CHAPTER

9 Classification of Living Things

the BIG idea

Scientists have developed a system for classifying the great diversity of living things.

Key Concepts

SECTION 1 **Scientists develop systems for classifying living things.**
Learn about why scientists classify living things and about taxonomy.

SECTION 2 **Biologists use seven levels of classification.**
Learn about scientific names, how to classify organisms in seven levels, and dichotomous keys.

SECTION 3 **Classification systems change as scientists learn more.**
Learn how classification systems have changed based on features of cells.

FCAT Practice

Prepare and practice for the FCAT
- Section Reviews, pp. 305, 314, 323
- Chapter Review, pp. 326–328
- FCAT Practice, p. 329

CLASSZONE.COM
- Florida Review: Content Review and FCAT Practice

How many different types of organisms do you see and how would you group them?

EXPLORE the BIG idea

How Are Fingerprints Different?

Make fingerprints of your thumb and the thumbs of several classmates on separate index cards.

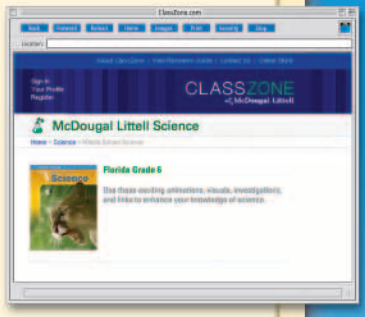
Observe and Think What traits do all fingerprints have in common? What traits of fingerprints allow you to tell them apart?

How Would You Sort Pennies?

Place 20 pennies in a plastic cup. Place your hand over the cup and shake it. Gently pour the pennies onto a table. Without flipping the pennies over, use one trait of the pennies to sort them into groups A and B. Again, without flipping them over, use a second trait to sort the pennies in group A into groups A1 and A2.

Observe and Think What traits do the pennies in each group share? Which group has the largest numbers of pennies?

Internet Activity: Linnaeus



Go to **ClassZone.com** to learn more about Carolus Linnaeus, who, over 200 years ago, laid the groundwork for how today's scientists classify things.

Observe and Think What evidence did Linnaeus use to classify organisms?

NSTA SCILINKS
scilinks.org

Classification Systems **Code: MDL037**

CHAPTER 9

Getting Ready to Learn

CONCEPT REVIEW

- Living organisms are divided into six kingdoms by scientists.
- Bacteria are the smallest living things.
- Viruses are nonliving things that copy themselves by using materials within living cells.
- Protists are a diverse group of organisms that include algae and protozoa.

VOCABULARY REVIEW

kingdom p. 257
virus p. 260
bacteria p. 262
protozoa p. 280

FLORIDA REVIEW
CLASSZONE.COM
Content Review and FCAT Practice

TAKING NOTES

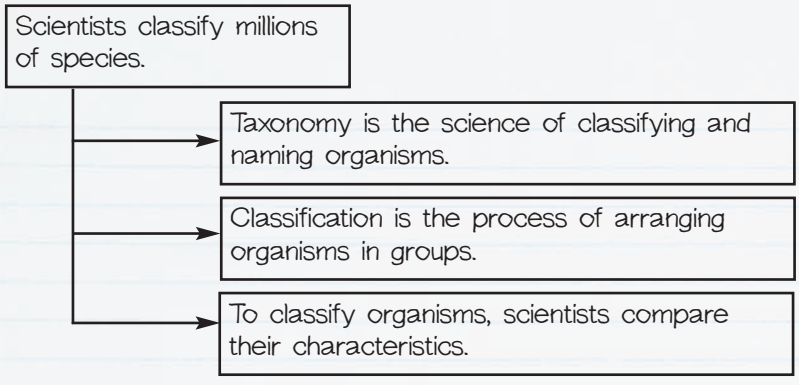
SUPPORTING MAIN IDEAS

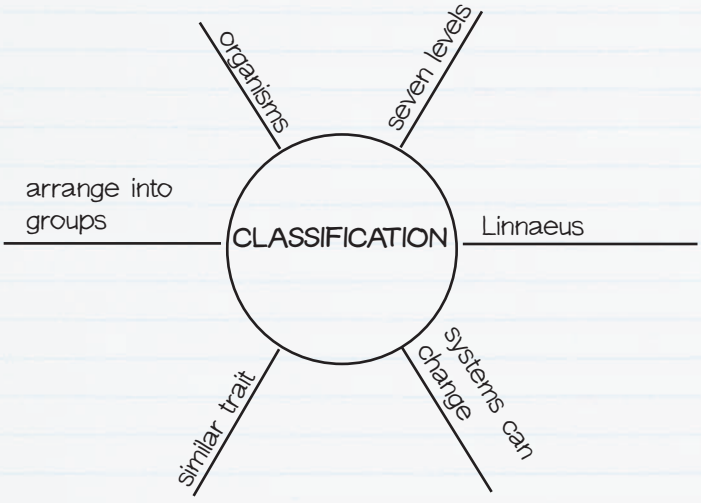
Make a chart to show main ideas and the information that supports them. Copy each blue heading. Below each heading, add supporting information, such as reasons, explanations, and examples.

VOCABULARY STRATEGY

Place each vocabulary term at the center of a **description wheel** diagram. Write some words describing it on the spokes.

SCIENCE NOTEBOOK





See the Note-Taking Handbook on pages R45–R51.

KEY CONCEPT

9.1 Scientists develop systems for classifying living things.

Sunshine State STANDARDS

SC.G.1.3.3: The student understands that the classification of living things is based on a given set of criteria and is a tool for understanding biodiversity and interrelationships.

SC.H.1.3.3: The student knows that science disciplines differ from one another in topic, techniques, and outcomes but that they share a common purpose, philosophy, and enterprise.

BEFORE, you learned

- All living organisms are divided into six kingdoms
- Bacteria are found in many environments
- Algae get energy from the Sun

NOW, you will learn

- Why scientists classify living things
- That taxonomists study biological relationships
- About evidence used to classify organisms

VOCABULARY

classification p. 300

taxonomy p. 300

THINK ABOUT

How are these organisms similar?

Both a worm and a caterpillar share many characteristics. Both have long, skinny bodies that are divided into segments. But an earthworm moves underground, has no legs or eyes, and can grow back segments that are lost. A caterpillar crawls aboveground and is just one part of a butterfly's life cycle. As you read this chapter, think about whether you would classify these animals together or separately.

Scientists classify millions of species.

About 400 years ago, scientists who studied insects classified them based upon their appearance and behavior. If animals looked alike, researchers concluded that they were related. In the last few centuries scientists have realized that appearances can suggest false connections. Although caterpillars look like worms, they are actually an earlier stage of a butterfly's life.

For some people, the world seemed to grow larger during the 1600s. Travelers sailed to distant lands and oceans. Scientists went on many of these trips, observing and collecting samples of living things they had never seen before. In addition, the microscope allowed scientists to see tiny organisms that had been invisible before. But how could scientists organize and talk about this wonderful new knowledge?

