



Vertebrate Animals

chapter preview

sections

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Lab Homes for Endangered Animals
-  **Virtual Lab** How are fish adapted to their environment?

Traits We Share With Animals

An eagle flies through the sky, a salmon swims through a stream, a snake slithers along the ground, and a grizzly bear walks along a river's edge. Each of these animals appears different, but these animals, as well as humans, share a common trait—an internal skeleton.

Science Journal What other traits do these animals and humans share?

Start-Up Activities



Animals with a Backbone

An internal skeleton is common to many animals. Skeletons are made of bones or cartilage. They give your body its overall shape and work with your muscles to help move your body. **WARNING:** Do not eat or drink anything in the lab.

1. Use pasta wheels, soft-candy circles, and long pipe cleaners to make a model of a backbone.
2. On a pipe cleaner, string in an alternating pattern the pasta wheels and the soft-candy circles until the string is about 10 cm long.
3. Fold over each end of the pipe cleaner so the pasta and candy do not slide off.
4. **Think Critically** Slowly bend the model. Does it move easily? How far can you bend it? What do you think makes up your backbone? Write your observations and answers in your Science Journal.



FOLDABLES™ Study Organizer

Vertebrates Make the following Foldable to help you organize your thoughts about vertebrate animals before you begin reading.

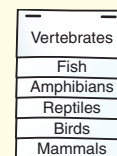
- STEP 1** **Collect** three sheets of paper and layer them about 1.25 cm apart vertically. Keep the edges level.



- STEP 2** **Fold** up the bottom edges of the paper to form 6 equal tabs.



- STEP 3** **Fold** the papers and crease well to hold the tabs in place. Staple along the fold. **Label** the flaps *Vertebrates, Fish, Amphibians, Reptiles, Birds, and Mammals*, as shown.



Sequence Before you read the chapter, write what you know about each group under the tabs. As you read the chapter, add to or change the information you wrote under the tabs.



Preview this chapter's content and activities at red.msscience.com



Chordate Animals

as you read

What You'll Learn

- **Identify** the major characteristics of chordates.
- **List** the major characteristics common to all vertebrates.
- **Explain** the difference between ectotherms and endotherms.
- **Name** the characteristics of the three classes of fish.

Why It's Important

You and other vertebrate animals have an internal skeleton that supports and protects your internal organs.



Review Vocabulary

invertebrate: an animal without a backbone

New Vocabulary

- chordate
- endotherm
- ectotherm
- cartilage

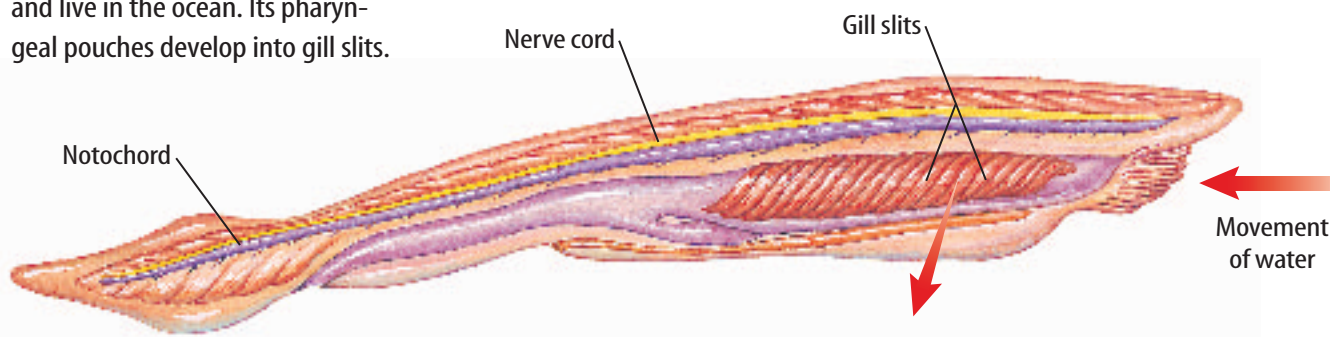
What is a chordate?

Suppose you asked your classmates to list their pets. Dogs, cats, birds, snakes, and fish probably would appear on the list. Animals that are familiar to most people are animals with a backbone. These animals belong to a larger group of animals called chordates (KOR days). Three characteristics of all **chordates** are a notochord, a nerve cord, and pharyngeal pouches at some time during their development. The notochord, shown in **Figure 1**, is a flexible rod that extends along the length of the developing organism. Pharyngeal pouches are slitlike openings between the body cavity and the outside of the body. They are present only during the early stages of the organism's development. In most chordates, one end of the nerve cord develops into the organism's brain.

Vertebrates Scientists classify the 42,500 species of chordates into smaller groups, as shown in **Figure 2**. The animals within each group share similar characteristics, which may indicate that they have a common ancestor. Vertebrates, which include humans, are the largest group of chordates.

Vertebrates have an internal system of bones called an endoskeleton. *Endo-* means “within.” The vertebrae, skull, and other bones of the endoskeleton support and protect internal organs. For example, vertebrae surround and protect the nerve cord. Many muscles attach to the skeleton and make movement possible.

Figure 1 Lancelets are filter feeders that grow to 7 cm in length and live in the ocean. Its pharyngeal pouches develop into gill slits.



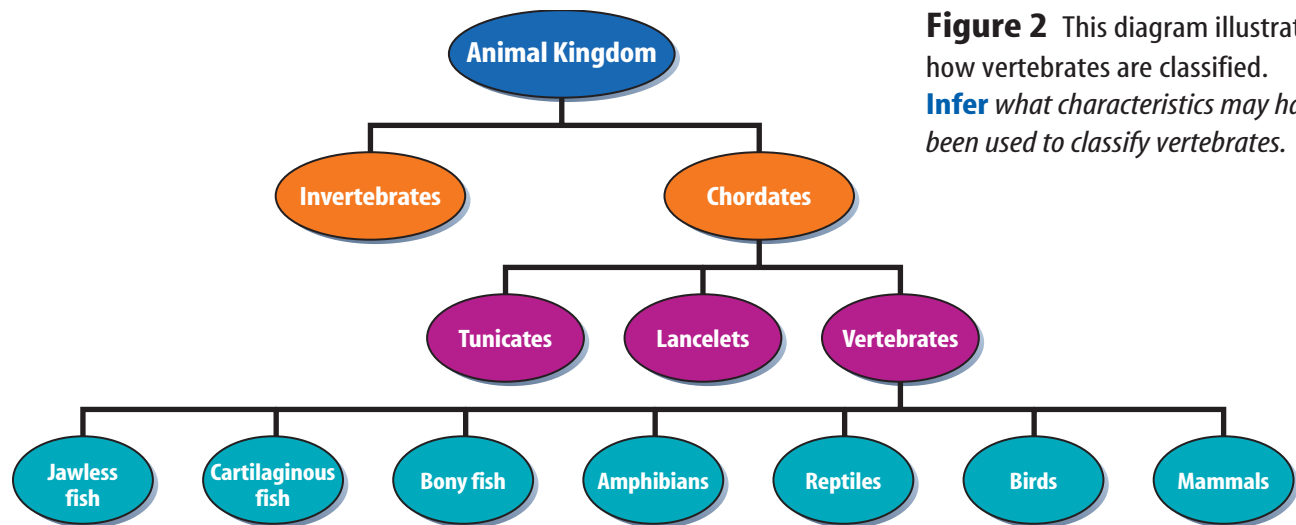


Figure 2 This diagram illustrates how vertebrates are classified. **Infer** what characteristics may have been used to classify vertebrates.

Body Temperature Most vertebrate body temperatures change as the surrounding temperature changes. These animals are **ectotherms** (EK tuh thurmz), or cold-blooded animals. Fish are examples of ectotherms.

