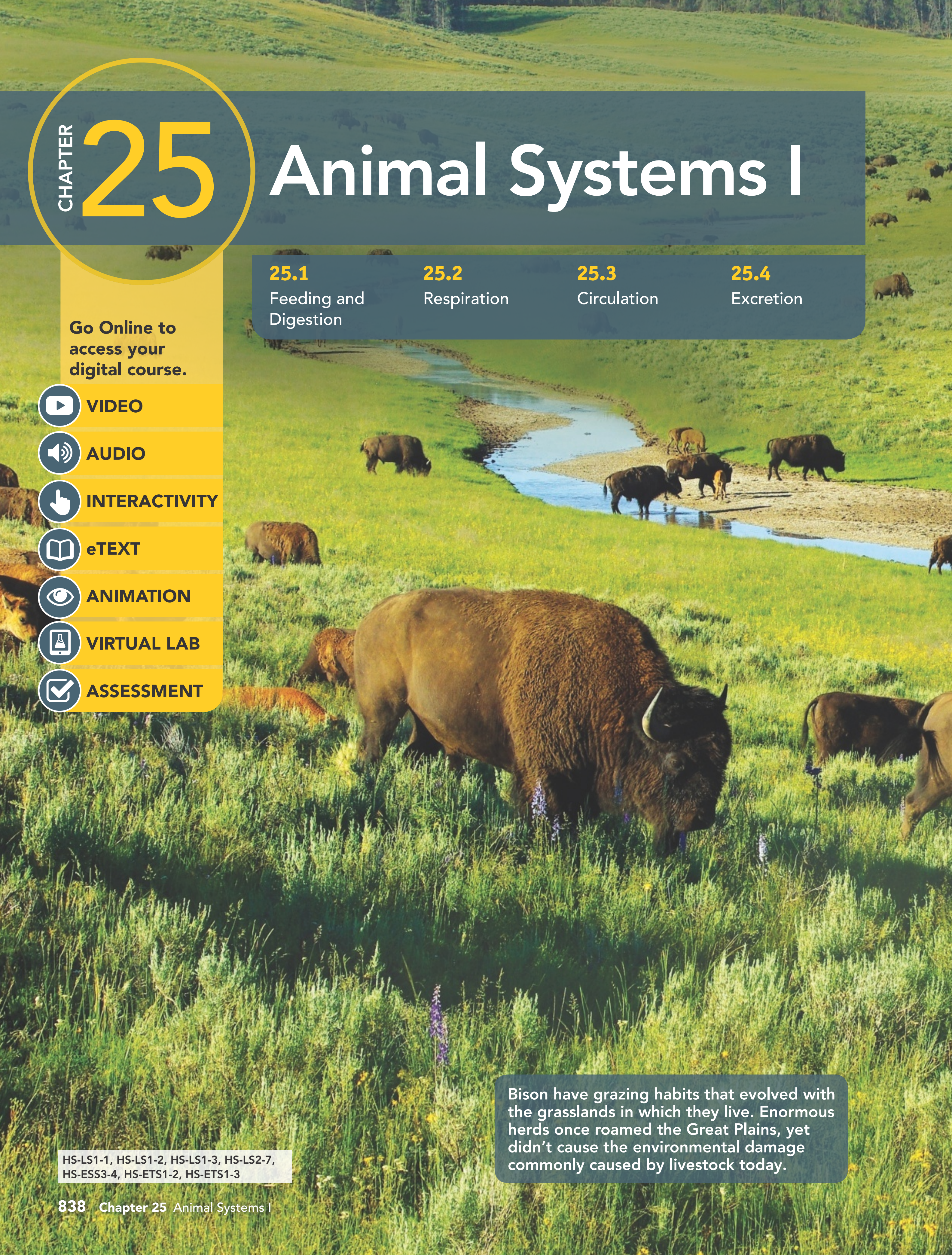

CHAPTER 25

Animal Systems I

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- INTERACTIVITY
- eTEXT
- ANIMATION
- VIRTUAL LAB
- ASSESSMENT

Bison have grazing habits that evolved with the grasslands in which they live. Enormous herds once roamed the Great Plains, yet didn't cause the environmental damage commonly caused by livestock today.

HS-LS1-1, HS-LS1-2, HS-LS1-3, HS-LS2-7, HS-ESS3-4, HS-ETS1-2, HS-ETS1-3

CASE STUDY

How do animal processes and human activity affect the environment?

All animals, large and small—including humans—must acquire food, oxygen, and water. All of us must also get rid of waste products, typically including solid wastes, liquid wastes, and carbon dioxide. These processes—feeding, breathing, and excreting—all affect the environment in which animals live. Therefore, there is no such thing as a form of life that has no environmental impact. What does vary among organisms, and among populations of different sizes, are the types of impact, and the size and scale of environmental effects.

Animals in nature interact with each other, with producers, and with their environment. Population sizes rise and fall. Nutrient cycles work differently at different times of year. However natural systems usually, although not always, pass through periods of stability and change without catastrophic effects.

Long before humans entered the scene, enormous herds of bison and other grazing animals roamed over the Great Plains of North America. Huge herds of wildebeest, antelope, zebra, buffalo, and other animals covered the grasslands and savannahs of Africa. The total biomass of these herds is almost unimaginable.

Yet today, when modern society raises beef or pork, environmental side effects seem to be everywhere. Overgrazing does permanent harm to ecosystems, killing plants and damaging soil structure. In feedlots for cattle and pigs, enormous quantities of solid and liquid wastes pollute ground and surface water, and give off a foul stench that spreads for miles. What happened?

Before humans, animal species and evolutionary lineages that survived and reproduced over the ages did so in ways that didn't create toxic conditions for themselves or for other species on which they depended.

The hooves and heavy footsteps of those giant herds buried grass seeds and decomposing organic matter, and churned and aerated the soil. Animals' wastes decomposed, returning nutrients to the soil. Herds were often on the move; so intense grazing was followed by periods of fewer disturbances. The plants of those great grasslands evolved ways to survive this kind of grazing by herbivores.

But when humans started raising livestock in large quantities, they did things differently. They raised large herds in fenced-in pastures, concentrating grazing in the same places for much of the year, including along fragile streambeds. Feedlots concentrate animals in higher numbers and at higher densities than any ecosystem could support naturally. Food and clean water are supplied, and the animals produce wastes in unmanageable quantities.

Does it have to be that way? Are there ways to raise animals for our use and preserve environmental services at the same time? What can we learn from ranchers and farmers who understand their crops and livestock?

Throughout this chapter, look for connections to the CASE STUDY to help you answer these questions.

LESSON 25.1 Feeding and Digestion

A whale shark is a vertebrate filter feeder.

KEY QUESTIONS

- *How do animals obtain food?*
- *How does digestion occur in animals?*
- *How are mouthparts adapted for different diets?*

HS-LS1-1: Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins which carry out the essential functions of life through systems of specialized cells.
HS-LS1-2: Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.
HS-LS1-3: Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis.

VOCABULARY
digestive tract
rumen

READING TOOL

As you read this lesson, complete the table in your **Biology Foundations Workbook** to explain how different types of animals obtain food.

VIDEO

Watch how black bears hibernate all winter without eating.

BUILD VOCABULARY

Word Origins The word part -*vore* comes from the Latin verb *vorare*, which means "to devour."

From mosquitoes that "bite" us to dine on our blood to bison that feed on prairie grasses to giant whale sharks that feed on plankton, all animals are heterotrophs that obtain nutrients and energy from food. The variety of feeding adaptations is a large part of what makes animals interesting.

Obtaining Food

There's an old saying that "You are what you eat." We can rephrase that as "What you eat and how you eat it determine how you look and act." Evolutionary adaptations for feeding on different foods have shaped the body structures and behaviors of animals, such as those in **Figure 25-1**.

Filter Feeders ***Most filter feeders catch algae and small animals by using modified gills or other structures as nets that filter food items out of water.*** Many invertebrate filter feeders are small or colonial organisms, like worms and sponges, that spend their adult lives in a single spot. Some vertebrate filter feeders, such as blue whales, are huge, and feed while swimming.

Detritivores Detritus is made up of decaying bits of plant and animal material. ***Detritivores feed on detritus, often obtaining extra nutrients from bacteria, algae, and other microorganisms that grow on and around it.*** Detritivores are essential members of many food webs.

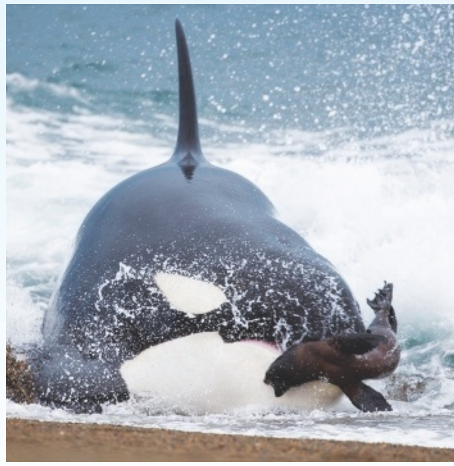
Herbivores ***Herbivores eat plants or parts of plants or algae.*** Fruits are often filled with energy-rich compounds, and are easy to digest. (That's why we eat so many of them!) Leaves don't have many calories, are tough to digest, and can contain poisons or hard particles that wear down teeth.


Filter Feeders: Barnacles


Detritivores: Earthworms


Herbivore: Green sea turtle

Carnivores ***Carnivores eat other animals.*** Mammalian carnivores, such as wolves, use teeth, claws, and speed or stealthy hunting tactics to capture prey. Many carnivorous invertebrates would be as menacing as tigers if they were larger. Some cnidarians paralyze prey with poison-tipped darts, while some spiders immobilize their victims with venomous fangs.


Carnivore: Orca

CASE STUDY

Figure 25-1

Obtaining Food

All animals take in food from their environment, but they do so in different ways.

Nutritional Symbionts Recall that a symbiosis is a close relationship between two or more species. Symbionts are the organisms involved in a symbiosis. ***Many animals rely upon symbiosis for their nutritional needs.***

Parasitic Symbiosis Parasites live within or on a host organism, where they feed on tissues or on blood and other body fluids, disrupting the health of their hosts. Some parasites are just nuisances, but many cause serious diseases in humans, livestock, and crop plants. Parasitic flatworms and roundworms harm millions of people, particularly in the tropics.

Mutualistic Symbiosis Mutualistic nutritional relationships benefit both participants, and are often important in maintaining the health of organisms. Reef-building corals depend on symbiotic algae that live within their tissues for most of their energy. Those algae capture solar energy, recycle nutrients, and help corals lay down calcium carbonate skeletons. The algae, in turn, obtain nutrients from coral wastes.

Many animals, including humans, have tightly knit relationships with symbiotic microorganisms that live within their digestive tracts. These microbial partners are vital parts of their hosts' microbiomes. Animals that eat wood or plant leaves rely on symbiotic microorganisms to break down cellulose, which no animal can digest on its own. Microorganisms living in our intestines help in digestion and nutrient absorption, manufacture some essential vitamins, and help protect us from other potentially harmful microorganisms. In fact, understanding the importance of the human microbiome is critical to maintaining our health.

INTERACTIVITY

Explore the different methods animals use to obtain food.

READING CHECK **Describe** What is the difference between a parasitic symbiosis and a mutualistic symbiosis?