Classification and Taxonomy

VOCABULARY
Add a description wheel for *classification* to your notebook. Include the word *group* in your diagram.

Two scientific processes deal with classifying and naming living things. **Classification** is the process of arranging organisms into groups based on similarities. **Taxonomy** is the science of naming and classifying organisms. A good system of classification allows you to organize a large amount of information so that it is easy to find and to understand. The system should provide a tool for comparing very large groups of organisms as well as smaller groups. Large groups might include all animals. Smaller groups might include birds, reptiles, or mammals.

A good system of taxonomy allows people to communicate about organisms. Before the 1700s, scientists had not agreed on a system of naming and grouping organisms. Take, for example, the common wild briar rose. Some scientists called it *Rosa sylvestris inodora seu canina* (odorless woodland dog rose). Others used the name *Rosa sylvestris alba cum rubore, folio glabro* (pinkish-white woodland rose with hairless leaves). Plus, any scientist studying a species could change the name.

These long Latin names may sound confusing, but even common names can be confusing. In England the bird called a robin—Britain's national bird—is only distantly related to the bird called a robin in the United States, even though they both have red feathers on their chests. A daddy longlegs could be either a long-legged relative of spiders (in the United States) or a long-legged relative of mosquitoes (in England).

British Daddy Longlegs

American Daddy Longlegs

RESOURCE CENTER
CLASSZONE.COM
Find out more about taxonomy.

Clearly, biologists need both a system for organizing and a system for naming. Each name should refer to one specific type of organism. That way, scientists can use the species name and be sure that everybody knows exactly which organism they are talking about.

CHECK YOUR READING What is the difference between classification and taxonomy?

Like other cats, a caracal has fur, sharp fangs, and is a meat eater.

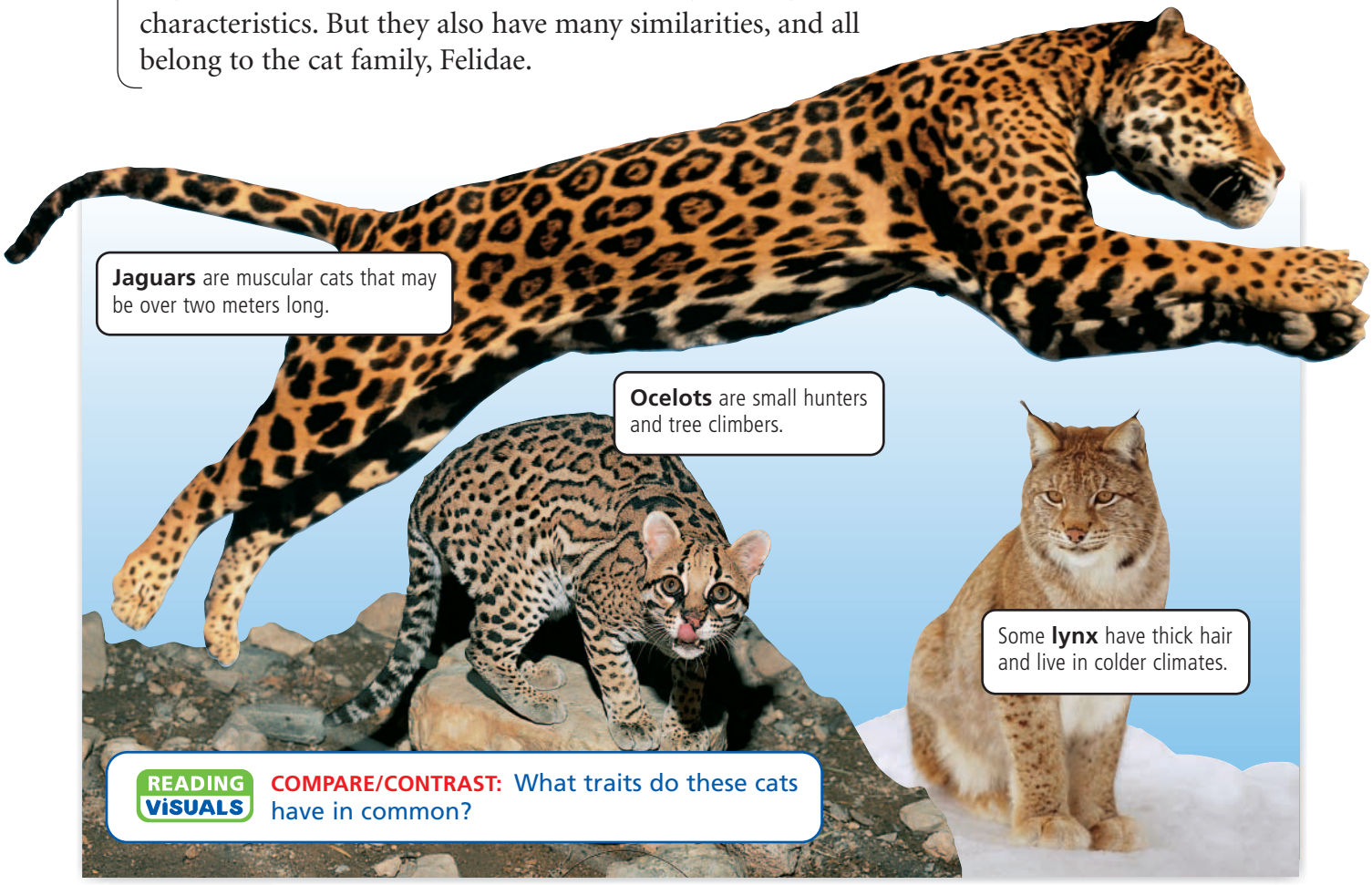
Using Classification

To classify organisms, scientists use similarities and differences among species. Sometimes these differences are easy to see, such as whether an animal has fur, feathers, or scales. Other times, seeing the differences requires special laboratory equipment, such as equipment to study DNA.

A classification system can help you identify unfamiliar organisms. For example, if you had never heard of a caracal but were told that it was a kind of cat, you already would know many things about it. It has fur, fangs, and sharp claws. It's a meat eater, not a plant eater. You would know these things because the caracal shares those characteristics with all of the members of the cat family.

If you looked up *caracal* in an encyclopedia, you'd find that your guesses were right. The caracal is a small wildcat native to Africa, the Middle East, and India. It weighs about 13 to 19 kilograms (29 to 42 pounds). The name *caracal* comes from a Turkish word meaning "black-eared."

The more characteristics two organisms share, the more similar their names should be in the classification system. The caracal, a pet cat, and all the cats below are different in size, habitat, and other characteristics. But they also have many similarities, and all belong to the cat family, Felidae.



Taxonomists study biological relationships.

READING TiP
Taxonomy, *taxonomist*, and *taxon* all share the same root.