Humans and many other vertebrates are **endotherms** (EN duh thurmz), or warm-blooded animals. Their body temperature doesn't change with the surrounding temperature. Your body temperature is usually about 37°C, but it can vary by about 1°C, depending on the time of day. Changes of more than a degree or two usually indicate an infection or overexposure to extreme environmental temperatures.

 **Reading Check** Are humans endotherms or ectotherms?

Fish

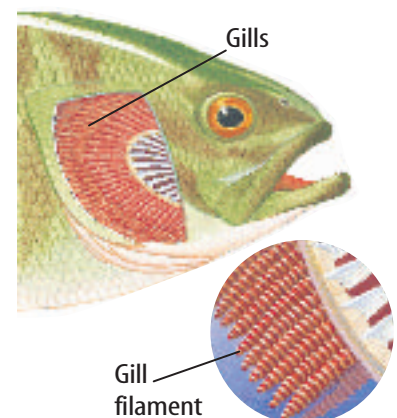
The largest group of vertebrates—fish—lives in water. Fish are ectotherms that can be found in warm desert pools and the subfreezing Arctic Ocean. Some species are adapted to swim in shallow freshwater streams and others in salty ocean depths.

Fish have fleshy filaments called gills, shown in **Figure 3**, where carbon dioxide and oxygen are exchanged. Water, containing oxygen, flows over the gills. When blood is pumped into the gills, the oxygen in the water moves into the blood. At the same time, carbon dioxide moves out of the blood in the gills and into the water.

Most fish have pairs of fanlike fins. The top and the bottom fins stabilize the fish. Those on the sides steer and move the fish. The tail fin propels the fish through the water.

Most fish have scales. Scales are thin structures made of a bony material that overlap like shingles on a house to cover the skin.

Figure 3 Gas exchange occurs in the gill filaments.





Changing Mass Submarines pump water into and out of special chambers, which causes the submarine to sink or rise. In a similar way, gases move into and out of a fish's swim bladder. This allows the fish to sink or rise in the water. How do fish without swim bladders move up and down in the water? Write your answer in your Science Journal.

Types of Fish

Scientists classify fish into three groups—bony, jawless, and cartilaginous (kar tuh LA juh nuhs)—which are illustrated in **Figure 4** on the opposite page. Bony fish have skeletons made of bone, while jawless fish and cartilaginous fish have endoskeletons made of cartilage. **Cartilage** (KAR tuh lihj) is a tough, flexible tissue that is similar to bone but is not as hard or brittle. Your external ears and the tip of your nose are made of cartilage.

Bony Fish About 95 percent of all fish have skeletons made of bone. Goldfish, trout, bass, and marlins are examples of bony fish. The body structure of a typical bony fish is shown in **Figure 5**. As a bony fish swims, water easily flows over its body because its scales are covered with slimy mucus.

If you've ever watched fish in a tank, you know that they rise and sink to different levels in the water. An important adaptation in most bony fish is the swim bladder. This air sac helps control the depth at which the fish swims. The swim bladder inflates and deflates as gases—mostly oxygen in deep-water fish and nitrogen in shallow-water fish—move between the swim bladder and the blood. As the swim bladder fills with gas, the fish rises in the water. When the gas leaves the bladder, it deflates and the fish sinks lower in the water.

Most bony fish use external fertilization (fur tuh luh ZAY shun) to reproduce. External fertilization means that the eggs are fertilized outside the female's body. Females release large numbers of eggs into the water. Then, a male swims over the eggs, releases the sperm into the water, and many eggs are fertilized.

Figure 5 The many types of bony fish range in size from a few millimeters to many meters in length.

Infer why all bony fish might have the same basic body plan.

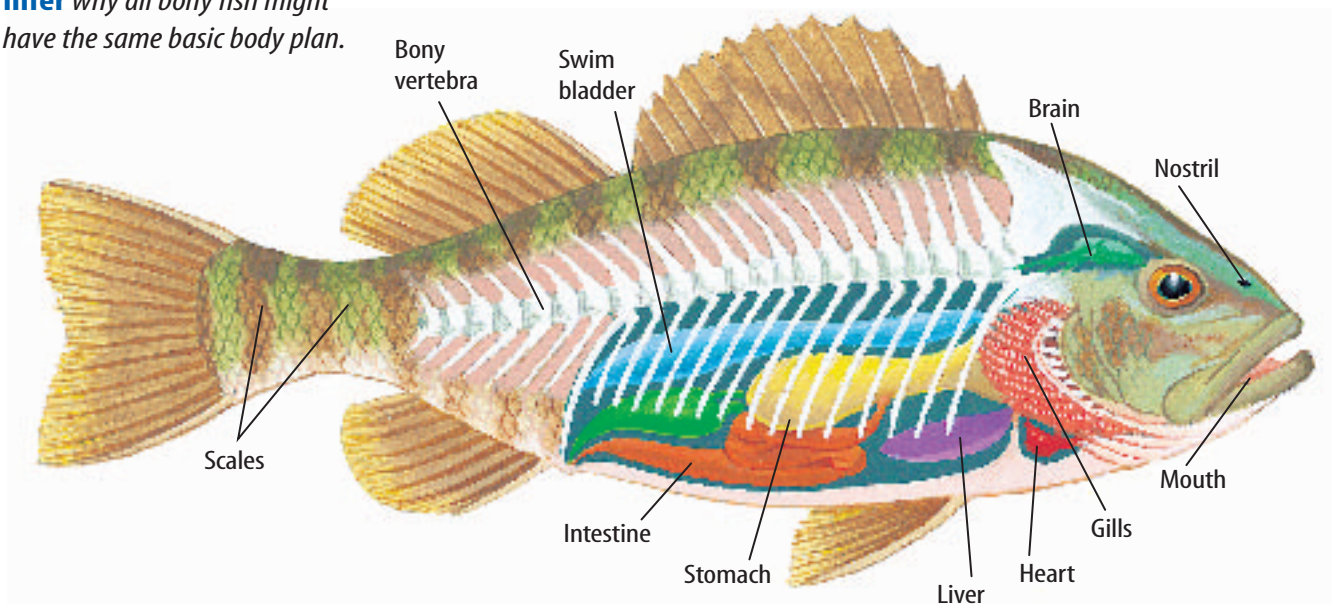


Figure 4

Fish are the most numerous and varied of all vertebrates, with more than 20,000 living species. These species can be organized into three groups—jawless, cartilaginous, and bony. Jawless fish are the most primitive and form the smallest group. Cartilaginous fish include more than 600 species, nearly all of them predators. Bony fish are the most numerous and diverse group. This page features photos of fish from each group.



Sturgeon



Whale Shark



Ratfish

CARTILAGINOUS FISH The cartilage that gives these fish their shape is a lightweight material that is softer than bone. The hammerhead shark below has been known to use the cartilage in its hammer-shaped head to pin down stingrays, one of its favorite meals, before it devours them.

Electric Ray



Hammerhead shark

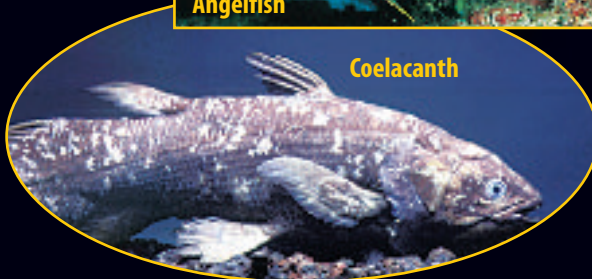
Wolf Eel



BONY FISH The bodies of bony fish vary. The fins of the coelacanth below have jointed bones, like the legs of many land animals. Amphibians may have evolved from ancestors of coelacanths.



Angelfish



Coelacanth

JAWLESS FISH Only about 70 species make up the jawless group of fish. Jawless fish are often parasitic. The hagfish, right, often crawls into fish trapped in nets and eats them from the inside out.

Hagfish





The inside of a lamprey's mouth contains structures that are used to attach to larger fish.