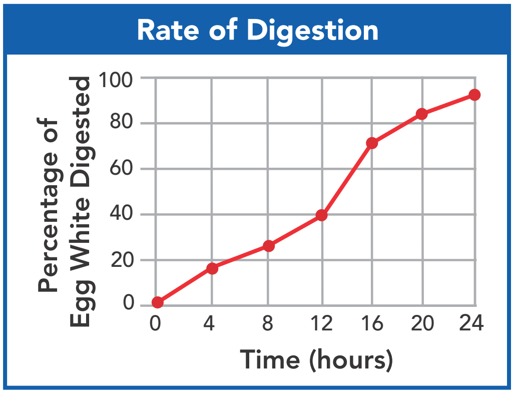
READING TOOL

Make a table of similarities and differences between carnivores and herbivores and fill it out as you read about them.

Analyzing Data

Protein Digestion

A biology student performed an experiment to determine the amount of time needed for an animal's stomach to digest animal protein. He placed pieces of hard-boiled egg white (an animal protein) in a test tube containing hydrochloric acid, water, and the enzyme pepsin, which is made by animals and digests protein. The graph shows the rate at which the egg white was "digested" over a 24-hour period.



1. **Analyze Graphs** Describe the trend in the rate at which the protein digested over time.
2. **Analyze Data** About how many hours did it take for half of the protein to be digested?
3. **Draw Conclusions** How would you expect the rate of meat digestion to differ in an animal whose digestive tract had less of the enzyme pepsin?

Processing Food

Obtaining food is just the first step. Food must then be broken down, or digested, and absorbed to make energy and nutrients available to body tissues. ***The simplest animals, such as sponges, digest food inside specialized cells that pass nutrients to other cells by diffusion. More complex animals break food down outside cells in a digestive cavity and then absorb the nutrients they need.*** A variety of digestive systems are shown in **Figure 25-2**.

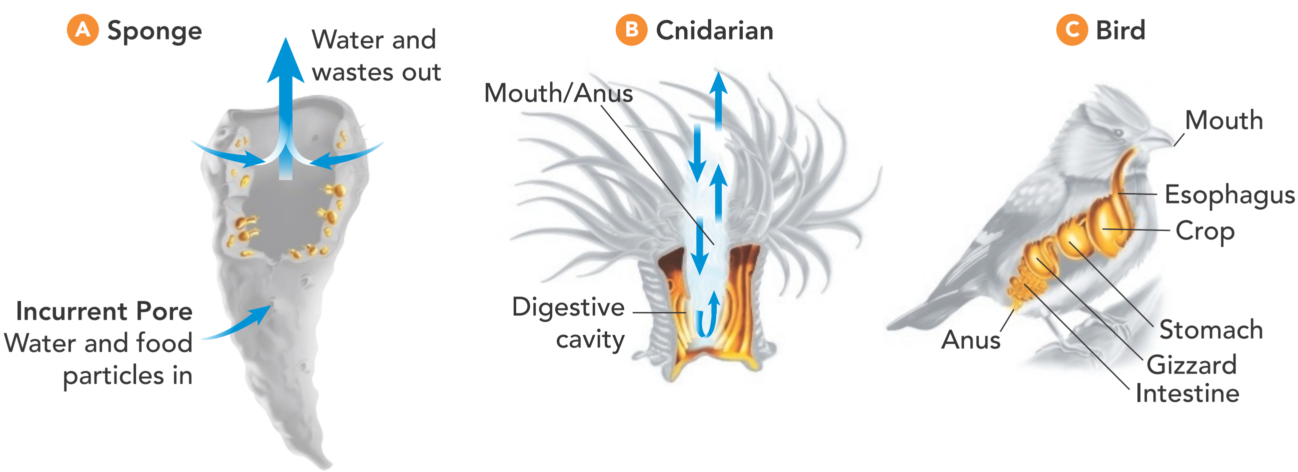
Some relatively simple invertebrates, such as cnidarians, have a digestive cavity with only one opening through which they both ingest food and expel wastes. Cells lining the cavity secrete enzymes and absorb digested food. Other cells surround food particles and digest them in vacuoles. Nutrients are then transported to cells throughout the body.

Many invertebrates and all vertebrates digest food as it passes through a tube called a **digestive tract**, which has two openings. Food moves in one direction, entering the body through the mouth. Wastes leave through the anus.

Figure 25-2

Digesting Food

Animals have different digestive structures with different functions. (A) Sponges filter water as it is drawn through their porous body walls. (B) The cnidarian processes its food in a digestive cavity with only one opening. (C) The bird has a one-way digestive tract with two openings.



One-way digestive tracts often have specialized structures, which perform different tasks, as food passes through them. You can think of a digestive tract as a kind of "disassembly line" that breaks down food one step at a time. In some animals, the mouth secretes digestive enzymes that start the chemical digestion of food.

Then, mechanical digestion may occur as specialized mouthparts or a muscular organ called a gizzard breaks down large pieces of food into small pieces. Then, chemical digestion begins or continues in a stomach that secretes digestive enzymes. Chemical breakdown continues in the intestines, sometimes aided by secretions from other organs such as a liver or pancreas. Intestines also absorb the nutrients released by digestion.

No matter how efficiently an animal breaks down food and extracts nutrients, some indigestible material will remain. These solid wastes, or feces, are expelled either through the single digestive opening or through the anus.

INTERACTIVITY

Explore how body systems function and interact, using a frog as a model.

READING CHECK **Compare and Contrast** How is mechanical digestion different from chemical digestion?

Specializations for Different Diets

The mouthparts and digestive systems of animals have evolved many adaptations to the physical and chemical characteristics of different foods, as shown in **Figure 25-3**. As a window into these specializations, we'll examine adaptations to two food types that are very different physically and chemically: meat and plant leaves.

Specialized Mouthparts Carnivores and leaf-eating herbivores usually have very different mouthparts. These differences are typically related to the different physical characteristics of meat and plant leaves.

INTERACTIVITY

Visual Analogy

Figure 25-3

Mouthparts

The specialized jaws and teeth of animals are well adapted to their diets.

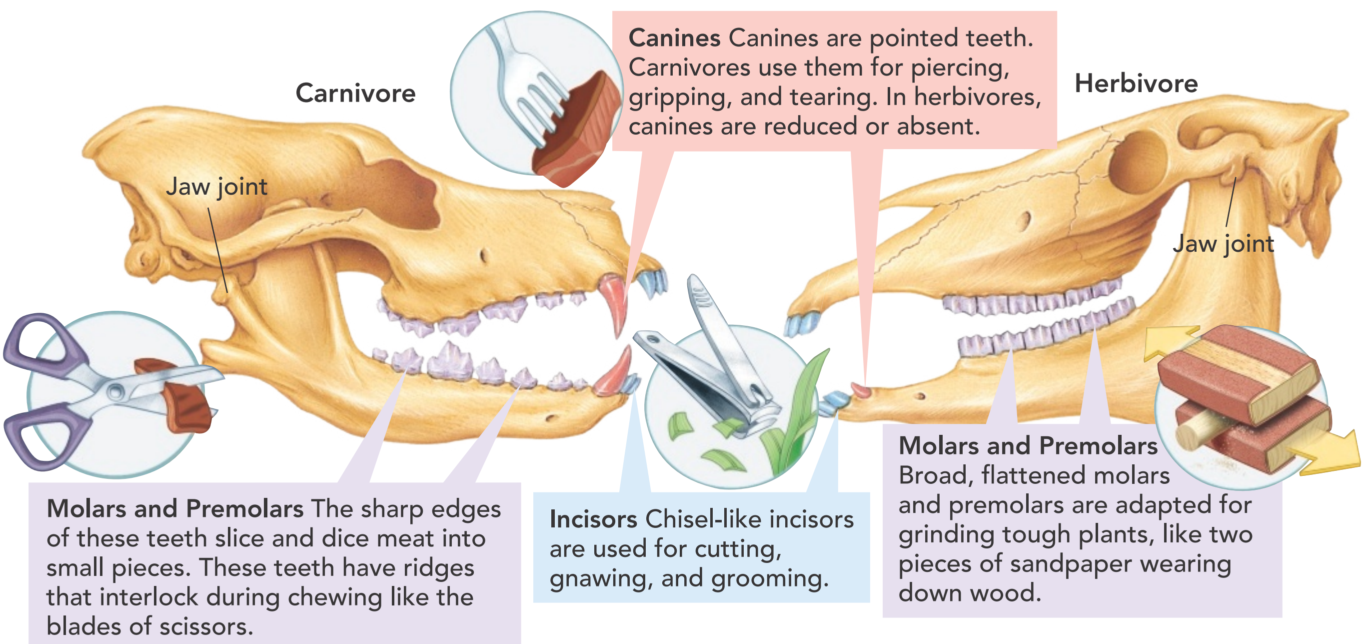


Figure 25-4

Eating Plant Leaves

The teeth and jaws of herbivores, such as giraffes, are adapted for pulling, rasping, and grinding plant leaves.

Eating Meat ***Carnivores typically have sharp mouthparts or other structures that can capture food, hold it, and "slice and dice" it into small pieces.*** Carnivorous mammals, such as wolves, have sharp teeth that grab, tear, and slice food like knives and scissors. The jaw bones and muscles of carnivores are adapted for up-and-down movements that chop meat into small pieces.

Eating Plant Leaves ***Herbivores have mouthparts adapted to rasping or grinding to tear plant cell walls and expose their contents.*** Many herbivorous invertebrates, from mollusks to insects, have mouthparts that grind and pulverize plant or algal tissues. Herbivorous mammals, such as the giraffe in **Figure 25-4**, have front teeth and muscular lips adapted to grabbing and pulling leaves, and flattened molars that grind leaves to a pulp. The jawbones and muscles of mammalian herbivores are also adapted for side-to-side "grinding" movements.

Specialized Digestive Tracts

Carnivorous invertebrates and vertebrates typically have short digestive tracts that produce fast-acting, meat-digesting enzymes. These enzymes can digest most cell types found in animal tissues.

No animal produces digestive enzymes that can break down the cellulose in plant tissue, however. Some herbivores have very long intestines or specialized pouches in their digestive tracts that harbor the kinds of symbiotic microorganisms discussed earlier.

Animals called ruminants, such as cattle, have a pouchlike extension of their esophagus called a **rumen** (plural: rumina), in which symbiotic bacteria digest cellulose. Ruminants regurgitate food that has been partially digested in the rumen, chew it again, and reswallow it. This process, called "chewing the cud," mechanically breaks down the food and exposes more surfaces to bacterial activity, which helps in digestion.

HS-LS1-1, HS-LS1-2, HS-LS1-3

LESSON 25.1 Review

KEY QUESTIONS

1. How might a person be affected if all the microorganisms living in his or her intestines died?
2. Describe how food is digested in a digestive cavity.
3. Describe the adaptations of the mouthparts of leaf eaters and meat eaters.

CRITICAL THINKING

4. **Use an Analogy** How is a digestive system like a "disassembly line," or an assembly line that acts to take apart a product instead of manufacturing it?
5. **Construct an Argument** The results of a laboratory test show that a type of bacteria called *E. coli* is living in the digestive tract of an animal. Do the results indicate that the animal is suffering a parasitic infection of *E. coli*? Cite evidence to support your argument.

Respiration

LESSON 25.2

A dolphin "breathes" through the blowhole on the top of its head.

KEY QUESTIONS

- *What characteristics do the respiratory structures of all animals share?*
- *How do aquatic animals breathe?*
- *What respiratory structures enable land animals to breathe?*

HS-LS1-1: Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins which carry out the essential functions of life through systems of specialized cells.
HS-LS1-2: Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.

VOCABULARY
gill
lung
alveolus

READING TOOL

Compare and contrast respiration in different types of animals. Fill in the chart in your **Biology Foundations Workbook.**

Cellular respiration requires oxygen and produces carbon dioxide as a waste product. So all animals must obtain oxygen from their environment and get rid of carbon dioxide. In other words, all animals need to breathe, or respire. Humans can drown because our lungs are not adapted to absorb sufficient amounts of oxygen from water. Most fishes have the opposite problem; out of water, their breathing structures don't work. How are these different respiratory systems adapted to their different environments?