Scientists need a simple, standard way of arranging all of the different species. The science of taxonomy is related to the Greek word *taxis*, which means "arrangement." Taxonomists are the scientists who classify and name organisms based on their similarities and differences. A taxon is a group of organisms that share certain traits. Taxons can be broad, like animals and plants, or more specific, like cats and roses.

A single species found in a fossil record might be the ancestor of many different species found on Earth today. Taxonomists study the relationships between species, trying to discover how one species evolved as compared with another species. Species that share ancestors are grouped together. You will learn more about how living things evolve over time in grade 7.

To determine how to classify organisms, scientists compare a variety of characteristics, or traits. A trait is a characteristic or behavior that can be used to tell two species apart, such as size or bone structure. If two organisms share a trait, taxonomists try to determine if they share the trait because they share an ancestor.

CHECK YOUR READING How do taxonomists use biological relationships to classify organisms?

INVESTIGATE Classifying Leaves

How can you classify leaves?

SKILL FOCUS
Classifying

MATERIALS
- leaves
- hand lens

TIME
20 minutes

PROCEDURE

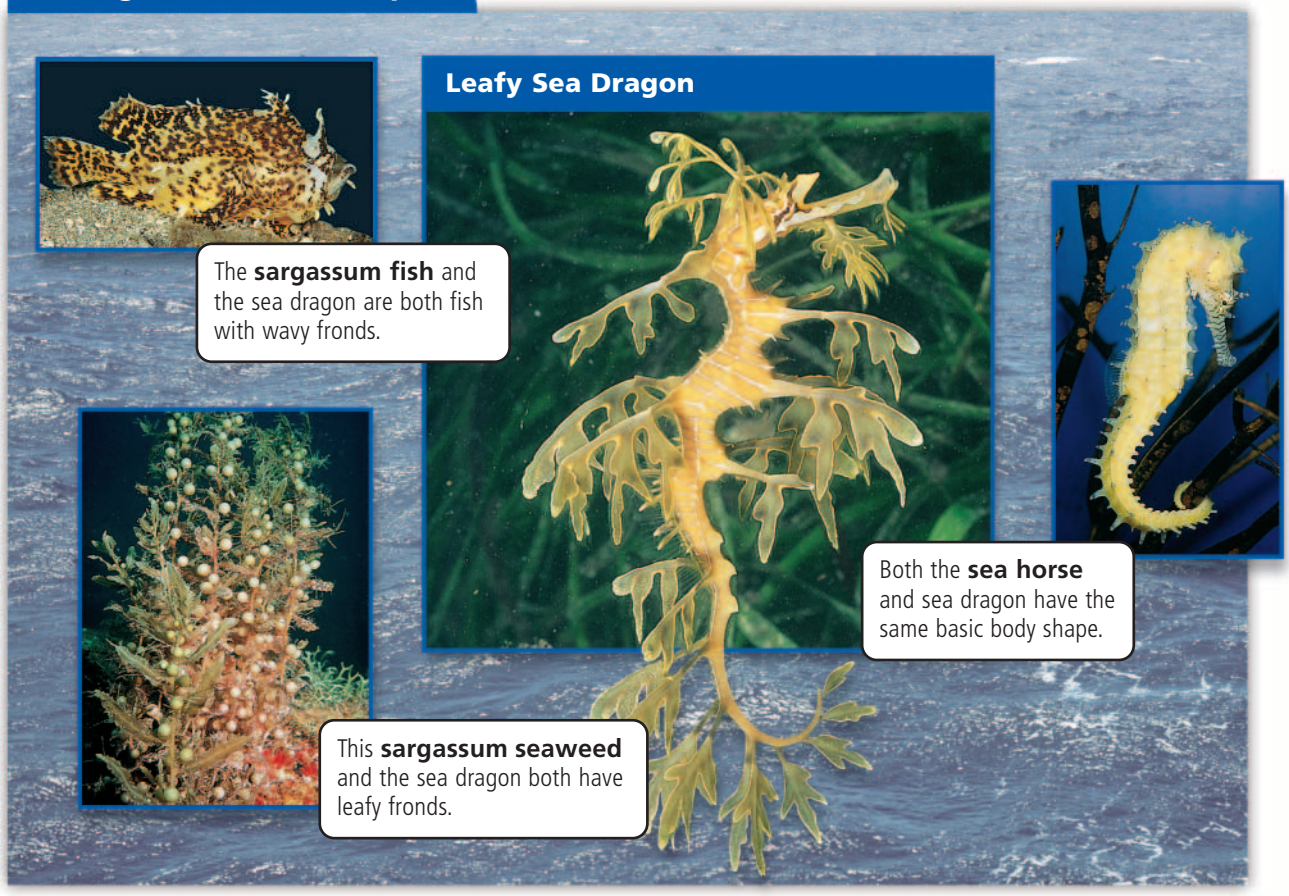
1. Decide, as a class, what traits you will use to classify leaves. You may use size, shape, color, vein patterns, texture, or anything else that you observe.
2. Work with a few classmates. Sort your leaves into four or five taxons, based on the characteristics chosen in step 1. Give each taxon a name that describes its common traits.
3. Compare your classification scheme with those of other groups.

WHAT DO YOU THINK?

- How did you arrange the leaves into groups?
- Did your methods of classifying leaves match those of other student groups?

CHALLENGE How does your group's classification scheme compare with the scheme scientists use for classification?

Biological Relationships



Look at the photographs and try to determine to which organism a leafy sea dragon is more closely related. The leafy sea dragon shares traits with all of the other organisms pictured. For example, the sea dragon and the sargassum seaweed look similar, with greenish wavy fronds. But the sea dragon is an animal that moves, gets food from other organisms, and breathes oxygen. The sargassum seaweed is not an animal, it is a type of algae.

The sargassum fish shares more traits with the sea dragon, but its body is a much different shape and has scales. In fact, the leafy sea dragon is an animal that is closely related to a sea horse. Both have heads and bodies with similar shapes, and neither has scales. The sea horse shares more traits with the leafy sea dragon than with the other two organisms.

Taxonomists take evidence and try to reconstruct the evolution of a species. Then they place the species in the classification system. Scientists use physical evidence, such as fur, bones, and teeth. They also use genetic evidence, which is found within an organism's DNA.

Physical Evidence

Physical Evidence

Steller's Jay
- Lives only west of the Rocky Mountains
- Has a solid black head and neck and almost no white feathers

Blue Jay
- Lives mostly east of the Rocky Mountains
- Has blue, black, and white feathers on its wings and neck

The primary tools early scientists used for taxonomy were their eyes and measuring devices. They collected examples of organisms and noted characteristics, such as color, size, weight, and how groups of organisms obtain energy. Scientists who studied animals observed the internal structure, as well as outward appearances. These physical features are still important today.