Figure 6 Lampreys are specialized predators. In places such as the Great Lakes, lampreys have caused a decrease in some fish populations.

Jawless and Cartilaginous Fish Only a few species of fish are classified as jawless fish, like the one in **Figure 6**. Jawless fish have scaleless, long, tubelike bodies; an endoskeleton made of cartilage; and a round, muscular mouth without a jaw. But the mouth contains sharp, toothlike structures. One type of jawless fish, the lamprey, attaches itself to a larger host fish using its strong mouth and toothlike structures. Its tongue has sharp ridges that scrape through the host fish's skin. The lamprey obtains nutrients by feeding on the host fish's blood.

Sharks, skates, and rays are cartilaginous fish. They have skeletons made of cartilage just like the jawless fish. However, cartilaginous fish have rough, sandpaperlike scales and movable jaws. Many sharks have sharp teeth made from modified scales. Most cartilaginous fish are predators.

section 1 review

Summary

Chordate

- All chordates have a notochord, a nerve cord, and pharyngeal pouches at some time during their development.
- A vertebrate is a chordate with an internal system of bones called an endoskeleton.
- Most vertebrates are ectotherms (cold-blooded animals), but humans and many other vertebrates are endotherms (warm-blooded animals).

Fish

- Fish are ectotherms that live in the water and belong to the largest group of vertebrates.

Types of Fish

- About 95 percent of all fish have bony skeletons.
- Lampreys, sharks, skates, and rays are fish with a skeleton made of cartilage.

Self Check

1. **List** the three groups of fish. What are some of the differences that separate these groups?
2. **Compare and contrast** ectothermic and endothermic animals.
3. **Form a Hypothesis** Sharks don't have swim bladders and must move constantly or they sink. Hypothesize about the amount of food that a shark must eat compared to the amount eaten by a bony fish of the same size.
4. **Think Critically** In one lake, millions of fish eggs are laid and fertilized annually. Why doesn't the lake become overcrowded with fish?

Applying Math

5. **Make and Use Graphs** Make a circle graph of the number of fish species currently classified: *jawless fish*—70; *cartilaginous fish*—820; and *bony fish*—23,500.

Amphibians and Reptiles

Amphibians

A spy might lead a double life, but what about an animal? Amphibians (am FIIH bee unz) are animals that spend part of their lives in water and part on land. In fact, the term *amphibian* comes from the Greek word *amphibios*, which means “double life.” Frogs, toads, newts, and salamanders, such as the red-spotted salamander pictured in **Figure 7**, are examples of amphibians.

Amphibian Adaptations Living on land is different from living in water. Think about some of the things an amphibian must deal with in its environment. Temperature changes more quickly and more often in air than in water. More oxygen is available in air than in water. However, air doesn’t support body weight as well as water does. Amphibians are adapted for survival in these different environments.

Amphibians are ectotherms. They adjust to changes in the temperature of their environment. In northern climates where the winters are cold, amphibians bury themselves in mud or leaves and remain inactive until the warmer temperatures of spring and summer arrive. This period of cold-weather inactivity is called **hibernation**. Amphibians that live in hot, dry environments move to cooler, more humid conditions underground and become inactive until the temperature cools down. This period of inactivity during hot, dry summer months is called **estivation** (es tuh VAY shun).

as you read

What You’ll Learn

- **Describe** how amphibians have adapted to live in water and on land.
- **Explain** what happens during frog metamorphosis.
- **Identify** the adaptations that allow reptiles to live on land.

Why It’s Important

Amphibians are sensitive to environmental changes, which may help identify problems that could affect humans.



Review Vocabulary

metamorphosis: change of body form that can be complete (egg, larva, pupa, adult) or incomplete (egg, nymph, adult)

New Vocabulary

- hibernation
- estivation
- amniotic egg



Figure 7 Amphibians have many adaptations that allow for life both on land and in the water. This red-spotted salamander spends most of its life on land. **Explain** why they must return to the water.



Topic: Amphibians

Visit red.msscience.com for Web links to information about the environment and amphibians.

Activity List as many possible causes of amphibian declines as you can find. Explain why it is important to humans to determine what could be causing these declines.

Amphibian Characteristics Amphibians are vertebrates with a strong endoskeleton made of bones. The skeleton helps support their body while on land. Adult frogs and toads have strong hind legs that are used for swimming and jumping.

Adult amphibians use lungs instead of gills to exchange oxygen and carbon dioxide. This is an important adaptation for survival on land. However, because amphibians have three-chambered hearts, the blood carrying oxygen mixes with the blood carrying carbon dioxide. This mixing makes less oxygen available to the amphibian. Adult amphibians also exchange oxygen and carbon dioxide through their skin, which increases their oxygen supply. Amphibians can live on land, but they must stay moist so this exchange can occur.

Amphibian hearing and vision also are adapted to life on land. The tympanum (TIHM puh nuhm), or eardrum, vibrates in response to sound waves and is used for hearing. Large eyes assist some amphibians in capturing their prey.



Reading Check

What amphibian senses are adapted for life on land?

Land environments offer a great variety of insects as food for adult amphibians. A long, sticky tongue extends quickly to capture an insect and bring it into the waiting mouth.

Figure 8 Most young amphibians, like these tadpoles, look nothing like their parents when they hatch. The larvae go through metamorphosis in the water and eventually develop into adult frogs that live on land.



Tadpoles hatch from eggs that are laid in or near water.



Tadpoles use their gills for gas exchange.



Amphibian Metamorphosis Young animals such as kittens and calves are almost miniature versions of their parents, but young amphibians do not look like their parents. A series of body changes called metamorphosis (me tuh MOR fuh sus) occurs during the life cycle of an amphibian. Most amphibians go through a metamorphosis, as illustrated in **Figure 8**. Eggs are laid most often in water and hatch into larvae. Most adult amphibians live mainly on land.

The young larval forms of amphibians are dependent on water. They have no legs and breathe through gills. Over time, they develop body structures needed for life on land, including legs and lungs. The rate at which metamorphosis occurs depends on the species, the water temperature, and the amount of available food. If food is scarce and the water temperature is cool, then metamorphosis will take longer.

Like fish, most amphibians have external fertilization and require water for reproduction. Although most amphibians reproduce in ponds and lakes, some take advantage of other sources of water. For example, some species of rain forest tree frogs lay their eggs in rainwater that collects in leaves. Even more unusual is the Surinam toad shown in **Figure 9**. The fertilized eggs are placed on the mother's back. Her skin swells and covers the eggs to keep them moist. After metamorphosis occurs, fully formed toads emerge from under her skin.

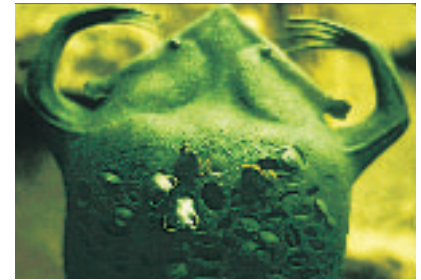


Figure 9 Surinam toads live along the Amazon River. A female carries 60 to 100 fertilized eggs on her back. Complete metamorphosis takes 12 to 20 weeks.

Explain how this would be an advantage for young Surinam toads.



Legs begin to develop. Soon, the tail will disappear.



An adult frog uses lungs and skin for gas exchange.



Figure 10 Reptiles have different body plans.

The rubber boa is one of only two species of boas in North America. Rubber boas have flexible jaws that enable them to eat prey that is larger than their head.



Crocodiles and American alligators like this one build their nests on land near a body of water. They protect their eggs while they wait for them to hatch.



Sea turtles, like this loggerhead turtle, are threatened around the world because of pollution, loss of nesting habitat, drowning in nets, and lighted beaches.

Colorado desert fringe-toed lizards are camouflaged, which helps them avoid their predators. These lizards mostly eat insects, but some include plants in their diet.