Gas Exchange

Despite all the amazing things living cells can do, none can actively pump oxygen or carbon dioxide across membranes. Yet, in order to breathe, all animals must exchange oxygen and carbon dioxide with their surroundings. How do they do it? One way that animals have adapted to different environments is by evolving respiratory structures that promote the movement of these gases by passive diffusion.

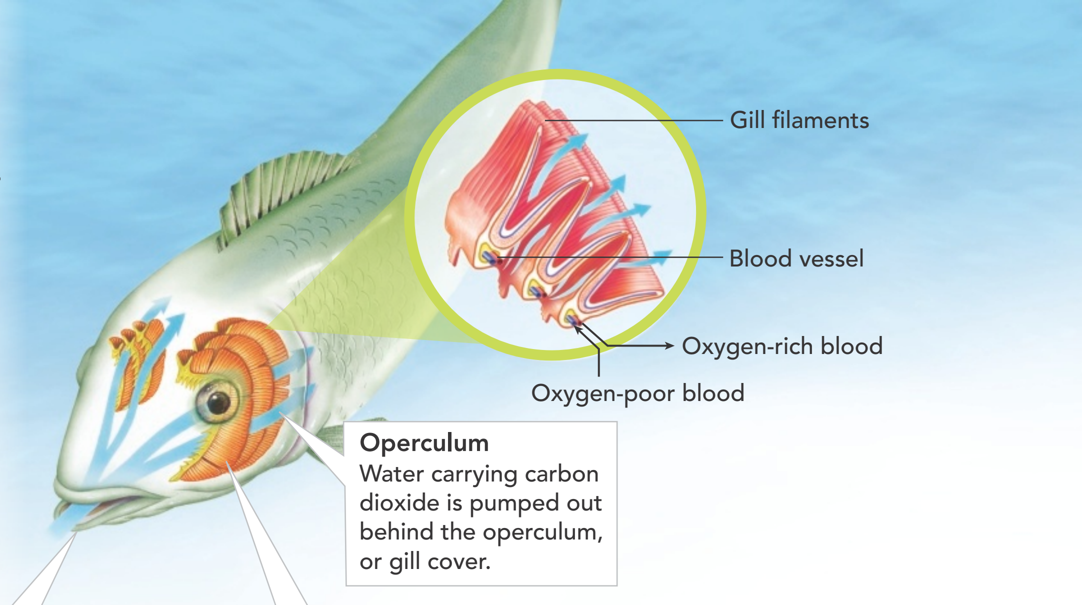
Gas Diffusion and Membranes Recall that substances diffuse from an area of higher concentration to an area of lower concentration. Gases diffuse most efficiently across a thin, moist membrane that is permeable to those gases. The larger the surface area of that membrane, the more diffusion can take place, just as a bumpy paper towel absorbs more liquid than a smooth one does. These principles of diffusion and absorption create a set of requirements that respiratory systems must meet.

Requirements for Respiration Because of the behavior of gases, all respiratory systems share certain basic characteristics. ***Respiratory structures provide a large surface area of moist, selectively permeable membrane. Respiratory structures maintain a difference in the relative concentrations of oxygen and carbon dioxide on either side of the respiratory membrane, promoting diffusion.***

Figure 25-5

Respiration with Gills

Many aquatic animals, such as fishes, respire with gills, which are thin, selectively permeable membranes. As water passes over the gills, gas exchange is completed within the gill capillaries.



INTERACTIVITY

Investigate fish respiration and the functioning of gills.

Respiratory Surfaces of Aquatic Animals

Some aquatic invertebrates, such as cnidarians and some flatworms, are relatively small and have thin-walled bodies whose outer surfaces are always wet. These animals rely on diffusion of oxygen and carbon dioxide through their outer body covering. A few aquatic chordates, including lancelets, some amphibians, and even some sea snakes, rely to varying extents on gas exchange by diffusion across body surfaces.

For large, active animals that consume much larger quantities of oxygen, skin respiration alone is not enough. ***Many aquatic invertebrates, fishes, and other animals exchange gases through gills.*** As shown in **Figure 25-5**, **gills** are feathery structures that expose a large surface area of thin, selectively permeable membrane to water. Inside the gill membranes is a network of tiny, thin-walled blood vessels called capillaries. Many animals, including aquatic mollusks and fishes, actively pump water over their gills as blood flows through inside. This helps maintain differences in oxygen and carbon dioxide concentrations that promote diffusion.

Aquatic reptiles and mammals breathe with lungs and must hold their breath underwater. **Lungs** are organs that exchange oxygen and carbon dioxide between blood and air. Aquatic animals with lungs include sea turtles, whales, dolphins, and manatees. All must come to the water's surface to breathe.

READING CHECK **Infer** Why do you think aquatic animals that rely on diffusion for respiration are often small in size?

Respiratory Surfaces of Terrestrial Animals

Land animals must keep their respiratory membranes moist in dry environments. They must also carry oxygen and carbon dioxide back and forth between those surfaces and the rest of their bodies. Interactions among several body systems are essential for this process.

BUILD VOCABULARY

Academic Words An interaction is when two different things act on each other, or do something that involves the other.

Respiratory Surfaces in Invertebrates The many body plans found among terrestrial invertebrates include many different strategies for respiration. ***Respiratory structures in terrestrial invertebrates include skin, mantle cavities, book lungs, and tracheal tubes.*** Some land invertebrates, such as earthworms, live in moist environments and can respire across their skin if it stays moist. Other invertebrates, such as land snails, respire using a mantle cavity lined with moist tissue and blood vessels. Insects and spiders have more complex respiratory systems, as you can see in **Figure 25-6**.

Lung Structure in Vertebrates ***All terrestrial vertebrates—reptiles, birds, mammals, and the land stages of most amphibians—breathe with lungs.*** Although lung structure in these animals varies, the processes of inhaling and exhaling are similar. Inhaling brings oxygen-rich air through the trachea, into the lungs. Inside the lungs, oxygen diffuses into the blood through lung capillaries. At the same time, carbon dioxide diffuses out of capillaries into the lungs. Oxygen-poor (and carbon dioxide-rich) air is then exhaled.

INTERACTIVITY

Compare different strategies for respiration.

Spider

Spiders respire using organs called book lungs, which are made of parallel, sheetlike layers of thin tissues that contain blood vessels.

Insect

In most insects, a system of tracheal tubes extends throughout the body. Air enters and leaves the system through openings in the body surface called spiracles. In some insects, oxygen and carbon dioxide diffuse through the tracheal system, and in and out of body fluids. In other insects, body movements help pump air in and out of the tracheal system.

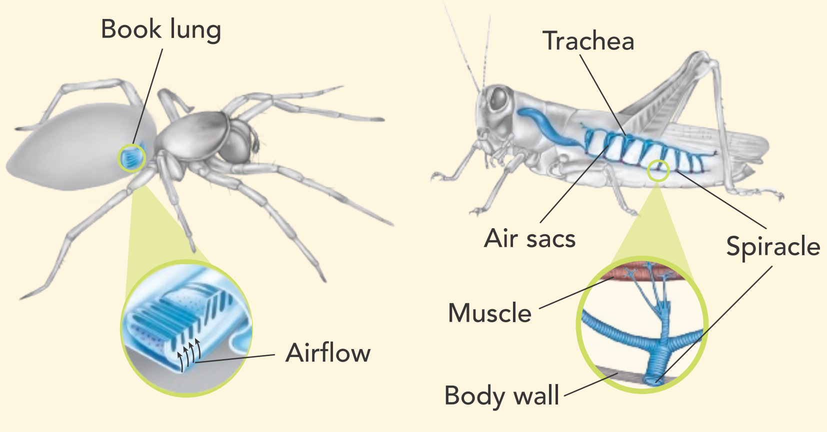
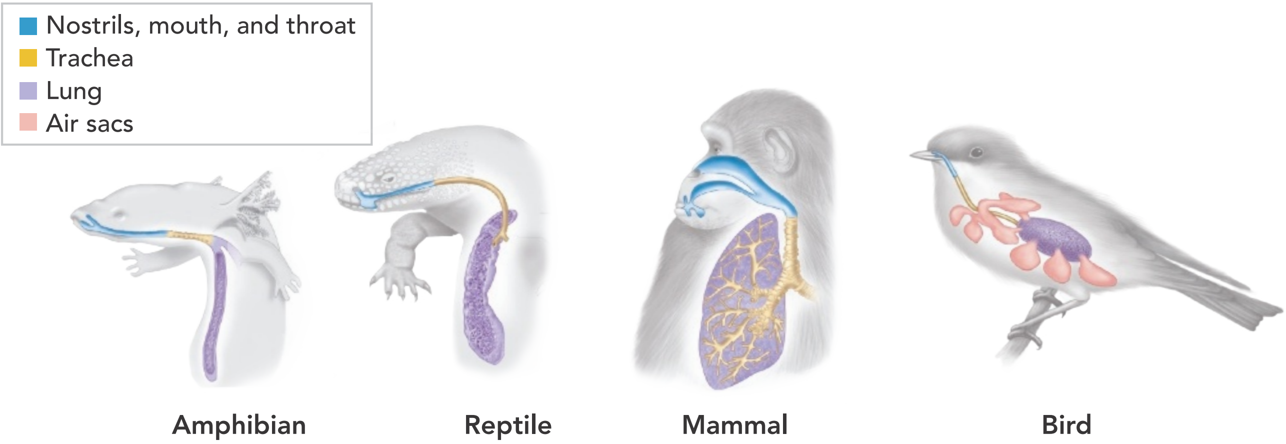


Figure 25-6

Respiratory Structures of Terrestrial Animals

Terrestrial invertebrates have a wide variety of respiratory structures, including skin, mantle cavities, book lungs, and tracheal tubes. These structures must stay moist even in the driest of conditions in order to function properly.



INTERACTIVITY

Figure 25-7

Lungs

Terrestrial vertebrates breathe with lungs. Lungs with a larger surface area can take in more oxygen and release more carbon dioxide.

Amphibian, Reptilian, and Mammalian Lungs The internal surface area of lungs increases from amphibians to reptiles to mammals, as shown in **Figure 25-7**. A typical amphibian lung is little more than a sac with ridges. Reptilian lungs are often divided into chambers that increase the surface area for gas exchange. Mammalian lungs branch extensively, and air passages branch and rebranch, ending in bubblelike structures called **alveoli** (singular: alveolus). Alveoli provide an enormous surface area for gas exchange. Alveoli are surrounded by a network of capillaries in which blood picks up oxygen and releases carbon dioxide. Mammalian lung structure helps take in the large amounts of oxygen required by high metabolic rates. When mammals and most other vertebrates breathe, air moves in and out through the same air passages, and some stale, oxygen-poor air remains. In humans, this stale air is typically equivalent to about one third of the air inhaled in a normal breath.

READING TOOL

Refer to **Figure 25-7** as you read about the lungs of amphibians, reptiles, and mammals. Use the figure to understand the differences in respiration structures between these types of animals.

Bird Lungs In birds, the lungs are structured so that air flows mostly in only one direction. No stale air gets trapped in the system. A unique system of tubes and air sacs in birds' respiratory systems enables this one-way airflow. Thus, gas exchange surfaces are continuously in contact with fresh air. This highly efficient gas exchange helps birds obtain the oxygen they need to power their flight muscles for long periods of time.

HS-LS1-1, HS-LS1-2

LESSON 25.2 Review

KEY QUESTIONS

1. In what ways are the respiratory structures of all animals similar?
2. Compare the functions of gills and lungs in aquatic animals.
3. How do terrestrial invertebrates and terrestrial vertebrates breathe?