Individuals of two species, such as the two jays shown to the left, can have many similarities as well as some differences. One obvious difference is the color pattern. Another is the area of the world in which they live. Blue jays live east of the Rocky Mountains, and steller's jays live west of the Rockies. The common names and the scientific names reflect the differences and the common ancestor: blue jay, *Cyanocitta cristata* and steller's jay, *Cyanocitta stelleri.*

Skeletons, shells, and other hard parts of organisms become fossilized more easily than soft parts do. Scientists can observe and measure fossilized bones or pieces of bones and compare them with each other. They can also compare bones of species that are extinct with bones of modern species. From such studies, scientists can determine many things about the organism. Physical evidence provides clues about how an organism may have lived, how it moved, or what type of food it ate.

All of this physical evidence helps scientists see that all living organisms are related by evolution. Some are more closely related than others. This means they share a more recent ancestor.

CHECK YOUR READING How could comparing fossilized bones with a modern animal's bones help you see the modern animal's evolutionary history?

Genetic Evidence

FLORIDA Content Preview

Many physical traits of an organism are determined by its genes. You will learn more about genes and DNA in grade 8.

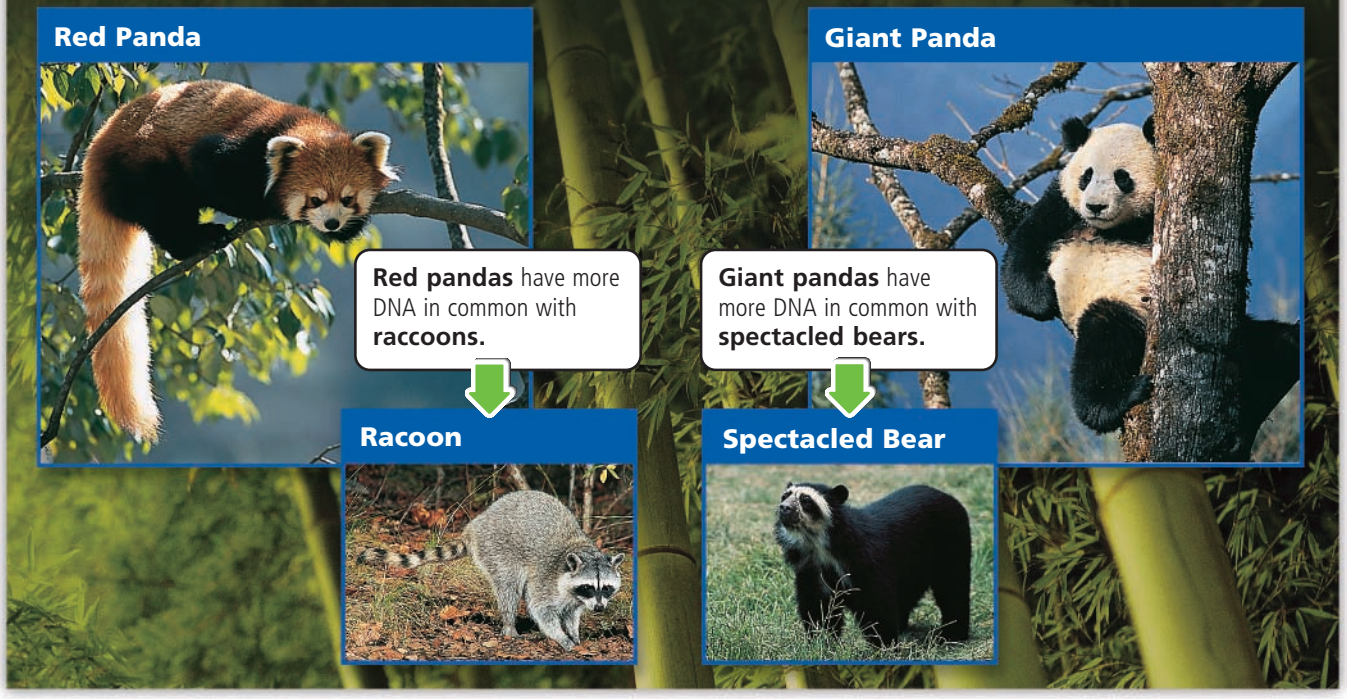
In the early 20th century scientists discovered that organisms inherit their traits through structures called genes. In the mid-1950s they observed that genes are made of DNA and that DNA stores coded information.

Today scientists can use laboratory machines to catalog each component of an organism's DNA. With that information stored on a computer, scientists can compare the components of a gene from one organism with the components of the same gene from another organism.

Genetic evidence usually supports physical evidence, but not always. Consider the example shown on page 305. For years, taxonomists argued about how to classify this small, reddish animal from China. Its scientific name is *Ailurus fulgens*, and the common name is red panda.

Genetic Evidence

Both of these pandas live in the same habitat, have similar faces, and eat bamboo. But genetic evidence shows that red pandas and giant pandas are only distant relatives.



Later, scientists discovered a larger, bearlike animal in China, which they called the giant panda. Both pandas ate only bamboo, shared a common name, and their faces looked similar. Scientists concluded they were related to each other and to raccoons. However, molecular evidence has shown that the red panda is more closely related to raccoons and the giant panda is more closely related to bears.

9.1 Review

KEY CONCEPTS

1. Describe the benefits of classifying species.
2. Why do taxonomists study biological relationships?
3. How do scientists use genetic evidence when classifying organisms?

CRITICAL THINKING

4. **Analyze** Why do people need a universal system of naming organisms?
5. **Predict** The animal called a marbled godwit is a bird. What traits would you predict it has?

CHALLENGE

6. **Synthesize** Suppose you found two species of cave-dwelling lizards without eyes living on opposite sides of the world. Explain how you would try to determine if the two species were closely related.