Reptiles

Reptiles come in many shapes, sizes, and colors. Snakes, lizards, turtles, and crocodiles are reptiles. Reptiles are ectothermic vertebrates with dry, scaly skin. Because reptiles do not depend on water for reproduction, most are able to live their entire lives on land. They also have several other adaptations for life on land.

Types of Reptiles As shown in **Figure 10**, reptilian body plans vary. Turtles are covered with a hard shell, into which they withdraw for protection. Turtles eat insects, worms, fish, and plants.

Alligators and crocodiles are predators that live in and near water. These large reptiles live in warmer climates such as those found in the southern United States.

Lizards and snakes make up the largest group of reptiles. They have a highly developed sense of smell. An organ in the roof of the mouth senses molecules collected by the tongue. The constant in-and-out motion of the tongue allows a snake or lizard to smell its surroundings. Lizards have movable eyelids and external ears, and most lizards have legs with clawed toes. Snakes don't have eyelids, ears, or legs. Instead of hearing sounds, they feel vibrations in the ground.

INTEGRATE Career

Herpetologist Most people are familiar with herpetologists, who are responsible for naming and classifying reptiles and amphibians. They often work in museums or universities. Their work usually involves field trips and gathering information for publication. What methods do taxonomists use to determine relationships between organisms? Write your answer in your Science Journal.



Reptile Adaptations A thick, dry, waterproof skin is an adaptation that reptiles have for life on land. The skin is covered with scales that reduce water loss and help prevent injury.

Reading Check What are two functions of a reptile's skin?

All reptiles have lungs for exchanging oxygen and carbon dioxide. Even sea snakes and sea turtles, which can stay submerged for long periods of time, must eventually come to the surface to breathe. Reptiles also have a neck that allows them to scan the horizon.

Two adaptations enable reptiles to reproduce successfully on land—internal fertilization and laying shell-covered, amniotic (am nee AH tihk) eggs. During internal fertilization, sperm are deposited directly into the female's body. Water isn't necessary for reptilian reproduction.

The embryo develops within the moist protective environment of the **amniotic egg**, as shown in **Figure 11**. The yolk supplies food for the developing embryo, and the leathery shell protects the embryo and yolk. When eggs hatch, young reptiles are fully developed. In some snake species, the female does not lay eggs. Instead, the eggs are kept within her body, where they incubate and hatch. The young snakes leave her body soon after they hatch.



Figure 11 Young reptiles hatch from amniotic eggs. **Describe** the advantages of this.

section 2 review

Summary

Amphibians

- Amphibians are animals that spend part of their lives in water and part on land.
- Although they have a strong endoskeleton to support their body while on land, amphibians depend on water for external fertilization.
- Amphibians go through a series of bodily changes called metamorphosis.

Reptiles

- Reptiles are ectothermic vertebrates with dry, scaly skin.
- Lizards and snakes make up the largest group of reptiles.
- Two adaptations enable reptiles to reproduce successfully on land: internal fertilization and laying shell-covered, amniotic eggs.

Self Check

1. **Infer** how a thick, dry, waterproof skin helps a reptile to live on land.
2. **Sequence** the steps of a frog's two-stage metamorphosis.
3. **Infer** why internal fertilization is efficient.
4. **Explain** how amphibians use adaptations to deal with cold winter months and hot, dry summer months.
5. **Think Critically** Some nonpoisonous snakes' patterns are similar to those of poisonous snakes. How is this coloring an advantage for a nonpoisonous snake?

Applying Skills

6. **Compare and contrast** the exchange of oxygen and carbon dioxide in adult amphibians and reptiles.
7. **Communicate** Write an explanation about why amphibians must live in wet or moist environments.

Frog Metamorphosis

Frogs and other amphibians use external fertilization to reproduce. Female frogs lay hundreds of jellylike eggs in water. Male frogs then fertilize these eggs. Once larvae hatch, the process of metamorphosis begins.

Real-World Question

What changes occur as a tadpole goes through metamorphosis?

Goals

- Observe** how body structures change as a tadpole develops into an adult frog.
- Determine** how long metamorphosis takes.

Materials

4-L aquarium or jar	aquatic plants
frog egg mass	washed gravel
lake or pond water	lettuce
stereoscopic microscope	(previously boiled)
watch glass	large rock
small fishnet	

Safety Precautions



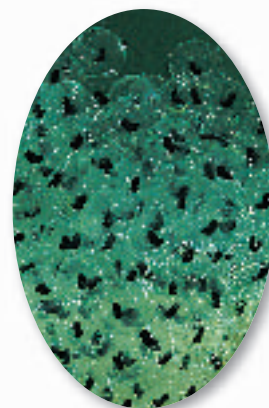
WARNING: Handle the eggs with care.

Procedure

- Copy the data table in your Science Journal.

Frog Metamorphosis	
Date	Observations
	Do not write in this book.

- As a class, use the aquarium, pond water, gravel, rock, and plants to prepare a water habitat for the frog eggs.
- Place the egg mass in the aquarium's water. Use the fishnet to separate a few eggs from the mass and place them on the watch glass. Observe the eggs using the microscope. Record all observations in your data table. Return the eggs to the aquarium.
- Observe** the eggs twice a week until hatching begins. Then observe the tadpoles twice weekly. Identify the mouth, eyes, gill cover, gills, nostrils, back fin, and legs.
- In your Science Journal, write a description of how tadpoles eat cooled, boiled lettuce.



Conclude and Apply

- Explain** why the jellylike coating around the eggs is important.
- Compare** the eyes of young tadpoles with the eyes of older tadpoles.
- Calculate** how long it takes for eggs to hatch, legs to develop, and to become a frog.

Communicating Your Data

Draw the changes you observe as the egg hatches and the tadpole goes through metamorphosis. For more help, refer to the **Science Skill Handbook**.

Birds

Characteristics of Birds

Ostriches have strong legs for running, and pelicans have specialized bills for scooping fish. Penguins can't fly but are excellent swimmers, and house wrens and hummingbirds are able to perch on branches. These birds are different, but they, and all birds, have common characteristics. Birds are endothermic vertebrates that have two wings, two legs, and a bill or beak. Birders, or bird-watchers, can tell where a bird lives and what it eats by looking at the type of wings, feet, and beak or bill it has. Birds are covered mostly with feathers—a feature unique to birds. They lay hard-shelled eggs and sit on these eggs to keep them warm until they hatch. Besides fish, birds are the most numerous vertebrates on Earth. **Figure 12** illustrates some of the more than 8,600 species of birds and their adaptations.

Figure 12 Emus can't fly but they have strong legs and feet that are adapted for running.

Horned puffins can fly and their sleek bodies and small, pointed wings also enable them to "fly" underwater.



An albatross glides in the air.

Birds of prey, like this osprey, have sharp, strong talons that enable them to grab their prey.

as you read

What You'll Learn

- **Identify** the characteristics of birds.
- **Describe** the adaptations birds have for flight.
- **Explain** the function of feathers.

Why It's Important

Humans modeled airplanes after the flight of birds.

Review Vocabulary

appendage: structure such as a claw, leg, or antenna that grows from the body

New Vocabulary

- contour feather
- down feather



Figure 13 Wings provide an upward force called lift in both birds and airplanes.



Bald eagles are able to soar for long periods of time because their wings have a large surface area to provide lift.



The glider gets lift from its wings the same way a bald eagle gets lift.



Topic: Wing Designs

Visit red.mssscience.com for Web links to information about wing designs of different aircraft.

Activity Draw as many wing designs as you can find and explain how they are different.

Adaptations for Flight

The bodies of most birds are designed for flight. They are streamlined and have light yet strong skeletons. The inside of a bird's bone is almost hollow. Internal crisscrossing structures strengthen the bones without making them as heavy as mammal bones are. Because flying requires a rigid body, a bird's tail vertebrae are joined together to provide the needed rigidity, strength, and stability. Birds use their tail to help them steer through the air. While a bird can still fly without a tail, their flight is usually shorter and not as smooth.