CRITICAL THINKING

4. **Construct an Explanation** Why must whales hold their breath while they are underwater?
5. **Develop Models** To show gas exchange in the gills of a fish, why is it useful to include the mouth of the fish as well? (*Hint:* See **Figure 25-5**.)
6. **Compare and Contrast** How do lungs and airways compare among birds and mammals?

Circulation

LESSON 25.3


Blood vessels in the eye

KEY QUESTIONS
- *How do open and closed circulatory systems compare?*
- *How do the patterns of circulation in vertebrates compare?*

HS-LS1-1: Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins which carry out the essential functions of life through systems of specialized cells.
HS-LS1-2: Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.
HS-LS1-3: Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis.

VOCABULARY
heart
open circulatory system
closed circulatory system
atrium
ventricle

READING TOOL
Compare and contrast the four-chambered heart with the three-chambered heart in the chart in your **Biology Foundations Workbook.**

When you eat food, your digestive tract breaks it down. But how do energy and nutrients from food get to your cells? How does oxygen from your lungs get to other tissues? How do carbon dioxide and wastes get eliminated? Some aquatic animals with bodies only a few cell layers thick rely on diffusion to transport materials. But in most animals, oxygen, carbon dioxide, nutrients, and wastes are transported through a circulatory system that interacts with other body systems.

Open and Closed Circulatory Systems

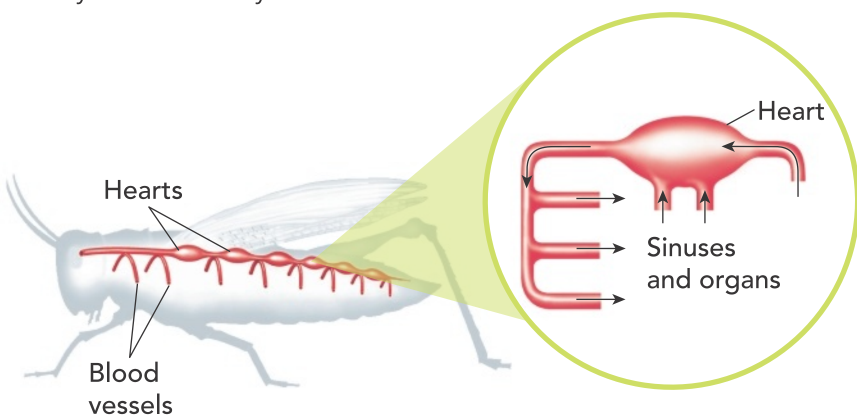
Many animals move blood through their bodies using one or more hearts. A **heart** is a hollow, muscular organ that pumps blood around the body. A heart can be part of any type of circulatory system.

Open Circulatory Systems

Arthropods and most mollusks have **open circulatory systems**. ***In open circulatory systems, hearts or heart-like organs pump blood through vessels that empty into a system of sinuses, or spongy cavities.*** Blood comes into direct contact with body tissues in those sinuses. Blood then collects in another set of sinuses and eventually makes its way back to the heart, as shown in **Figure 25-8**.

Figure 25-8
Open Circulatory System

In an open circulatory system, blood is not entirely contained within blood vessels. Grasshoppers, for example, have open circulatory systems in which blood leaves vessels and moves through sinuses before returning to a heart.



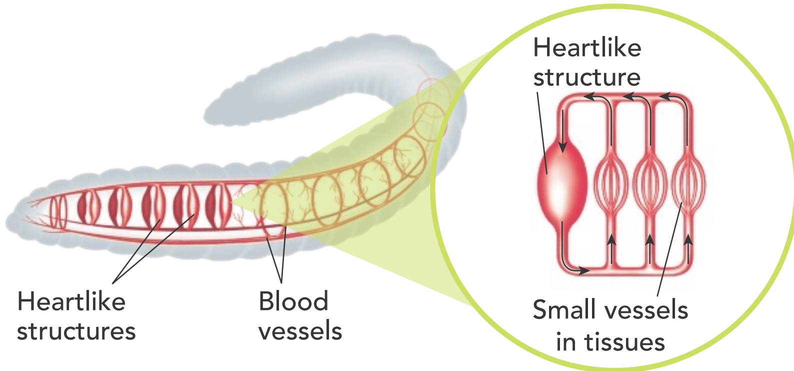


Figure 25-9

Closed Circulatory System

Annelids, such as earthworms, and many more complex animals have closed circulatory systems. Blood stays within the vessels of a closed circulatory system.

Closed Circulatory Systems Many larger, more active invertebrates, including annelids and some mollusks, and all vertebrates have **closed circulatory systems**, as shown in **Figure 25-9**. ***In closed circulatory systems, blood circulates entirely within blood vessels that extend throughout the body.*** A heart or heart-like organ pumps blood through the vessels. Nutrients and oxygen reach body tissues by diffusing across thin walls of capillaries, the smallest blood vessels. Blood that is completely contained within blood vessels can be pumped under higher pressure, and can be circulated more efficiently, than blood in an open system.

READING CHECK **Compare** How are open and closed circulatory systems alike and different?

Single- and Double-Loop Circulation

As chordates evolved, they evolved more complex organ systems and more efficient channels for internal transport. You can see two main types of circulatory systems of vertebrates in **Figure 25-10**.

ANIMATION

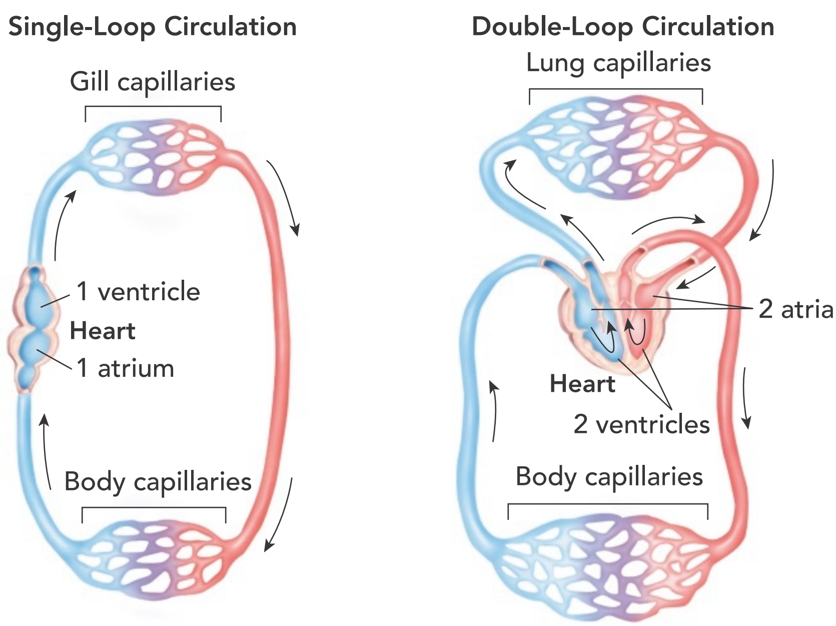


Figure 25-10

Single- and Double-Loop Circulation

Most vertebrates that use gills for respiration have a single-loop circulatory system that forces blood around the body in one direction. Vertebrates that use lungs have a double-loop system. (Note that in diagrams of animals' circulatory systems, blood vessels carrying oxygen-rich blood are red, while blood vessels carrying oxygen-poor blood are blue.)

Single-Loop Circulation ***Most vertebrates with gills have a single-loop circulatory system with a single pump that forces blood around the body in one direction.*** In fishes, for example, the heart consists of two chambers: an atrium and a ventricle. The **atrium** (plural: atria) receives blood from the body. The **ventricle** pumps blood out of the heart and to the gills. Oxygen-rich blood then travels from the gills to the rest of the body, and oxygen-poor blood returns to the atrium.

READING TOOL

As you read, make an ordered list to show how blood passes through the parts of the circulatory system.

Double-Loop Circulation As terrestrial vertebrates evolved into larger and more active forms, their capillary networks became larger. Using a single pump to force blood through the entire system would have been increasingly difficult and inefficient. ***Most vertebrates that breathe with lungs have evolved a double-loop, two-pump circulatory system.*** The first loop, powered by one side of the heart, forces oxygen-poor blood from the heart to the lungs. After the blood picks up oxygen and drops off carbon dioxide in the lungs, it returns to the heart. Then the other side of the heart pumps this oxygen-rich blood through the second circulatory loop to the rest of the body. Oxygen-poor blood from the body returns to the heart, and the cycle begins again.

BUILD VOCABULARY

Multiple Meanings An *atrium* can also be a large open area in a building, and people may gather there. In biology, the **atrium** is a chamber in the heart that receives blood.

Heart-Chamber Evolution Four-chambered hearts like those in modern mammals are actually two separate pumps working next to one another. But where did the second pump come from? During chordate evolution, partitions evolved that divided the original two chambers into four. Those partitions transformed one pump into two parallel pumps. The partitions also separated oxygen-rich blood from oxygen-poor blood. We can get an idea of how the partitions evolved by looking at other modern vertebrates.

INTERACTIVITY

Explore open and closed circulatory systems in animals.

Modeling Lab Guided Inquiry

Modeling Vertebrate Hearts

Problem How did hearts evolve in vertebrates?

In this lab, you will make models of several different vertebrate hearts. You will use the models to analyze the flow of blood in each of the hearts and identify the strengths and limitations of each heart model. Then you will infer how the heart developed as vertebrates evolved.

You can find this lab in your digital course.

Figure 25-11

Reptilian Heart

Under the armor-like hide of this crocodile lies a heart with four chambers, like those of birds and mammals. Although most reptiles have a single ventricle with a partial partition, in crocodiles and their close relatives the ventricle is fully partitioned into two chambers.

VIDEO

Compare the blood and circulatory systems of a variety of animals.

Amphibian Hearts Amphibian hearts usually have three chambers: two atria and one ventricle. The left atrium receives oxygen-rich blood from the lungs. The right atrium receives oxygen-poor blood from the body. Both atria empty into the ventricle. This undivided ventricle allows blood to be diverted away from the lungs when these animals dive under water. Some mixing of oxygen-rich and oxygen-poor blood in the ventricle occurs. However, the internal structure of the ventricle directs blood flow so that most oxygen-poor blood goes to the lungs, and most oxygen-rich blood goes to the rest of the body.

Reptilian Hearts Reptilian hearts typically have three chambers. However, most reptiles have a partial partition in their ventricle, or in some cases a full partition as in the crocodile in **Figure 25-11**. Because of this partition, there is even less mixing of oxygen-rich and oxygen-poor blood than there is in amphibian hearts.

Mammalian Hearts Four-chambered hearts like those in modern mammals are actually two separate pumps working next to one another. But where did the second pump come from? During chordate evolution, partitions evolved that divided the original two chambers into four. Those partitions transformed one pump into two parallel pumps. The partitions also separated oxygen-rich blood from oxygen-poor blood. We can get an idea of how the partitions evolved by looking at other modern vertebrates.

HS-LS1-1, HS-LS1-2, HS-LS1-3

LESSON 25.3 Review

KEY QUESTIONS

1. How does an open circulatory system differ from a closed circulatory system?
2. Explain the two different patterns of circulation found in vertebrates.

CRITICAL THINKING

3. **Evaluate Claims** A student observes a blood vessel in a grasshopper. Because the grasshopper has blood vessels, the student claims that it has a closed circulatory system. Evaluate the student's claim.
4. **Construct an Explanation** In closed circulatory systems, how are nutrients and oxygen transported from the blood to body cells? Does this transport occur in all parts of the system? Explain.
5. **Integrate Information** Describe the advantages of a four-chambered heart compared to hearts with two or three chambers.
6. **Develop Models** Make a model to illustrate how respiratory structures interact with double-loop circulatory structures to provide oxygen to body tissues.