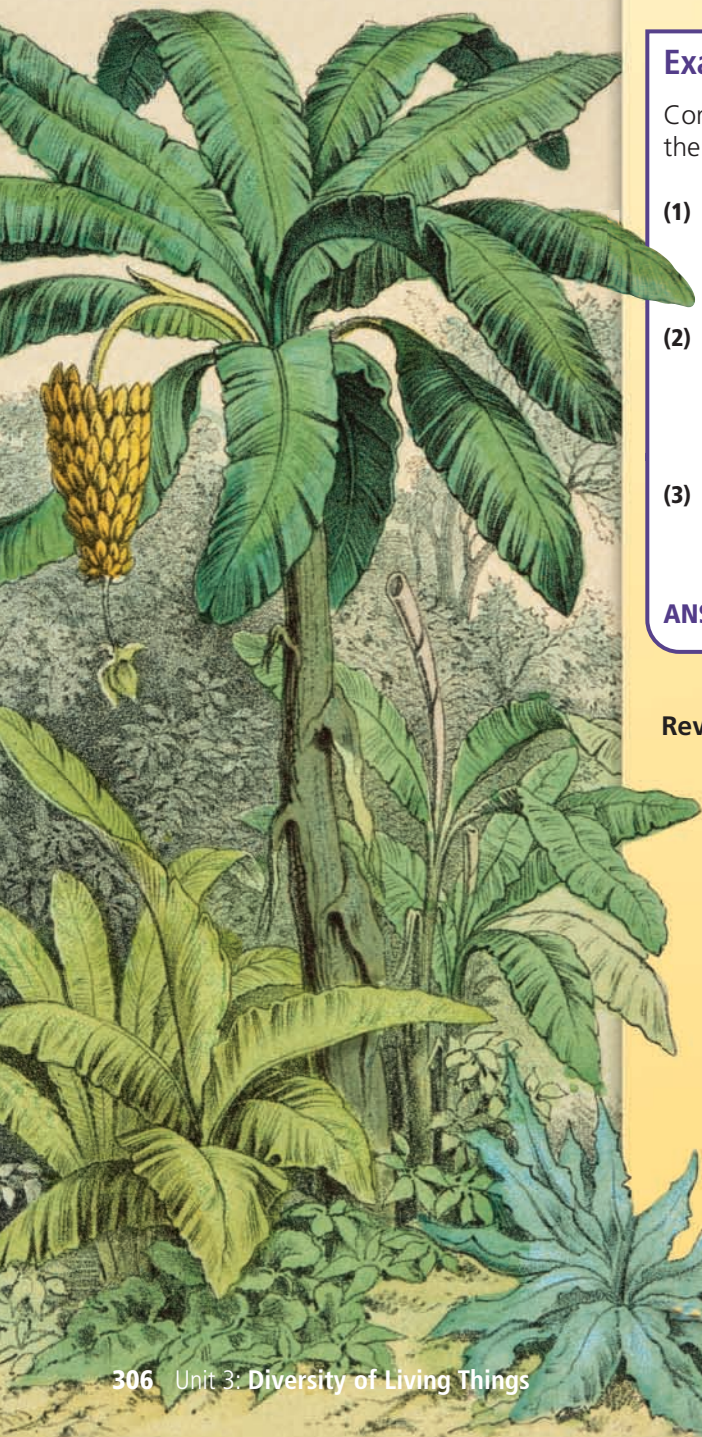
MATH in SCIENCE

SKILL: WRITING PERCENTS

Differences Between Species

MATH TUTORIAL
CLASSZONE.COM
Click on Math Tutorial for more help with percents and fractions.

Does it surprise you to learn that roughly 50 percent of the DNA in your cells is nearly identical to the DNA in the cells of a banana? You probably know from experience that 50 percent is the same as one half. But you can also convert any percent to a fraction by using the number 100 to represent the whole. Fifty parts out of 100 is the same as one half. Another example is shown below.



Example

Comparing the cells of two species, scientists find 40 percent of the DNA is identical. How can you show what fraction that is?

(1) Rewrite the percent as a numerator with a denominator of 100.

$$\frac{40}{100}$$

(2) Reduce the fraction. Use the greatest common factor (GCF) to write the numerator and the denominator as products.

$$\frac{40}{100} = \frac{2 \cdot 20}{5 \cdot 20}$$

(3) Divide the GCF by itself to get $\frac{1}{1}$, or 1.

$$\frac{2}{5} \cdot \frac{20}{20} = \frac{2}{5} \cdot 1 = \frac{2}{5}$$

ANSWER: 40 percent $= \frac{2}{5}$

Rewrite each sentence, changing the percent to a fraction.

1. About 85 percent of the DNA in human cells is similar to the DNA in mouse cells.
2. The tooth of a modern great white shark can be 34 percent of the length of a fossil tooth from a prehistoric shark.
3. There are about 20 percent as many penguin species as there are pine tree species in the world today.
4. There are about 8 percent as many bear species as pine tree species.

CHALLENGE Choose one example or exercise on this page. Tell whether the comparison works better as a fraction or a percent. Explain why.

KEY CONCEPT

9.2 Biologists use seven levels of classification.

Sunshine State STANDARDS

SC.G.1.3.3: The student understands that the classification of living things is based on a given set of criteria and is a tool for understanding biodiversity and interrelationships.

SC.H.1.3.3: The student knows that science disciplines differ from one another in topic, techniques, and outcomes but that they share a common purpose, philosophy, and enterprise.

BEFORE, you learned

- Classification is a system of organization
- Evidence is used to classify organisms

NOW, you will learn

- About scientific names
- About seven levels of classification
- How to use a dichotomous key

VOCABULARY

genus p. 308

binomial nomenclature p. 308

dichotomous key p. 312

EXPLORE Classification

What data do you need to identify objects?

PROCEDURE

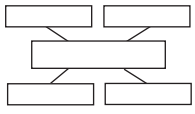
1. Have one student in your group think of a secret object. The student should then tell the group one characteristic (shape, color, size, type, and so on) of that object.
2. The rest of the group guesses the object's identity. Each time someone guesses incorrectly, another characteristic of the object should be given. Record the characteristics and guesses as you go.
3. When the secret object is guessed correctly, begin again with a different student picking a different secret object.

WHAT DO YOU THINK?

- How many characteristics did it usually take to guess an object's identity?
- How does this exercise relate to identifying organisms?

SUPPORTING MAIN IDEAS

Make a chart to show information that supports the first main idea presented: *Linnaeus named about 4000 species.*



Linnaeus named about 4000 species.

Scientists name species and arrange them into groups. One scientist named Carolus Linnaeus developed systems for both naming species and organizing them into groups. All 4000 species that Linnaeus named were plants or animals. Today, scientists have named over a million species. Linnaeus used appearance to group species. As you have read, modern scientists also use appearance, along with other types of evidence, to arrange species into groups.

Naming Species

Sometimes using only one word to name an organism isn't specific enough. If you are telling a friend about your favorite writer, you might name Mary Oliver or Mary Whitebird or Mary Shelley. Using only "Mary" won't help your friend know the author you name, so you use two words. In a similar way, scientists use two words to name organisms.

A **genus** (JEE-nuhs) is a group of species that have similar characteristics. For example, the genus *Ursus* groups all of the animals known as bears. Included in this genus are *Ursus arctos* (grizzly bears), and *Ursus maritimus* (polar bears). Members of the same genus are closely related.

The system for naming species developed by Linnaeus is the basis of modern taxonomy. We call this system **binomial nomenclature** (by-NOH-mee-uhl NOH-muhn-KLAY-chuhr). *Binomial* means "two names" and *nomenclature* means "list of names." So binomial nomenclature describes a system of naming something using two names, or words. Most scientific names are Latin terms.

INVESTIGATE Binomial Nomenclature

How do you assign names?

SKILL FOCUS
Classifying

MATERIALS
- objects
- dictionary
- 10 index cards

TIME
30 minutes

PROCEDURE

1. Place ten objects on a table where everybody in the class can see them.
2. Give each object a genus name. Use a dictionary to come up with names that sound scientific. You may use only three genus names for the ten objects, so some names must apply to more than one objects.
3. Give each object a species name, using the dictionary again if you wish.
4. Write each object's full scientific name on an index card.
5. Trade your index cards with those of another group. Try to match their cards with the ten objects.