Reading Check

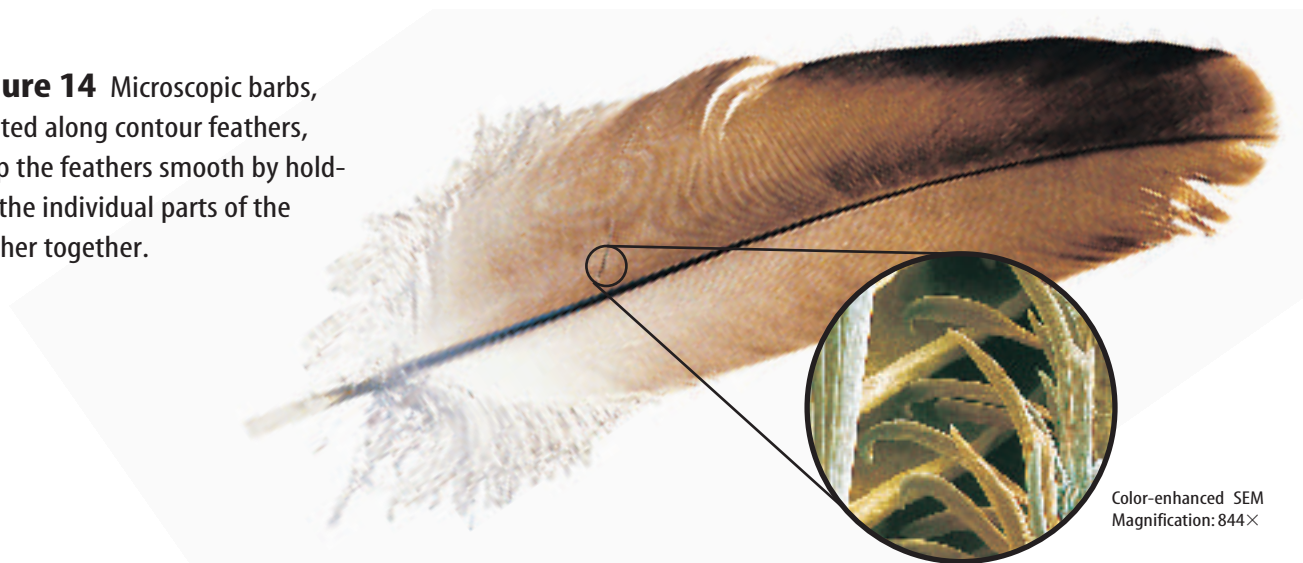
What advantage do birds' bones give them for flight?

Flight requires a lot of energy and oxygen. Birds eat insects, nectar, fish, meats, or other high-energy foods. They also have a large, efficient heart and a specialized respiratory system. A bird's lungs connect to air sacs that provide a constant supply of oxygen to the blood and make the bird more lightweight.

Slow-motion video shows that birds beat their wings up and down as well as forward and back. A combination of wing shape, surface area, air speed, and angle of the wing to the moving air, along with wing movements, provide an upward push that is needed for the flight of a bald eagle, as shown in **Figure 13**. Inventors of the first flying machines, such as gliders, used the body plan of birds as a model for flight. As wind passes above and below the wing, it creates lift. Lift is what allows birds, as well as planes, to stay in flight.



Figure 14 Microscopic barbs, located along contour feathers, keep the feathers smooth by holding the individual parts of the feather together.



Functions of Feathers

Birds are the only animals with feathers. They have two main types of feathers—contour feathers and down feathers. Strong, lightweight **contour feathers** give adult birds their streamlined shape and coloring. A close look at the contour feather in **Figure 14** shows the parallel strands, called barbs, that branch off the main shaft. Outer contour feathers help a bird move through the air or water. It is these long feathers on the wings and tail that help the bird steer and keep it from spinning out of control. Feather colors and patterns can help identify species. They also are useful in attracting mates and protecting birds from predators because they can be a form of camouflage.

Have you ever noticed that the hair on your arm stands up on a cold day? This response is one way your body works to trap and keep warm air close to your skin. Birds have **down feathers** that trap and keep warm air next to their bodies. These fluffy feathers, as shown in **Figure 15**, provide an insulating layer under the contour feathers of adult birds and cover the bodies of some young birds.



Reading Check

What are two ways feathers protect birds?

Figure 15

Some species of birds, like chickens and these pheasants, are covered with feathers when they hatch. **Explain** how this might be an advantage.



Modeling Feather Function

Procedure

1. Wrap **polyester fiber** or **cotton** around the bulb of an **alcohol thermometer**. Place it into a **plastic bag**. Record the temperature in your **Science Journal**.
2. Place a second **alcohol thermometer** into a **plastic bag** and record the temperature.
3. Simultaneously submerge the thermometers into a **container of cold water**, keeping the top of each bag above the water's surface.
4. After 2 min, record the temperature of each thermometer.

Analysis

1. Which thermometer had the greater change in temperature?
2. Infer the type of feather that the fiber or cotton models.





Figure 16 Cormorants' feathers get wet when they go underwater to catch fish. When they return to their roost, they have to hold their wings out to dry.



Care of Feathers Clothes keep you warm only if they are dry and in good condition. In a similar way, well-maintained feathers keep birds dry, warm, and able to fly. Birds preen to clean and reorganize their feathers. During preening, many birds also spread oil over their bodies and feathers. This oil comes from a gland found on the bird's back at the base of its tail. The oil helps keep the skin soft, and feathers and scales from becoming brittle. The oil does not waterproof the feathers as once thought. It is the arrangement of a feather's microscopic structures that repels water more than the oil does. Cormorants, like the one in **Figure 16**, have wettable outer feathers that must be air-dried after diving for food.

section 3 review

Summary

Characteristics of Birds

- Birds are endothermic vertebrates, have two wings, two legs, and a bill or beak, and are covered mostly with feathers.

Adaptations for Flight

- Birds are streamlined and have light, yet strong, skeletons.
- The inside of a bird's bone is almost hollow.
- Wings provide an upward force called lift.

Functions of Feathers

- Birds have contour feathers that help them move through the air or water.
- Down feathers trap and keep warm air next to birds' bodies.

Self Check

1. **List** several reasons why birds preen their feathers.
2. **Describe** how a bird's skeletal system, respiratory system, and circulatory system all work together to enable it to fly.
3. **Think Critically** Explain why birds can reproduce in Antarctica when temperatures are below 0°C.

Applying Math

4. **Use an Electronic Spreadsheet** During every 10 seconds of flight, a crow beats its wings 20 times, a robin 23 times, a chickadee 270 times, and a hummingbird 700 times. Use a spreadsheet to find out how many times the wings of each bird beat during a 5-minute flight.

Mammals

Mammal Characteristics

How many different kinds of mammals can you name? Moles, dogs, bats, dolphins, horses, and people are all mammals. They live in water and in many different climates on land. They burrow through the ground and fly through the air.

Mammals are endothermic vertebrates. They have mammary glands in their skin. In females, mammary glands produce milk that nourishes the young. A mammal's skin usually is covered with hair that insulates its body from cold and heat. It also protects the animal from wind and water. Some mammals, such as bears, are covered with thick fur. Others, like humans, have only patches of thick hair while the rest of their body is sparsely covered with hair. Still others, like the dolphins shown in **Figure 17**, have little hair. Wool, spines, quills, and certain horns are modified hair. What function do you think quills and spines serve?

Mammary Glands Mammals put a great deal of time and energy into the care of their young, even before birth. When female mammals are pregnant, the mammary glands increase in size. After birth, milk is produced and released from these glands. For the first weeks or months of a young mammal's life, the milk provides all of the nutrition the young mammal needs.

as you read

What You'll Learn

- **Identify** the characteristics common to all mammals.
- **Explain** how mammals are adapted to the different environments on Earth.
- **Distinguish** among monotremes, marsupials, and placentals.

Why It's Important

All mammals have similar body structures.