Excretion

LESSON 25.4

Some aquatic animals, such as this flatworm, release ammonia as soon as they produce it.

KEY QUESTIONS

- *How do animals manage toxic nitrogenous waste?*
- *How do aquatic animals eliminate wastes?*
- *How do land animals remove wastes while conserving water?*

HS-LS1-2: Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.

VOCABULARY

excretion
kidney
nephridium
Malpighian tubule

READING TOOL

As you read each section of this lesson, briefly describe the main ideas and key takeaways in the graphic organizer in your **Biology Foundations Workbook.**

Cellular metabolism generates several kinds of wastes that are released into body fluids and that must be eliminated from the body. What are these wastes and how do animals get rid of them?

The Ammonia Problem

When cells break down proteins, they produce a nitrogen-containing waste in a poisonous form: ammonia. Even moderate concentrations of ammonia can kill most cells. Animal systems address this difficulty in one of two ways. ***Animals either eliminate ammonia from the body quickly or convert it into other compounds that are less toxic.*** The elimination of metabolic wastes, such as ammonia, is called **excretion**. Some small animals that live in wet environments, such as the flatworm in **Figure 25-12**, rid their bodies of ammonia by allowing it to diffuse out of their body fluids across their skin. Most larger animals, and even some smaller ones that live in dry environments, have excretory systems that process ammonia and eliminate it from the body.

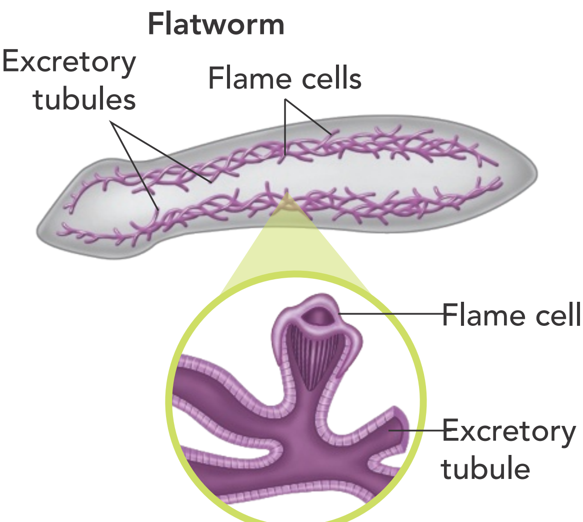


Figure 25-12

Eliminating Ammonia

Flatworms excrete ammonia directly into the water and use flame cells to remove excess water.

Figure 25-13

Other Nitrogen-Containing Compounds

Large and/or terrestrial animals either convert ammonia to uric acid and excrete it as sticky white guano, as these gulls do, or they convert ammonia into urea and release it, diluted, as urine.

Storing Wastes That Contain Nitrogen Animals that cannot dispose of ammonia as it is produced have evolved ways to hold, or "store," nitrogen-containing wastes until they can be eliminated. In most cases, ammonia is too toxic to be stored in body fluids. Insects, reptiles, and birds typically solve this problem by converting ammonia into a sticky white compound called uric acid, which you can see in **Figure 25-13**. Uric acid is much less toxic than ammonia and is also less soluble in water. Mammals and some amphibians, on the other hand, convert ammonia to a different nitrogen-containing compound—urea. Like uric acid, urea is less toxic than ammonia, but unlike uric acid, urea is highly soluble in water.

Maintaining Water Balance Getting rid of any type of nitrogen-containing waste involves water. For that reason, excretory systems interact with other systems involved in regulating water balance in blood and body tissues. In some cases, excretory systems eliminate excess water along with nitrogenous wastes. In other cases, excretory systems must eliminate nitrogenous wastes while conserving water.

Many animals use **kidneys** to separate wastes and excess water from blood in a fluid called urine. Kidneys must perform this function despite a serious limitation: No living cell can actively pump water across a membrane! You may recall that cells can pump ions across their membranes. Kidney cells pump ions from dissolved salts in blood in ways that create an osmotic gradient. Water then "follows" those ions passively by osmosis. This process can get rid of nitrogenous wastes and retain water, but leaves kidneys with one weakness: They usually cannot excrete excess salt.

READING CHECK Summarize How do kidneys help maintain water balance?

Excretion in Aquatic Animals

Aquatic animals have an advantage in getting rid of nitrogenous wastes because they are surrounded by water. ***In general, aquatic animals can allow ammonia to diffuse out of their bodies into surrounding water, which dilutes the ammonia and carries it away.*** But aquatic animals still face excretory challenges. Many have adaptations that either eliminate water from their bodies or conserve it, depending on whether they live in fresh or saltwater ecosystems, as summarized in **Figure 25-14**.

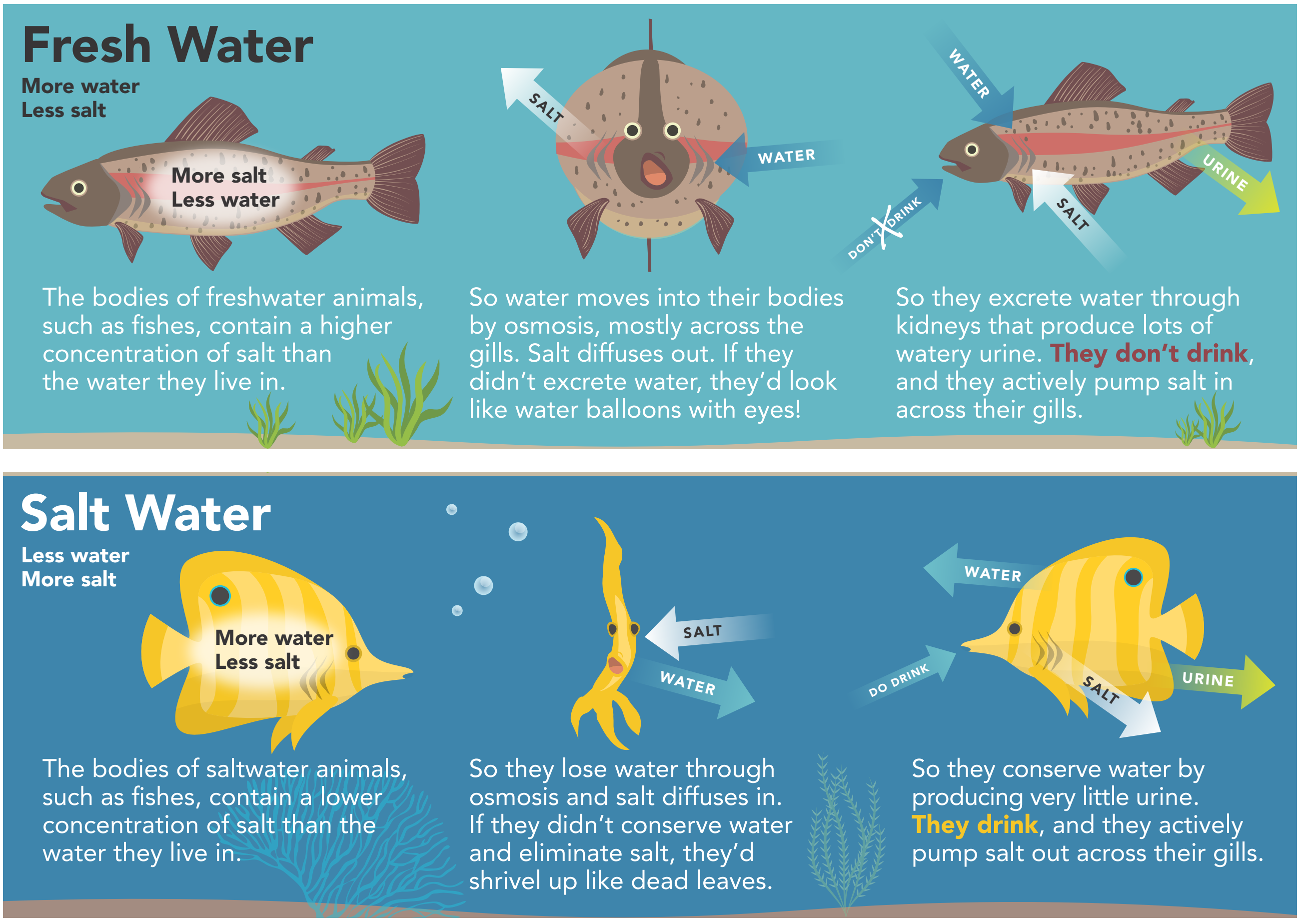
Quick Lab **Guided Inquiry**

Water and Nitrogen Excretion

1. Place 2 grams of urea in a test tube. Place 2 grams of uric acid in another test tube. Label the test tubes.
2. Add 15 mL of water to each test tube. Stopper and shake the test tubes for 3 minutes.
3. Observe each test tube. Record your observations.
4. Dispose of all chemicals as instructed by your teacher. Wash your hands with soap and warm water.

ANALYZE AND INTERPRET DATA

1. **Observe** Which substance—urea or uric acid—is less soluble in water? Explain how you know.
2. **Construct an Explanation** Reptiles excrete nitrogenous wastes in the form of uric acid. Explain how this adaptation helps reptiles survive on land.



Freshwater Animals Many freshwater invertebrates lose ammonia to their environment by simple diffusion across their skin. Many freshwater fishes and amphibians eliminate ammonia by diffusion across the same gill membranes they use for respiration.

But invertebrates and fishes that live in fresh water must excrete wastes while managing an osmotic challenge. The concentration of water surrounding their bodies is higher than the concentration of water in their body fluids. So water moves passively into their bodies by osmosis, and salt leaves by diffusion. Amphibians and freshwater fishes typically excrete excess water in very dilute urine, and pump salt actively inward across their gills.

Saltwater Animals Marine invertebrates and vertebrates typically release ammonia by diffusion across their body surfaces or gill membranes. Many marine invertebrates have body fluids with solute concentrations similar to that of the seawater around them. For that reason, these animals have less of a problem with water balance than freshwater invertebrates. Marine fishes, however, tend to lose water to their surroundings because their bodies are less salty than the water they live in. These animals actively excrete salt across their gills. Their kidneys also produce small quantities of urine—an adaptation that conserves water.

Visual Analogy

Figure 25-14

Excretion in Aquatic Animals

All animals must rid their bodies of ammonia while maintaining appropriate water balance. Freshwater and saltwater animals face very different challenges in this respect

Interpret Visuals What are two ways freshwater fishes avoid looking like "water balloons with eyes"?

Excretion in Terrestrial Animals

Land animals also face challenges. In dry environments, they can lose large amounts of water from respiratory membranes that must be kept moist. In addition, they must eliminate nitrogenous wastes in ways that require disposing of water—even though they may not have access to water to drink. **Figure 25-15** shows the excretory systems of some terrestrial animals.

Terrestrial Invertebrates ***Some terrestrial invertebrates, including annelids and mollusks, produce urine in nephridia.*** **Nephridia** (singular: nephridium) are tubelike excretory structures that filter body fluid. Typically, body fluid enters nephridia and becomes more concentrated as it moves through the tubes. Urine leaves the body through excretory pores. ***Other terrestrial invertebrates, such as insects and arachnids, convert ammonia into uric acid.*** Nitrogenous wastes, such as uric acid, are absorbed from body fluids by structures called **Malpighian tubules**. Then the wastes are added to digestive wastes traveling through the gut. The wastes lose water, and then crystallize into a thick paste. The paste leaves the body through the anus. This paste contains little water, so these adaptations minimize water loss.