WHAT DO YOU THINK?

- How did the other group arrange the objects into genus names? How was their arrangement different from your group's?
- Why is it important for the names to be as descriptive as possible?

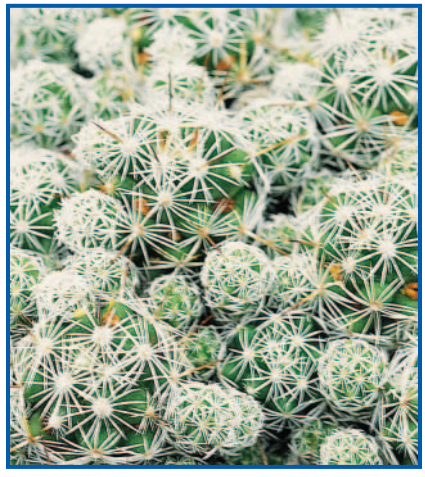
CHALLENGE Repeat the exercise, but now give each object a one-word name. Does this limitation make coming up with names easier or harder?

Binomial Nomenclature

All organisms are given a unique two-part name. Some organisms have the same species names: *gracilis* means "slender" or "graceful." Without the genus name, the species name is unclear.

Aubrieta gracilis
(false rockcress)

Chameleo gracilis
(gracile chameleon)



Mammillaria gracilis
(thimble cactus)

Using Scientific Names

Linnaeus's system of binomial nomenclature made communication about certain species much easier. When naming an organism, the use of a genus name as well as a species name is necessary.

If the genus name is not included in the scientific name, the identity of a species can be a mystery. For example, the species name of the three different species shown above is *gracilis*. The word *gracilis* means "graceful" or "slender" in Latin.

- *Aubrieta gracilis* is a type of flower found in a rock garden.
- *Chameleo gracilis* is a type of lizard called a chameleon.
- *Mammillaria gracilis* is a type of cactus.

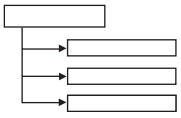
People follow certain rules when they write scientific names. The genus name comes first; the first letter is capitalized and the entire name is in italics. The species name is also written in italics, it follows the genus name, and the first letter is lowercased.

CHECK YOUR READING What is the difference between a genus and a species?

In addition to species and genus, the classification system includes several larger groups. Each larger group includes one or more smaller groups. Turn to page 310 to read about the larger groups in our modern system of classification.

Organisms can be classified into seven levels.

SUPPORTING MAIN IDEAS
Make a chart to show information that supports the main idea that *organisms can be classified into seven levels.*



You've read about species and genus, the most specific levels of the classification system most scientists use today. There are seven levels that describe a species. The largest level is the kingdom, the group containing the most species. The seven levels of classification for a spotted turtle and a housecat are listed below.

1. Kingdom (Animalia—the animals)
2. Phylum (Chordata—animals with backbones)
3. Class (Mammalia—mammals, or furry animals that nurse their young)
4. Order (Carnivora—carnivores, or animals that kill and eat other animals)
5. Family (Felidae—the cat family)
6. Genus (*Felis*—housecats, cougars, and many others)
7. Species (*catus*—all housecats, no matter what their breed)

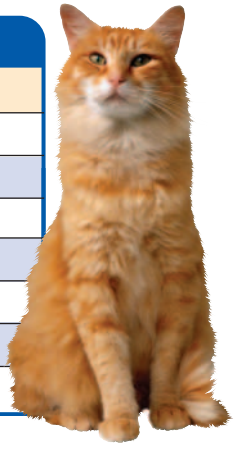
READING TiP
Phyla is the plural form of *phylum.*

Like the cat, the turtle is also classified into seven levels. However, only the two largest levels, Animalia and Chordata, are the same as the classification for a housecat. The more names an organism shares with another organism, the more closely related the two organisms are. Cats and turtles are both animals with backbones, but are otherwise different. Spotted turtles have more traits in common with snakes and lizards than with cats. Lizards, snakes, and turtles all belong in the class Reptilia. Phyla are more specific than kingdoms, classes are more specific than phyla, and so on. The illustration on page 311 shows how kingdom is the broadest grouping of organisms, and species is the most specific.

Classification Hierarchy

	Spotted turtle	Cat
Kingdom	Animalia	Animalia
Phylum	Chordata	Chordata
Class	Reptilia	Mammalia
Order	Testudines	Carnivora
Family	Emydidae	Felidae
Genus	*Clemmys*	*Felis*
Species	*guttata*	*catus*

Clemmys guttata



Felis catus

Classifying Organisms

Moving from kingdom to species, each level includes a smaller set of organisms.

1. **Kingdom**
   Animalia:
   Animals

2. **Phylum**
   Chordata:
   With backbone or similar structure

3. **Class**
   Reptilia:
   Reptiles

4. **Order**
   Testudines:
   Turtles

5. **Family**
   Emydidae:
   Water turtles

6. **Genus**
   Clemmys:
   North American pond turtles

7. **Species**
   guttata:
   Spotted turtle

Spotted turtle
Clemmys guttata

Scientists can compare very broad categories of organisms, such as kingdoms and phyla. Or they can compare very specific categories, such as species. If scientists wish to compare all the different types of turtles to one another, then they will compare the organisms in the order Testudines. But if scientists want to compare turtles that live in or near water, then they will compare only organisms in the family Emydidae.

You can remember the classification levels and their order with this memory aid: Kings Play Chess On Fat Green Stools. The first letter of each word is the same as the first letter in each level of classification: *kingdom, phylum, class, order, family, genus,* and *species.* A complete classification of humans goes like this: kingdom Animalia, phylum Chordata, class Mammalia, order Primates, family Hominidae, genus *Homo,* species *sapiens.*

CHECK YOUR READING Which level of classification in the seven-level system includes the most species?

Dichotomous keys and field guides help people identify organisms.

With millions of organisms on Earth, how could a specific one be identified? Even if you know some of the larger categories, it can be difficult to find the species, genus, or even family name of many organisms from a long list of possibilities.

Take a beetle, for example. Even if you knew that it is in the kingdom Animalia, phylum Arthropoda (animals with jointed legs), class Insecta (insects), and order Coleoptera (hard-winged insects), you'd still have to choose among 300,000 known species of beetles that have been discovered around the world.

READING TiP
The prefix *di-* means "two."

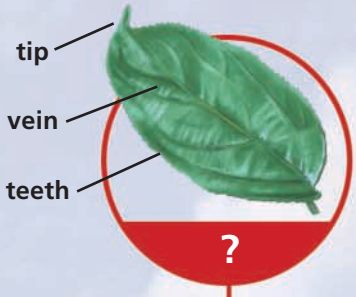
Taxonomists have come up with a tool to identify organisms such as this beetle. A **dichotomous key** (dy-KAHT-uh-muhs) asks a series of questions that can be answered in only two ways. Your answer to each question leads you to another question with only two choices. After a number of such questions, you will identify the organism. One example of a dichotomous key for trees is shown on page 313.