Review Vocabulary

symmetry: refers to the arrangement of the individual parts of an object that can be divided into matching halves

New Vocabulary

- | | |
|-------------|--------------|
| ● herbivore | ● monotremes |
| ● carnivore | ● marsupial |
| ● omnivore | ● placental |



Porcupines have fur next to their skin but sharp quills on the outside. Quills are modified hairs.



Dolphins do not have much hair on their bodies. A layer of fat under the skin acts as insulation.

Figure 17 The type of hair mammals have varies from species to species.

Explain the advantages and disadvantages of having hair.



Figure 18 Mountain lions are carnivores. They have sharp canines that are used to rip and tear flesh.



Humans are omnivores. They have incisors that cut vegetables, premolars that are sharp enough to chew meat, and molars that grind food.

Herbivores, like this beaver, have incisors that cut vegetation and large, flat molars that grind it.



Mini LAB

Inferring How Blubber Insulates

Procedure

1. Fill a **self-sealing plastic bag** about one-third full with solid **vegetable shortening**.
2. Turn another **self-sealing plastic bag** inside out. Place it inside the first bag so you are able to zip one bag to the other. This is a blubber mitten.
3. Put your hand in the blubber mitten. Place your mittened hand in **ice water** for 5 s. Remove the blubber mitten when finished.
4. Put your other bare hand in the same bowl of ice water for 5 s.

Analysis

1. Which hand seemed colder?
2. Infer the advantage a layer of blubber would give in the cold.

Different Teeth Mammals have teeth that are specialized for the type of food they eat. Plant-eating animals are called **herbivores**. Animals that eat meat are called **carnivores**, and animals that eat plants and animals are called **omnivores**. As shown in **Figure 18**, you usually can tell from the kind of teeth a mammal has whether it eats plants, other animals, or both. The four types of teeth are incisors, canines, premolars, and molars.



Reading Check

How are herbivores, carnivores, and omnivores different?

Body Systems Mammals live active lives. They run, swim, climb, hop, and fly. Their body systems must interact and be able to support all of these activities.

Mammals have well-developed lungs made of millions of microscopic sacs called alveoli, which enable the exchange of carbon dioxide and oxygen during breathing. They also have a complex nervous system and are able to learn and remember more than many other animals. The brain of a mammal is usually larger than the brain of other animals of the same size.

All mammals have internal fertilization. After an egg is fertilized, the developing mammal is called an embryo. Most mammal embryos develop inside a female organ called the uterus. Mammals can be divided into three groups based on how their embryos develop. The three groups of mammals are monotremes, marsupials, and placentals.



Mammal Types

The duck-billed platypus, shown in **Figure 19**, along with two species of echidnas (ih KID nuhs)—spiny anteaters—belong to the smallest group of mammals called the monotremes. They are different from other mammals because **monotremes** lay eggs with tough, leathery shells instead of having live births. The female incubates the eggs for about ten days. Monotremes also differ from other mammals because their mammary glands lack nipples. Instead, the milk seeps through the skin onto their fur. The young monotremes then nurse by licking the milk from the fur surrounding the mammary glands. Duck-billed platypuses and spiny anteaters are found in New Guinea and Australia.



Figure 19 Duck-billed platypuses and spiny anteaters are the only species of mammals that lay eggs.

Applying Math

Working with Percentages

HOW MUCH TIME? It is estimated that during the four months elephant seals spend at sea, 90 percent of their time is spent underwater. On a typical day, how much of the time between the hours of 10:00 A.M. and 3:00 P.M. does the elephant seal stay at the surface?

Solution

- 1 *This is what you know:*
 - Total time: From 10:00 A.M. to 3:00 P.M. is 5 h.
1 h = 60 min, so $5 \times 60 = 300$ min
 - % of time on surface = $100\% - 90\% = 10\% = 0.10$
- 2 *This is what you need to know:* How much time is spent on the surface?
- 3 *This is the procedure you need to use:*
 - Use this equation:
surface time = (total time)(% of time on surface)
 - Substitute the known values:
surface time = $(300 \text{ min})(0.10) = 30 \text{ min}$
- 4 *Check your answer:* Divide your answer by the total time. Is the answer equal to 10 percent?

Practice Problems

1. On a typical day during those four months, how much time do elephant seals stay at the surface from 11:00 P.M. until 6:00 A.M.?
2. On a typical day during those four months, how much time do elephant seals spend underwater from 9:00 A.M. until 6:00 P.M.?



For more practice, visit
[red.msscience.com/
math_practice](http://red.msscience.com/math_practice)



Figure 20 Marsupials, such as opossums, are born before they are completely developed. Newborn marsupials make the journey to a nipple that is usually in the mother's pouch where they will finish developing.

Marsupials Most **marsupials** carry their young in a pouch. Their embryos develop for only a few weeks within the uterus. When the young are born, they are without hair, blind, and not fully formed. Using their sense of smell, the young crawl toward a nipple and attach themselves to it. Here they feed and complete their development. Most marsupials—such as kangaroos, koalas, Tasmanian devils, and wallabies—live in Australia, Tasmania, and New Guinea. The opossum, shown in **Figure 20**, is the only marsupial that lives in North America.



Reading Check

Why do most marsupials have a pouch?

Figure 21 Placental embryos rely on the umbilical cord to bring nutrients and to remove wastes. Your navel is where your umbilical cord was connected to you.

Placentals The largest number of mammals belongs to a group called placentals. **Placentals** are named for the placenta, which is a saclike organ that develops from tissues of the embryo and uterus. In the placenta, food, oxygen, and wastes are exchanged between the mother's blood and the embryo's blood, but their bloods do not mix. An umbilical cord, as seen in **Figure 21**, connects the embryo to the placenta. Food and oxy-

gen are absorbed from the mother's blood for the developing young. Blood vessels in the umbilical cord carry food and oxygen to the developing young, then take away wastes. In the placenta, the mother's blood absorbs wastes from the developing young. This time of development, from fertilization to birth, is called the gestation period. Mice and rats have a gestation period of about 21 days. Human gestation lasts about 280 days. The gestation period for elephants is about 616 days, or almost two years.



Mammals Today

More than 4,000 species of mammals exist on Earth today. Mammals can be found on every continent, from cold arctic regions to hot deserts. Each kind of mammal has certain adaptations that enable it to live successfully within its environment.

Mammals, like all other groups of animals, have an important role in maintaining a balance in the environment. Large carnivores, such as wolves, help control populations of herbivores, such as deer and elk, thus preventing overgrazing. Bats and other small mammals such as honey possums help pollinate flowers. Other mammals unknowingly pick up plant seeds in their fur and distribute them. However, mammals and other animals are in trouble today because their habitats are being destroyed. They are left without enough food, shelter, and space to survive as millions of acres of wildlife habitat are damaged by pollution or developed for human needs. The grizzly bear, pictured in **Figure 22**, lives in North America and Europe and is an endangered species—a species in danger of becoming extinct—in most of its range because of habitat destruction.



Figure 22 Grizzly bears, sometimes called brown bears, used to range all over the western half of the United States. Now, because of human settlement, habitat loss, and overhunting, grizzly bears are found only in Alaska, Montana, Wyoming, Idaho, and Washington.

section 4 review

Summary

Mammal Characteristics

- Mammals have mammary glands that produce milk for their young.
- Mammals have teeth that are specialized for the type of food they eat.
- The body systems of mammals are designed to support activities such as running, swimming, climbing, hopping, and flying.

Mammal Types

- The smallest group of mammals, called monotremes, lay eggs with leathery shells.
- Marsupials are born before they are completely developed, and most marsupials carry their young in a pouch.
- The placentals are the largest group of mammals.

Mammals Today

- More than 4,000 species of mammals exist on Earth today.