Terrestrial Vertebrates In terrestrial vertebrates, excretion is carried out mostly by the kidneys. ***Mammals and land amphibians convert ammonia into urea, which is excreted in urine. In most reptiles and birds, ammonia is converted into uric acid.*** Reptiles and birds pass uric acid through ducts into a cavity that also receives digestive wastes from the gut. The walls of this cavity absorb most of the water from the wastes, causing the uric acid to separate out as white crystals. The result is a thick, milky-white paste that you would recognize as "bird droppings."

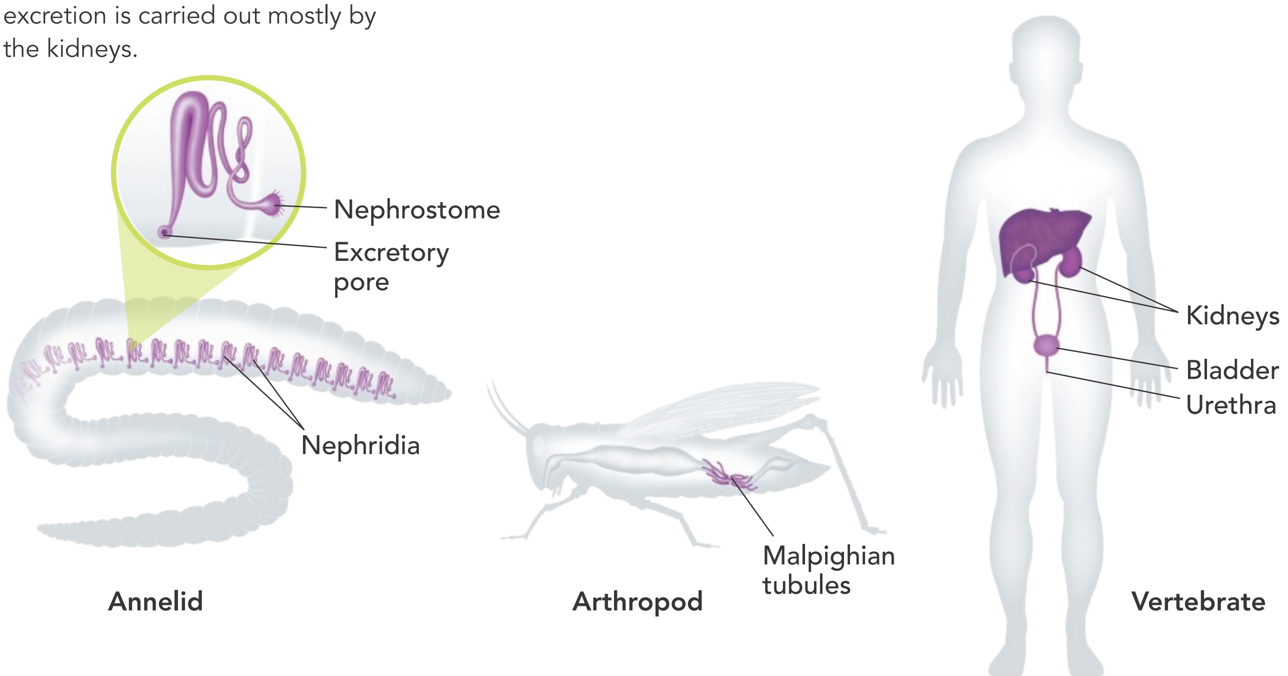
INTERACTIVITY

Investigate the different adaptations that animals have for excreting waste products and maintaining proper water balance.

Figure 25-15

Excretion in Terrestrial Animals

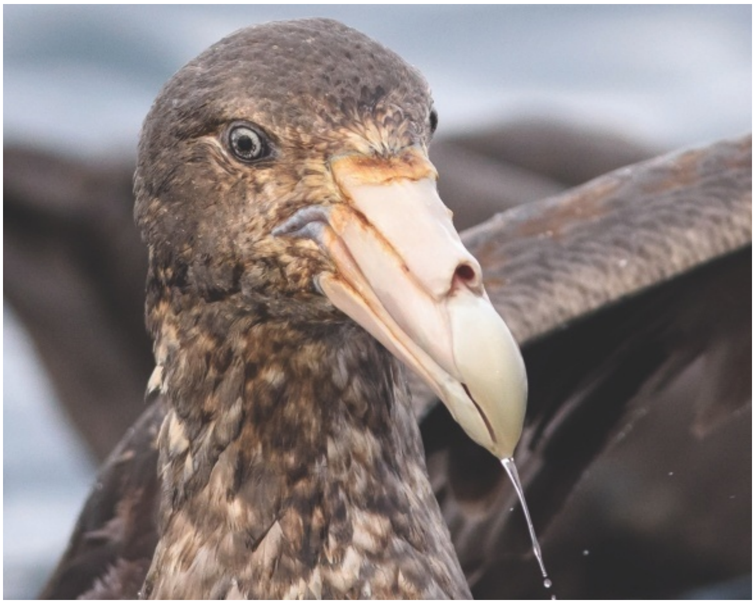
Some terrestrial invertebrates, such as annelids, rid their bodies of ammonia by releasing urine created in their nephridia. Some insects and arachnids have Malpighian tubules, which absorb uric acid from body fluids and combine it with digestive wastes. In vertebrates, such as humans, excretion is carried out mostly by the kidneys.



Adaptations to Extreme Environments Vertebrate kidneys are remarkable organs, but the way they operate results in some limitations. Most vertebrate kidneys, for example, cannot excrete concentrated salt. That's why most vertebrates cannot survive by drinking seawater. Taking in extra salt would overwhelm the kidneys, and the animal would die of dehydration. Some marine reptiles and birds, such as the petrel in **Figure 25-16**, have evolved adaptations in the form of specialized glands in their heads that excrete very concentrated salt solutions. Another excretory adaptation is found in the kangaroo rats of the American southwest. The kidneys of these desert rodents produce urine that is 25 times more concentrated than their blood! In addition, their intestines are so good at absorbing water that their feces are almost completely dry.

INTERACTIVITY

Analyze the ideal conditions needed for clam farming.



INTERACTIVITY

Figure 25-16

Excretion Adaptations

Some terrestrial animals that spend a large amount of time in salt water, such as this petrel, have special adaptations to excrete excess salt. Specialized salt glands produce a concentrated salt solution, which can sometimes be seen dripping out of their elongated nostrils.

HS-LS1-1, HS-LS1-2, HS-LS1-3

LESSON 25.4 Review

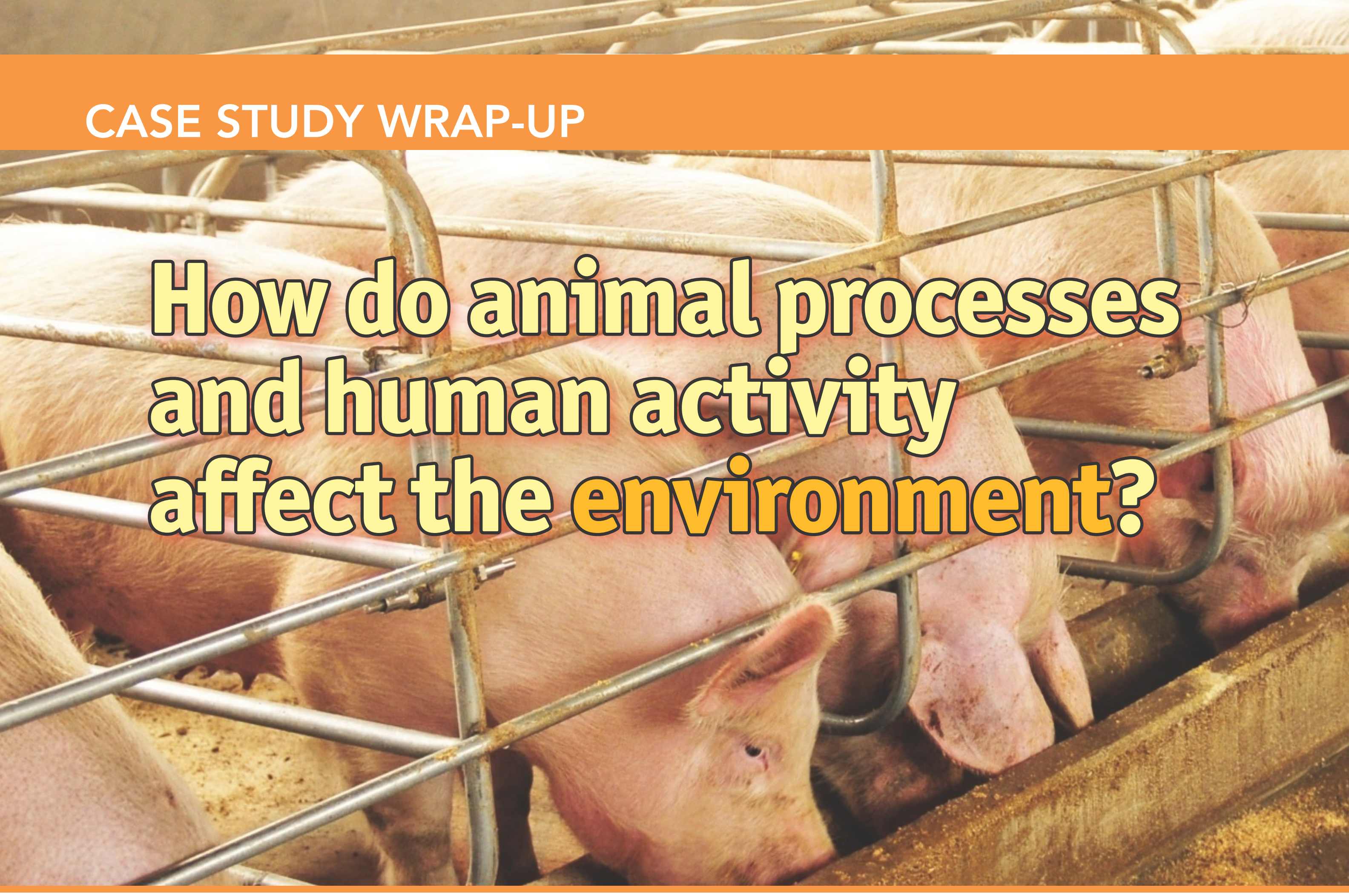
KEY QUESTIONS

1. Why does the metabolic waste ammonia pose a problem for all animals?
2. How do most aquatic animals remove ammonia?
3. In what form do (a) annelids and mollusks, (b) insects and arachnids, (c) mammals and land amphibians, and (d) reptiles and birds excrete nitrogenous wastes?

CRITICAL THINKING

4. **Compare and Contrast** How do the differing water balance needs of freshwater animals and saltwater animals explain the difference in their excretion of nitrogenous wastes?
5. **Develop Models** Make a model to illustrate how kidneys interact with other systems to help maintain homeostasis while processing nitrogenous wastes.
6. **Synthesize Information** Why are most terrestrial animals, including humans, not able to survive by drinking salt water?
7. **CASE STUDY** Predict how the wastes of large, crowded herds of cattle could affect surrounding ecosystems. (*Hint:* Recall what you learned about nutrient limitation.)

CASE STUDY WRAP-UP



How do animal processes and human activity affect the environment?

Vast herds of grazing animals once roamed Earth's grasslands. Can we learn from history to raise livestock in ways that make sense both ecologically and economically?

HS-LS2-7, HS-ESS3-4

Make Your Case

Ranchers on family farms have close connections to their land, and are learning to move herds around and keep them away from streams to minimize environmental impacts. Conservationists hoping to use management practices to store carbon in soil are learning that properly managed livestock can play an important role.

Develop a Solution

1. **Conduct Research** Use print or digital resources to research sustainable ranching. Using a variety of reliable sources, make a list of some of the benefits and possible drawbacks of some of the methods.
2. **Evaluate a Solution** Based on your research, how would you evaluate the progress so far in changing ranching practices? Write a short summary of your findings.