The questions in a dichotomous key gradually narrow down the list of possible organisms. The questions can ask about any trait. The idea is simply to make identifying an organism as easy as possible. The dichotomous key for trees, for example, asks a set of questions that only ask about the traits of the leaves. Leaves are usually easy to get from a tree that needs to be identified, and they include many characteristics that can be used to tell different trees apart.

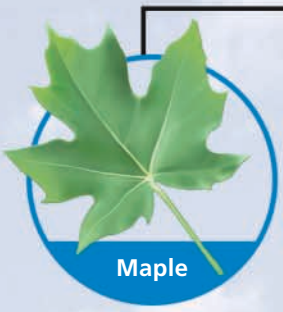
SIMULATION CLASSZONE.COM
Use an interactive dichotomous key.

Dichotomous Key

Use the dichotomous key below to discover on what tree the circled leaf is found.



- ☐ Leaf has three or more main veins
- ☑ Leaf has single main vein



- ☐ Leaf has no teeth, no lobes
- ☑ Leaf has teeth or lobes

- ☐ Leaf is somewhat lobed
- ☑ Leaf is not lobed

- ☐ Leaf has veins that end in teeth
- ☑ Leaf has more teeth than side veins

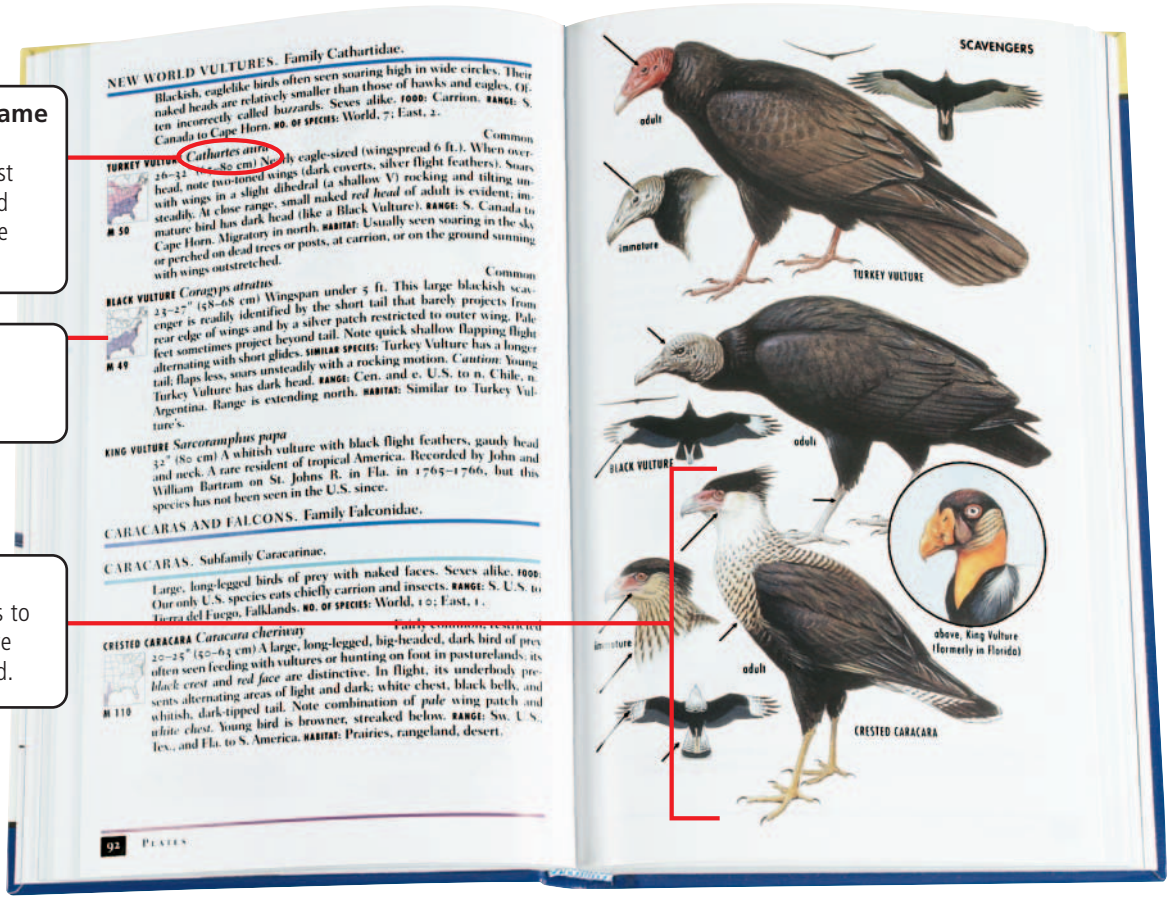
- ☐ Leaf has a bristle on its tip
- ☐ Leaf has no bristle

- ☐ Leaf tapers at both ends
- ☐ Leaf is heart shaped

A bird's **scientific name** is shown next to its common name. The first name is the genus, and the second name is the species.

Range maps show where a bird can be found in each season.

Body shape and body size give clues to determining if you have identified the right bird.



Another tool for identifying organisms is a field guide. Field guides include paintings or photographs of familiar species. Flower guides may start with the flower's color. Bird guides are arranged by orders and families. Field guides also include maps showing where organisms live.

CHECK YOUR READING What two tools have taxonomists developed to identify organisms?

9.2 Review

KEY CONCEPTS

1. What is binomial nomenclature?
2. Write the names of the seven levels of classification. Which level contains the most organisms?
3. What makes a dichotomous key easy to use?

CRITICAL THINKING

4. **Summarize** What were Carolus Linnaeus's main contributions to taxonomy?
5. **Compare and Contrast** Compare a dichotomous key with a typical field guide. What are the strengths and weaknesses of each?

CHALLENGE

6. **Synthesize** Predict what differences you might find among organisms in the same species.

EXTREME SCIENCE

NEW INSECT SPECIES

The Undiscovered

Everyone agrees that insects are the largest group of animals on Earth, but nobody knows exactly how many insect species exist. Some estimates predict that there are as many as 30 million. However, only about 900,000 have been classified. Twenty-nine million insect species may be waiting to be discovered!

Where in the World?

Many of the new insect species are found in tropical forests of South America and Asia. But plenty may be hiding close to your own home.

- The most massive bug in Southern California went undiscovered until April 4, 2002. This wingless relative of the Jerusalem cricket looks something like a puffed-up 3-inch-long ant.
- While studying for her graduate degree, Christina Sandoval captured insects in Santa Barbara, California. She caught an unidentified species of walking stick insect, which she named after herself: *Timema cristinae.*
- The Hanford Nuclear Reservation, in Washington state, was closed to the public for about 50 years. After it opened for cleanup, the Nature Conservancy found 27 new insect species in just 4 years, including a new micromoth less than 1/8 inch long.

Scientists think that over one third of the estimated 164,000 insect species in the United States have yet to be discovered and named. Start looking. Who knows where they'll be!