Self Check

1. **Infer** why the brain of a mammal usually is larger than the brain of other animals of the same size.
2. **Explain** why animals are in trouble today.
3. **List** examples of how the teeth of mammals are specialized.
4. **Research Information** The monotremes are the smallest group of mammals. Using the library and online resources, explain where monotremes likely originated from and what continents monotreme fossils have been found on.
5. **Think Critically** Compare and contrast the development of embryos in placentals and marsupials.

Applying Math

6. **Solve One-Step Equations** The tallest mammal is the giraffe at 5.6 m. Calculate your height in meters and determine how many of you it would take to be as tall as a giraffe.

HOMES FOR ENDANGERED ANIMALS

Goals

- **Research** the natural habitat and basic needs of one endangered vertebrate species.
- **Research and model** an appropriate zoo, animal park, or aquarium environment for this animal. Working cooperatively with your classmates, design an entire zoo or animal park.

Possible Materials

poster board
markers or colored pencils
materials with which to
make a scale model

Real-World Question

Zoos, animal parks, and aquariums are safe places for endangered animals. Years ago, captive animals were kept in small cages or behind glass windows. The animals were on display like artwork in a museum. Now, some captive animals are kept in exhibit areas that closely resemble their natural habitats. These areas provide suitable environments for the animals so that they can reproduce, raise young, and have healthier and longer lives. What types of environments are best suited for raising animals in captivity? How can endangered animals be rescued?



Using Scientific Methods

▶ **Make a Model**

1. **Choose** an endangered animal to research. Find out where this animal is found in nature. What does it eat? Who are its natural predators? Does it exhibit unique territorial, courtship, or other types of social behavior? How is this animal adapted to its natural environment?
2. Why is this animal considered to be endangered?
3. **Design** a model of your proposed habitat in which this animal can live successfully.
4. **Research** how a zoo, animal park, or aquarium provides a habitat for this animal. This information can be obtained by contacting a zoo, animal park, or aquarium.
5. **Present** your design plan to your class in the form of a poster, slide show, or video. Compare your proposed habitat with that of the animal's natural environment. Make sure you include a picture of your animal in its natural environment.



▶ **Test the Model**

1. Using all of the information you have gathered, create a model exhibit area for your animal.
2. List other plants and animals that might be present in the exhibit area.

▶ **Analyze Your Data**

1. **Decide** whether all of the endangered animals studied in this activity could exist in the same zoo or wildlife preserve.
2. **Predict** which animals could be grouped together in exhibit areas.

▶ **Conclude and Apply**

1. **Determine** how much land your zoo or wildlife preservation needs. Which animals require the largest habitat?
2. Using the information provided by all your classmates, design a zoo or wildlife preserve for the majority of endangered animals you've studied.
3. **Analyze** which type of problems might exist in your design.

Communicating **Your Data**

Give an oral presentation on endangered animals and wildlife conservation to another class of students using your model. Use materials from zoos to supplement your presentation.

Cosmic Dust and Dinosaurs

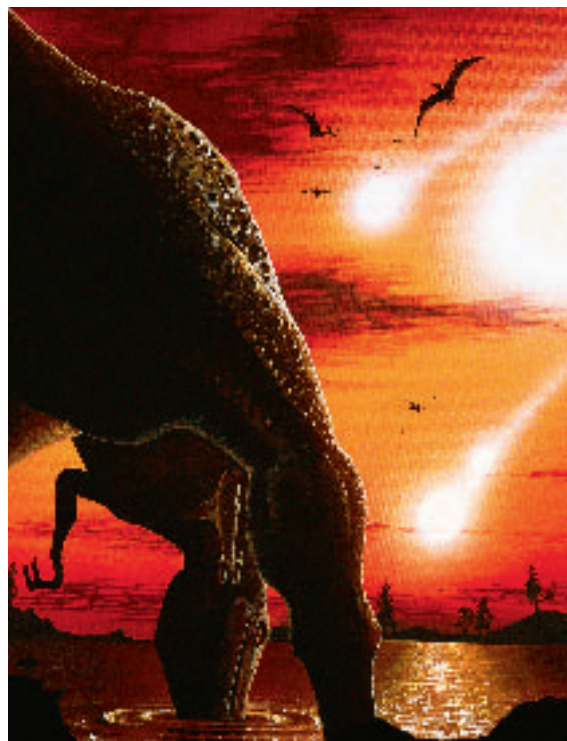
**What killed the dinosaurs?
Here is one theory.**

Tiny bits of dust from comets and asteroids constantly sprinkle down on Earth. This cosmic dust led scientists Luis and Walter Alvarez to a hypothesis about one of science's most intriguing mysteries: What caused the extinction of dinosaurs?

It began some 65 million years ago when mass extinction wiped out 60 percent of all species alive on Earth, including the dinosaurs. Walter Alvarez and his father Luis Alvarez were working together on a geology expedition in Italy analyzing a layer of sedimentary rock. Using dating techniques, they were able to determine that this layer was deposited at roughly the same time that the dinosaurs became extinct. The younger Alvarez hypothesized that the rock might hold some clue to the mass extinction.

The Alvarizes proposed that the sedimentary rock be analyzed for the presence of the element iridium. Iridium is a dense and rare metal found in very low concentrations in Earth's core. The scientists expected to find a small amount of iridium. To their surprise, the sedimentary rock contained unusually high levels of iridium.

High concentrations of iridium are believed to be common in comets and asteroids.



Did asteroids kill the dinosaurs? An artist drew this picture to show how Earth might have looked.

If a huge asteroid collided with Earth, its impact would send tons of dust, debris, and iridium high into the atmosphere. The dust would block the Sun, causing global temperatures to decrease, plants to die, and animals to starve, resulting in a mass extinction. When the dust settled, iridium would fall to the ground as evidence of the catastrophe.

The Alvarez hypothesis, published in 1980, is still debated. However, it has since been supported by other research, including the discovery of a huge, ancient crater in Mexico. Scientists theorize that this crater was formed by the impact of an asteroid as big as Mount Everest.

Write Imagine that an asteroid has collided with Earth. You are one of the few human survivors. Write a five-day journal describing the events that take place.

Science  **online**

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red.msscience.com/time

Reviewing Main Ideas

Section 1 Chordate Animals

1. All chordates, at some time in their development, have a notochord and gill slits.
2. Endothermic animals maintain an internal body temperature. Ectothermic animals have body temperatures that change with the temperature of their surroundings.
3. The three classes of fish are jawless, cartilaginous, and bony. All fish are ectotherms.

Section 2 Amphibians and Reptiles

1. Amphibians are ectothermic vertebrates that spend part of their lives in water and part on land. Most amphibians go through a metamorphosis, which includes water-living larva and land-living adult stages.
2. Reptiles are ectothermic land animals that have dry, scaly skin.
3. Most reptiles lay eggs with a leathery shell.

Section 3 Birds

1. Birds are endotherms with feathers, and they lay eggs enclosed in hard shells.
2. Wings, feathers, and a light, strong skeleton are adaptations that allow birds to fly.

Section 4 Mammals

1. Mammals are endotherms that have mammary glands. All mammals have some hair.
2. Mammals have specialized teeth that mostly determine what foods they eat.
3. There are three groups of mammals. Monotremes lay eggs. Most marsupials have pouches in which embryos develop. Placentals have a placenta, and the embryos develop within the female's uterus.
4. Mammals have a variety of adaptations that allow them to live in different types of environments.

Visualizing Main Ideas

Copy and complete the following table comparing the characteristics of fish, amphibians, and reptiles.

Vertebrate Characteristics			
Characteristic	Fish	Amphibians	Reptiles
Body temperature	ectotherm		
Body covering			
Respiratory organs	Do not write in this book.		
Method of movement		legs	
Fertilization			internal
Kind of egg	lacks shell		



Using Vocabulary

amniotic egg p. 539	estivation p. 535
carnivore p. 546	herbivore p. 546
cartilage p. 532	hibernation p. 535
chordate p. 530	marsupial p. 548
contour feather p. 543	monotreme p. 547
down feather p. 543	omnivore p. 546
ectotherm p. 531	placental p. 548
endotherm p. 531	

Using complete sentences, explain how the vocabulary words in each pair listed below are alike and how they are different.