Society on the Case

Feedlot Frenzy

Around the world, livestock live for at least part of their lives in feedlots and other places where they are packed together under extremely crowded conditions. There, they eat grains (including corn) instead of grass or other kinds of food more like their ancestors' natural diets. The unnaturally crowded conditions create stress for the animals, and the unnatural diets affect their systems in various ways.

Critics argue that these kinds of agricultural practices are not sustainable, meaning that they cannot continue in the future without causing long-term problems. For example, life in feedlots enables infection-causing bacteria to hop easily from animal to animal. That situation is a threat to public health, and not just because it means the animals themselves can get sick easily. Many feedlot operations add significant amounts of antibiotics to animal feed, in part because those drugs help control infection, and in part because they act as growth stimulants.

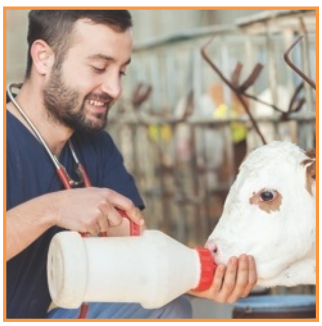
But the constant presence of antibiotics in crowded, bacteria-rich conditions is known to drive the evolution of antibiotic resistance. And once antibiotic-resistant bacterial populations evolve, they can spread from livestock to humans in a number of ways. The search for sustainable alternatives to feedlots is underway.

Careers on the Case

Work Toward a Solution

Understanding animal body systems is essential in any career that involves animals.

Animal Nutritionist



Every animal has its own dietary needs. Animal nutritionists study these needs, and they work to develop a cost-effective diet. Many animal nutritionists work for companies that make animal food. Others work for universities or government agencies.

VIDEO

Watch this video to learn about other careers in biology.

STUDY GUIDE

Lesson Review

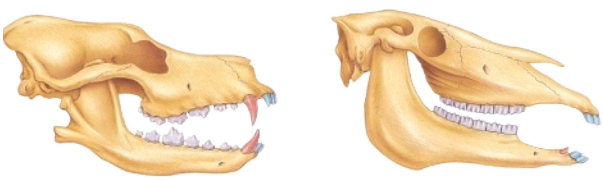
Go to your Biology Foundations Workbook for longer versions of these lesson summaries.

25.1 Feeding and Digestion

Adaptations for feeding on different foods in different ways have shaped the body structures of animals. Most filter feeders catch algae and small animals by using modified gills or other structures that filter food items out of water. Detritivores feed on detritus. Herbivores eat plants or algae. Carnivores eat other animals. Many animals rely on symbiosis for their nutritional needs.

Food must be digested and absorbed to make energy and nutrients available to body tissues. The simplest animals digest food inside specialized cells that pass nutrients to other cells by diffusion. More complex animals break food down outside cells in a digestive cavity or a digestive tract. Specialized mouthparts are related to the different characteristics of meat and plant leaves. Carnivores have sharp mouthparts that capture food and tear or slice it. Herbivores eat plants or algae. Because cellulose in plant tissues cannot be digested, some herbivores re-chew food after it has been partially digested in the rumen.

- digestive tract
- rumen



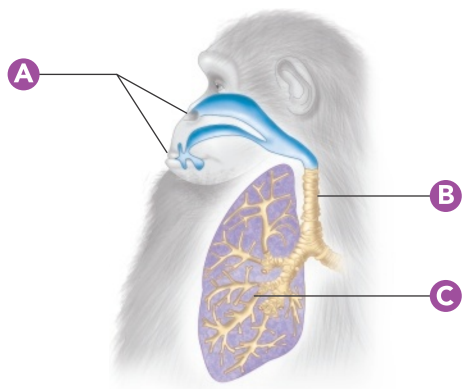
Compare and Contrast Which jaw is that of a carnivore? Which is the herbivore's? Explain how the differences in the structures relate to the types of food eaten by carnivores and herbivores.

25.2 Respiration

All animals must exchange oxygen and carbon dioxide with their surroundings. Gases diffuse most efficiently across a thin, moist membrane that is permeable to those gases. Respiratory structures provide a large surface area of moist, selectively permeable membranes. They maintain a difference in the relative concentrations of oxygen and carbon dioxide on either side of the respiratory membranes, promoting diffusion. Some aquatic animals rely on diffusion through their outer body covering. Many aquatic invertebrates exchange gases through gills. Some aquatic reptiles and mammals breathe with lungs and must hold their breath underwater.

Respiratory surfaces in terrestrial invertebrates include skin, mantle cavities, book lungs, and tracheal tubes. All terrestrial vertebrates breathe with lungs. Mammalian lungs branch extensively, with branches ending in alveoli that provide a large surface area for gas exchange. Bird lungs have evolved a system of tubes and air sacs that permit more efficient gas exchange, helping birds obtain the oxygen they need to power flight muscles for long periods of time.

- gill
- lung
- alveolus



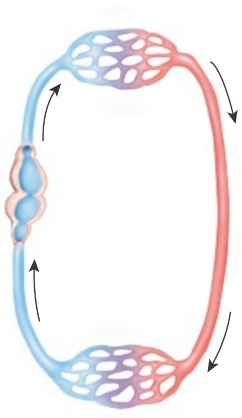
Identify What are the structures labeled A, B, and C? What are their functions in respiration?

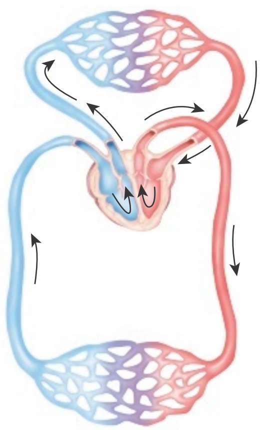
25.3 Circulation

Many animals move blood through their bodies using one or more hearts. A heart is a hollow, muscular organ that pumps blood. Open circulatory systems pump blood through vessels that empty into a system of sinuses or spongy cavities. In closed circulatory systems blood circulates entirely within blood vessels. Nutrients and oxygen reach body tissues by diffusing across thin walls of capillaries.

Most vertebrates with gills have a single-loop circulatory system with a single pump that circulates blood in one direction. Most vertebrates that breathe with lungs have a double-loop, two-pump circulatory system. One side of the heart pumps oxygen-poor blood from the heart to the lungs, where it picks up oxygen and drops off carbon dioxide. It returns to the other side of the heart, which pumps the oxygen-rich blood to the rest of the body.

- heart
- open circulatory system
- closed circulatory system
- atrium
- ventricle





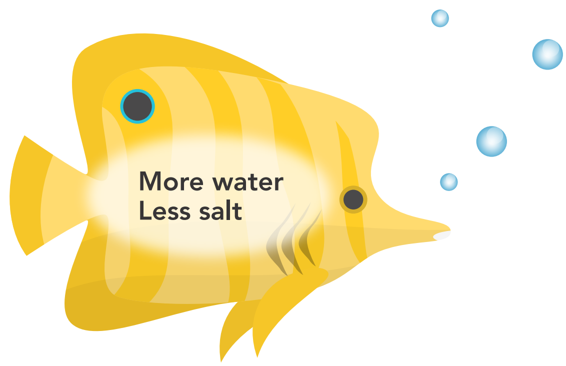
Compare and Contrast How are these two circulatory systems alike? How do they differ?

25.4 Excretion

When cells break down proteins, they produce ammonia. Ammonia is poisonous, so it must be either excreted quickly or converted to a less harmful form. Insects, reptiles, and birds convert ammonia to a white pasty compound called uric acid. Mammals and some amphibians convert ammonia to urea, which is soluble in water. Many animals use kidneys to separate wastes and excess water from blood in the fluid called urine. Aquatic animals can allow ammonia to diffuse out of their bodies into surrounding water. Saltwater animals must actively maintain their osmotic balance by excreting salt across their gills.

Some terrestrial invertebrates produce urine in tube-like excretory structures called nephridia. Insects and arachnids convert ammonia into uric acid, which is absorbed from body fluids by structures called Malpighian tubules. In many terrestrial vertebrates, kidneys generate urine that is excreted out of the body.

- excretion
- kidney
- nephridium
- Malpighian tubule



Interpret Visuals How does this saltwater fish maintain its osmotic balance?

Organize Information

Describe how each of these organ systems contributes to the maintenance of homeostasis.

Digestive	Respiratory	Circulatory	Excretory
1.	2.	3.	4.

PERFORMANCE-BASED ASSESSMENT

Design a Zoo Exhibit

Design a Solution

HS-LS2-7, HS-ETS1-2, HS-ETS1-3, CCSS.ELA-LITERACY.WHST.9-10.7, CCSS.ELA-LITERACY.WHST.9-10.8, CCSS.ELA-LITERACY.WHST.9-10.9

STEM Throughout the 1800s, zoos began opening in cities around the world. The zoos were founded to display wild animals to a curious public. Most animals were kept in cages or simple pens. Some animals were taught tricks to entertain visitors.

Today, zoos are more popular than ever. In the United States, more than 50 million people visit zoos every year. However, the purpose of zoos has grown beyond entertainment. Today, zoos promote the conservation of wildlife. Sometimes they act as a temporary stop for an animal before it is returned to the wild. Zoos may also become the last refuge for endangered animals, such as elephants, tigers, and baboons. The natural habitats of these animals have been disappearing. In the near future, only the artificial habitats in zoos may remain.

In this activity, you will design an animal exhibit for a zoo. This task is complex because the exhibit must meet many criteria. The exhibit should provide for the safety, health, and well-being of the animals it houses.

It must also allow visitors to observe and interact with the animals. Zookeepers must have access to the exhibit so that they can feed and care for the animals when necessary.

To begin, your teacher will assign one of the animals listed in the table. Alternatively, choose one of these animals or another wild animal that interests you. Then follow the steps to design and construct a model of a zoo exhibit.

Criteria for Animal Exhibits

Animal	Natural Habitat	Exhibit Criteria
Penguins	Coastlines of Antarctica, Southern Ocean	• Water and land • Aboveground and underwater viewing stations
Giraffes	African savanna	• Tall feeding platforms • Elevated viewing stations
Bats (many species)	Caves, forests	• Artificial day/night cycle, so viewers can see nocturnal activity

ENGINEERING PROJECT

1. **Define the Problem** In your own words, describe the problem that your design for a zoo exhibit should solve.
2. **Ask Questions** What questions would help you gather information to design the zoo exhibit? List at least three questions.
3. **Conduct Research** Use the Internet or print reference sources to research answers to the questions you asked. Find out about the animals' natural habitat, and how the animals are displayed in existing zoo or aquarium exhibits. Look for ideas that you could include or adapt in the exhibit you are designing.
4. **Identify Criteria** Review the criteria for a zoo exhibit. Add criteria that apply to the animal that you selected.
5. **Develop Possible Solutions** Discuss your ideas for the exhibit with group members. Draw sketches to illustrate your ideas and to help you revise them. Work as a group to agree on a plan that incorporates all useful ideas and suggestions. Make a sketch or simple blueprint to show the plan for the exhibit.
6. **Revise Solutions** Review the criteria that you listed in step 4. Evaluate your plan to see if it meets all the criteria. Revise your plan if necessary.
7. **Develop Models** Follow the plan you devised to construct a model of the animal exhibit. The model could be a detailed drawing, a virtual model on a computer, or a physical model built from simple materials. Your model should include the following features:
   - an enclosure for the animals
   - viewing stations or platforms for zoo visitors to observe the animals
   - descriptions of any unusual materials needed to construct the exhibit
   - a written explanation of the features of the model and how they meet the criteria
8. **Revise Your Model** Present your model to classmates, and ask them to evaluate and critique it. If appropriate, revise the model to incorporate useful suggestions.