- contour feather—down feather
- ectotherm—endotherm
- chordate—cartilage
- estivation—hibernation
- carnivore—herbivore
- marsupial—monotreme
- amniotic egg—monotreme
- down feather—endotherm
- omnivore—carnivore
- placental—marsupial

Checking Concepts

Choose the word or phrase that best answers the question.

- Which of the following animals have fins, scales, and gills?
 - amphibians
 - crocodiles
 - reptiles
 - fish
- Which of these is an example of a cartilaginous fish?
 - trout
 - bass
 - shark
 - goldfish

- Which of the following fish has a swim bladder?
 - shark
 - lamprey
 - trout
 - skate
- Which of the following is an adaptation that helps a bird fly?
 - lightweight bones
 - webbed feet
 - hard-shelled eggs
 - large beaks
- Which of the following animals has skin without scales?
 - dolphin
 - snake
 - lizard
 - fish
- Lungs and moist skin are characteristics of which of the following vertebrates?
 - amphibians
 - fish
 - reptiles
 - lizards
- Which of these are mammals that lay eggs?
 - carnivores
 - marsupials
 - monotremes
 - placentals
- Which of the following animals eat only plant materials?
 - carnivores
 - herbivores
 - omnivores
 - endotherms

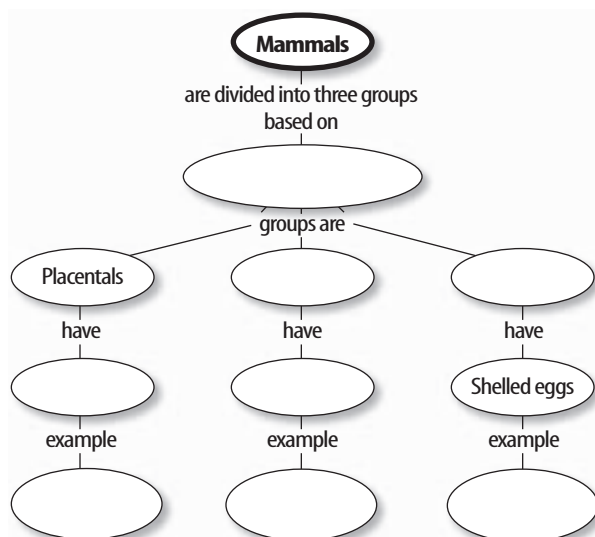
Use the illustration below to answer question 19.



- What is the primary function of the feather in the illustration above?
 - flight
 - insulation
 - attracting mates
 - repelling water

Thinking Critically

20. **Discuss** why there are fewer species of amphibians on Earth than any other type of vertebrate.
21. **List** the important adaptation that allows a reptile to live and reproduce on land while an amphibian must return to water to reproduce and complete its life cycle.
22. **Draw a Conclusion** You observe a mammal in a field catching and eating a rabbit. What kind of teeth does this animal probably have? Explain how it uses its teeth.
23. **Explain** how the development of the amniotic egg led to the early success of reptiles on land.
24. **Compare and contrast** the teeth of herbivores, carnivores, and omnivores. How is each type of tooth adapted to the animal's diet?
25. **Draw a Conclusion** How can a bird like the arctic tern stand on ice and not lose too much body heat?
26. **Concept Map** Copy and complete this concept map that describes groups of mammals.



Performance Activities

27. **Identify and Manipulate Variables and Controls** Design an experiment to find out the effect of water temperature on frog egg development.
28. **Debate** Reptiles are often portrayed as dangerous and evil in fairy tales, folktales, and other fictional stories. Nonfiction information about reptiles presents another view. What is your opinion? Use the library or online resources to find evidence to support your position. Debate this issue with a classmate who has an opposing opinion.

Applying Math

Use the following table to answer questions 29 and 30.

Bull Trout Population	
Year	Number per 100-m ² Section
1996	4
1997	7
1998	5
1999	3
2000	4

29. **Population Changes** Make a line graph from the data in the table above.
30. **Fish Population Density** Calculate the average number of bull trout per 100-m² section of stream for all years combined. Which years had a larger population than the average?
31. **Egg Development** A salamander egg in water at 15–16°C will hatch after 60–70 days. A salamander egg in water at 17°C will hatch after 69–92 days. What are the minimum and maximum differences in hatching times?

Part 1 Multiple Choice

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

- Which of the following is NOT an ectotherm?
 - amphibian
 - mammal
 - reptile
 - fish
- Three of the following are made of cartilage. Which is made of bone?
 - goldfish
 - ears
 - tip of your nose
 - jawless fish
- Which of the following is NOT a group of fish?
 - cartilaginous
 - jawless
 - bony
 - angelfish

Use the photo below to answer questions 4 and 5.



- The fish in the illustration is an example of
 - jawless fish
 - ratfish
 - bony fish
 - cartilaginous fish
- Which of the following is NOT one of its traits?
 - scaleless, long, tubelike body
 - rough, sandpaperlike scales
 - round, muscular mouth without a jaw
 - sharp, toothlike structures

- Which of the following spend part of their life on land and part in the water?
 - reptiles
 - fish
 - amphibians
 - mammals

Use the photo below to answer questions 7 and 8.



- This animal becomes inactive in cold weather using which of the following?
 - hibernation
 - estivation
 - hydration
 - hyperthermia
- This animal has three of the following characteristics. Which one doesn't it possess?
 - three-chambered heart
 - vibrating tympanum
 - exchange of oxygen and carbon dioxide through skin
 - lays shell-covered, amniotic eggs
- Which of the following is a monotreme?
 - kangaroo
 - koala
 - wallaby
 - platypus

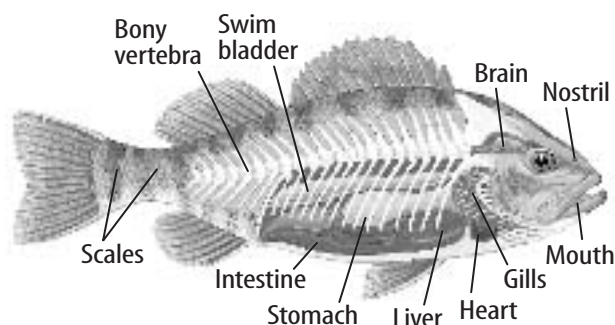
Test-Taking Tip

Listen and Read Listen carefully to the instructions from the teacher and read the directions and each question carefully.

Part 2 Short Response/Grid In

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

Use the illustration below to answer questions 10 and 11.



10. This animal has a particular method of swimming to different levels. Explain how they do this.
11. How do most of these animals reproduce?
12. How are jawless fish different from bony fish?
13. How do amphibians survive hot summers?
14. Animals need to get oxygen and dispose of carbon dioxide. How do adult amphibians get enough oxygen and get rid of carbon dioxide?
15. Birds use a special method to keep their feathers in good shape. What is this process called and how do they do it?
16. What characteristics do all mammals have in common?
17. Mammals also can be classified by what they eat. What are these three different classifications?
18. Name two ways that monotremes are different from other animals.

Part 3 Open Ended

Record your answers on a sheet of paper.

19. Animals possess a great variety of body plans that help them reproduce. Compare and contrast the way fish and mammals reproduce.
20. Animals may have to compete with one another for survival. Explain how some animals compete for the same food and how predators can help in this process.

Use the illustration below to answer questions 21 and 22.



21. Walter Alvarez and his father, Luis Alvarez, came up with a theory as to how dinosaurs became extinct. This illustration is an artist's rendering of this theory. Explain it.
22. They did not set out to determine how dinosaurs became extinct. How did the theory depicted in the illustration come about?
23. Animals have various outer coverings for protection and various functions. Compare and contrast the various outer coverings of birds and mammals.