CHAPTER 25

ASSESSMENT

KEY IDEAS AND TERMS

25.1 Feeding and Digestion

HS-LS1-1, HS-LS1-2, HS-LS1-3

1. Aquatic animals that strain plants and animals from the water that they live in are
   a. parasites.
   b. herbivores.
   c. detritus feeders.
   d. filter feeders.
2. Look at the teeth in the photograph. The sharp, pointed teeth in the lion's mouth are best suited for

   a. tearing meat.
   b. filtering plankton.
   c. grinding leaves.
   d. cracking seeds.
3. Describe the differences between the canine and molar teeth of herbivorous and carnivorous animals.
4. What is the difference between mechanical and chemical digestion?
5. How do vertebrate filter feeders obtain food?
6. Explain the function of the rumen in digestion. What advantage is provided to animals that have a rumen?

25.2 Respiration

HS-LS1-1, HS-LS1-2

7. Which of the following groups of animals has the most efficient gas exchange?
   a. amphibians
   b. reptiles.
   c. birds.
   d. mammals.
8. Gases diffuse most efficiently across a
   a. thin, moist, selectively permeable membrane.
   b. thin, dry, permeable membrane.
   c. thick, dry, selectively permeable membrane.
   d. thick, moist, impermeable membrane.
9. Why do whales and sea turtles come to the surface regularly to breathe?
10. How are some aquatic animals able to breathe without lungs or gills?
11. What respiratory organ is present in all terrestrial vertebrates?
12. What do skin, mantle cavities, book lungs, and tracheal tubes have in common?

25.3 Circulation

HS-LS1-1, HS-LS1-2, HS-LS1-3

13. A closed circulatory system is one in which
    a. blood spreads freely throughout the body's tissues.
    b. blood travels through a system of blood vessels that extend throughout the body.
    c. blood travels through blood vessels into spongy cavities called sinuses.
    d. blood travels through a system of blood vessels and air sacs.
14. Oxygen constantly diffuses from air or water into an animal's bloodstream. For this to happen, the concentration of oxygen in the blood must be
    a. greater than the concentration of oxygen in the air or water.
    b. greater than the concentration of carbon dioxide in the air or water.
    c. lower than the concentration of oxygen in the air or water.
    d. lower than the concentration of carbon dioxide in the air or water.
15. What are the different functions of the atrium and the ventricle?
16. How do the circulatory systems of arthropods and most mollusks differ from those of larger mollusks and all vertebrates?
17. What characteristic of the reptilian heart shows an evolutionary similarity toward the mammalian four-chambered heart?
18. You are dissecting an organism that has a three-chambered heart, but no partition in the ventricle. What type of animal are you likely working with?

25.4 Excretion

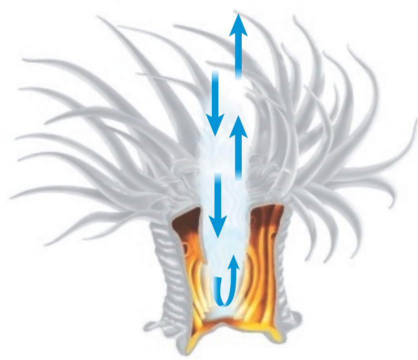
HS-LS1-1, HS-LS1-2, HS-LS1-3

19. Kidneys that can conserve water are essential to homeostasis because
    a. some animals live in dry or salty environments.
    b. some animals drink water.
    c. urea is not soluble in water.
    d. cells will be unable to convert ammonia into urea if excess water is excreted.
20. Insects convert ammonia to uric acid in their
    a. nephrons.
    b. nephridia.
    c. kidneys.
    d. Malpighian tubules.
21. What do animals do to eliminate ammonia from their bodies?
22. What is the difference in kidney function of freshwater fishes and saltwater fishes?
23. How do some desert animals overcome the disadvantage of excreting urine?
24. Why can drinking salt water kill an animal?

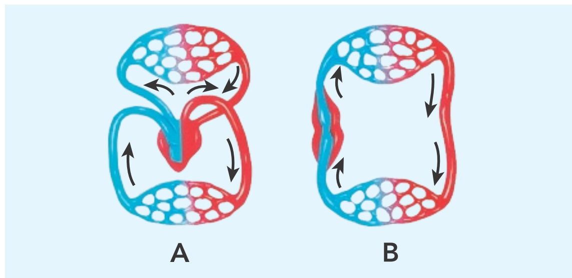
CRITICAL THINKING

HS-LS1-2

25. **Construct an Explanation** Why are fruits more commonly used as foods than the leaves of plants?
26. **Integrate Information** How is mutualistic symbiosis essential for human life? Include an example as evidence.
27. **Classify** In a cnidarian, water and food particles flow in and out of an interior space. Is this space classified as a digestive cavity or a digestive tract? Explain your answer.



28. **Ask Questions** Hummingbirds eat high-energy foods such as nectar. Many ducks eat foods that contain less energy, such as plant leaves. What are some research questions you could investigate to discover more about the diet of a bird species and its energy needs?
29. **Infer** A student is studying the skeleton of a large mammal. Which feature of the skeleton is most likely to be useful for classifying the animal as an herbivore or carnivore? Explain.
30. **Interpret Visuals** The diagrams represent two kinds of circulatory systems.



    a. Which diagram illustrates a heart with blood containing carbon dioxide but little oxygen?
    b. Which diagram shows the type of circulatory system that occurs with a four-chambered heart?
31. **Construct an Explanation** How do a fish's respiratory and circulatory systems work together to maintain homeostasis in the body as a whole?
32. **Critique** The textbook describes ammonia as a problem for organisms to solve. Critique this statement.
33. **Apply Concepts** Of all the nitrogenous wastes that animals generate, uric acid requires the least water to eliminate. Why is the production of uric acid an advantage to animals that live on land?
34. **Infer** How is it useful for tissues of the respiratory system to cover a large surface area?
35. **Evaluate Claims** A classmate claims that with enough time and food, an earthworm could grow as large as an alligator. How do you evaluate this claim? Apply facts about the earthworm's body systems to support your evaluation.
36. **Construct an Explanation** Kidneys are able to vary the concentration of urine they produce. How does this ability help an animal that lives in dry environments on land?

ASSESSMENT

CROSSCUTTING CONCEPTS

37. **Structure and Function** How do digestive tracts differ between grass-eating herbivores, such as cattle and sheep, and carnivores, such as lions and tigers? Explain this difference.

38. **Systems and System Models** How do the respiratory systems of fishes compare with those of animals that live on land?

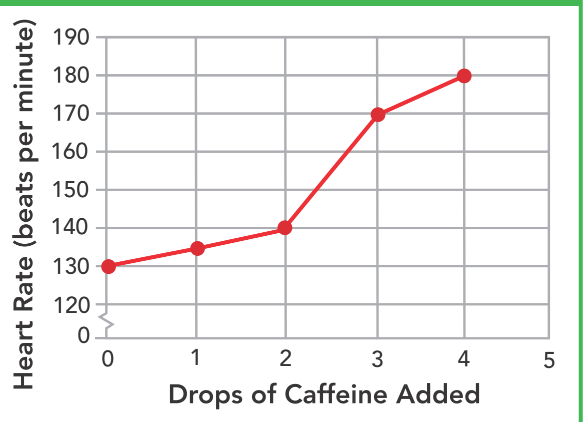
MATH CONNECTIONS

Analyze and Interpret Data

CCSS.MATH.CONTENT.MP.2

A student conducts an experiment to measure the effect of caffeine on the heart rate of a small pond-water crustacean called *Daphnia*. The heart of this animal is visible through its transparent shell. With the help of a dissecting microscope, the student counts the heartbeats per minute before and after adding increasing amounts of caffeine to the water surrounding the animal. Each data point in the graph represents the mean of five trials. Use the graph to answer questions 39 and 40.

***Daphnia* Heart Rate and Caffeine**



39. **Interpret Graphs** Describe the effect of caffeine on the heart rate of *Daphnia*.

40. **Predict** What would be your prediction of the effect of five or more drops of caffeine on the heart rate of *Daphnia*?

A researcher conducted an experiment to see how air temperature affects the speed at which a snake can hunt for food. The experimenter placed the snake a fixed distance away from a piece of food and recorded the air temperature. Then she recorded the time it took for the snake to reach the food. She repeated the experiment four times. Each time, the experimenter changed the air temperature. The data collected are shown in the data table.

The Effect of Temperature on Snake Hunting Speed

Temperature (°C)	Time (seconds)
4	51
10	50
15	43
21	37
27	35

41. **Interpret Tables** At what temperature did the snake reach the food the fastest?

42. **Analyze Data** How did the time to reach the food change as the temperature increased?

43. **Draw Conclusions** What conclusions about snake hunting and temperature can you draw from the data?

LANGUAGE ARTS CONNECTIONS

Write About Science

CCSS.ELA-LITERACY.WHST.9-10.2, HS-LS1-2

44. **Write Explanatory Texts** Write a paragraph to compare and contrast the structure and function of the fish heart and the mammal heart.

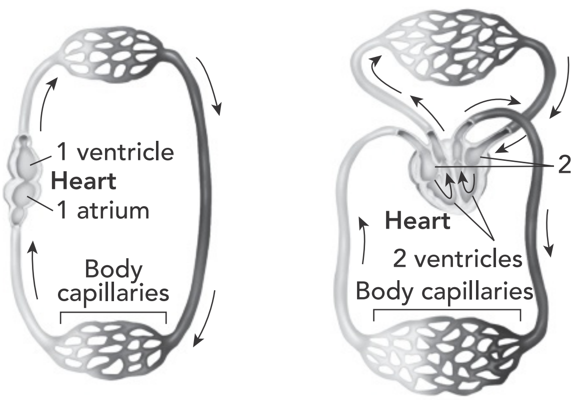
Read About Science

HS-LS1-2, CCSS.ELA-LITERACY.RST.9-10.1

45. **Cite Textual Evidence** How does a bird's specialized respiratory system provide an adaptation that helps it to fly? Cite evidence from this chapter to support your answer.

END-OF-COURSE TEST PRACTICE

1. The illustration below shows models of two different circulatory systems.



How do these models illustrate two body systems working together?

A. The heart of the circulatory system pumps oxygen-poor blood to the tissues of the excretory system so it can be excreted.

B. The heart of the circulatory system pumps oxygen-poor blood to the tissues of the respiratory system where the blood is oxygenated.

C. The heart of the circulatory system pumps blood to the tissues of the digestive system where the blood is oxygenated during digestion.

D. The ventricles of the respiratory system contract to force blood throughout the tissues of the circulatory system.

E. The ventricles of the respiratory system contract to force oxygenated air through the digestive system.

2. Which of the following is a relationship between the digestive system and another system that allows carnivores to eat meat?

A. The respiratory system has passages where food particles can enter the digestive system.

B. Food is digested inside specialized immune system cells that are in the digestive system.

C. Muscles within the digestive system contract to regurgitate partially digested meat.

D. The jaw bones of the skeletal system are specialized to chop meat and begin the process of digestion.

E. The circulatory system pumps food particles throughout the tissues of the digestive system.

3. Renee is creating a diagram of nitrogen metabolism in animals. How do animals get rid of their nitrogen-containing wastes?

A. they are removed from the blood in the lungs and exhaled

B. they are removed from the blood in the kidneys and excreted

C. they are digested by symbiotic microorganisms in the gut

D. they are converted to amino acids

E. they are converted to nucleic acids

ASSESSMENT

For additional assessment practice, go online to access your digital course.

If You Have Trouble With...			
Question	1	2	3
See Lesson	25.3	25.1	25.4
Performance Expectation	HS-LS1-2	HS-LS1-2	HS-LS1-2