A Whole New Order

In March 2002, for the first time in 87 years, a whole new order of insects was discovered. Insects in this order look like a cross between stick insects, praying mantises, and grasshoppers. Upon its discovery, the order was nicknamed *gladiators.* Now called *Mantophasmatodea,* the "gladiator bugs" raised the total number of insect orders to 31.

EXPLORE

1. **ANALYZE** List some things about an insect that could be included in its species name. Tell why each is important.
2. **CHALLENGE** Scientists recently discovered a new centipede in New York's Central Park, the first new species in the park in over 100 years. Centipedes are related to insects. Find out what centipedes and insects have in common and how they differ.

RESOURCE CENTER
CLASSZONE.COM
Learn more about newly discovered insects.

An adult Jerusalem cricket can reach 2 inches in length.

KEY CONCEPT

9.3 Classification systems change as scientists learn more.

Sunshine State STANDARDS

SC.G.1.3.3: The student understands that the classification of living things is based on a given set of criteria and is a tool for understanding biodiversity and interrelationships.

SC.H.1.3.3: The student knows that science disciplines differ from one another in topic, techniques, and outcomes but that they share a common purpose, philosophy, and enterprise.

BEFORE, you learned

- Scientists give each species a unique scientific name
- There are seven levels of classification
- Dichotomous keys help us identify organisms

NOW, you will learn

- About the connection between new discoveries and taxonomy
- About three domains
- About six kingdoms

VOCABULARY

domain p. 317
Plantae p. 319
Animalia p. 319
Protista p. 319
Fungi p. 319
Archaea p. 319
Bacteria p. 319

THINK ABOUT

How do scientists define kingdoms?

Look at this photograph of a sea urchin. It lives its life buried in or slowly moving across the ocean floor. The sea urchin's mouth is located on its underside. It feeds on food particles that settle on or are buried in the ocean floor. The sea urchin doesn't appear to have much in common with a tiger, an alligator, even a human. Yet all of these organisms belong in the same kingdom, called Animalia. Why do you think scientists would group these organisms together?

Taxonomy changes as scientists make discoveries.

The list of species continues to grow as scientists discover new species. In addition, taxonomists are learning more about the evolutionary history of species. As you read in Section 2.1, new knowledge resulted in the reclassification of species such as the giant panda. Both the names of species and the groups into which they are arranged may change as a result of discoveries about the evolution of these species.

Early scientists described two large groups of organisms—plants and animals. Plants were described as green and nonmoving. Animals moved. Most scientists today use a system that includes six kingdoms. In addition, taxonomists have added a level of organization above the kingdom level.

Three Domains

Microscopes and other advances in technology have allowed scientists to observe that there are three fundamentally different types of cells. On the basis of this observation, scientists have arranged kingdoms into larger groups called **domains.** For example, the domain Eukarya contains the protists, fungi, plants, and animals.

The table below summarizes the relationships among the six kingdoms and the three domains. You will learn more about kingdoms in the rest of this section.

RESOURCE CENTER
CLASSZONE.COM
Find out more about modern classification.

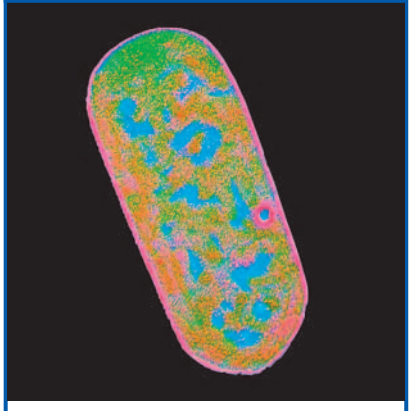
Domains and Kingdoms

Domain	Bacteria	Archaea	Eukarya			
Kingdom	Bacteria	Archaea	Protista	Fungi	Plantae	Animalia
Cell type	No nucleus	No nucleus	With nucleus	With nucleus	With nucleus	With nucleus
Cell number	Unicellular	Unicellular	Unicellular	Mostly multicellular	Multicellular	Multicellular
How organisms get energy	Varies	Varies	Varies	Absorbs materials	Uses sunlight	Consumes food

The photographs below show examples of cells from each domain. One of the traits that distinguishes cells of Eukarya from cells of Bacteria and Archaea is the presence of a nucleus. Cells that contain a nucleus are called eukaryotic cells, and cells that do not contain a nucleus are called prokaryotic cells. The domains Bacteria and Archaea include only organisms with prokaryotic cells. The domain Eukarya includes only organisms with eukaryotic cells.

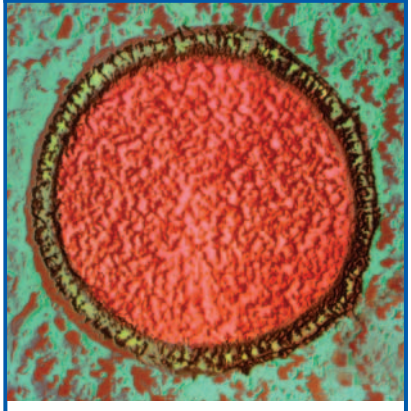
CHECK YOUR READING How are prokaryotic cells different from eukaryotic cells?

Bacteria



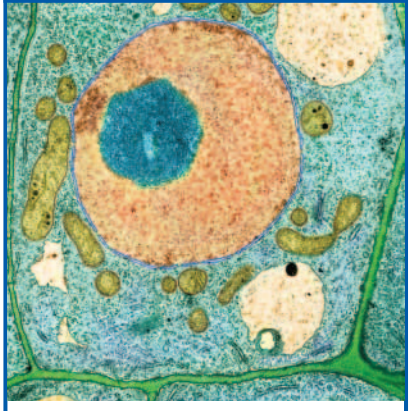
Bacterial cells are smaller than Eukarya cells and have no nucleus.

Archaea



Archaea cells have a distinctive chemistry and can survive extreme environments.

Eukarya



Eukarya cells are larger and contain more complex structures.

Six Kingdoms

All living things on Earth can be classified in six kingdoms.

Plantae

- Plants are multicellular and live on land.
- Plants obtain energy from sunlight.
- A plant cell has a nucleus, a cell wall, and chloroplasts.

Animalia

- Animals are multicellular and able to move.
- Animals obtain energy by eating food.
- An animal cell has a nucleus but no cell wall or chloroplasts.

Protista

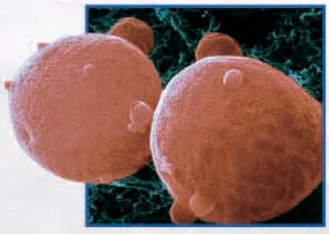
- Most protists are single-celled.
- Multicellular protists lack complex structure.
- A protist cell has a nucleus.

Fungi

- All fungi except yeasts are multicellular.
- Fungi obtain energy by absorbing materials.
- A fungus cell has a nucleus and a cell wall, but no chloroplasts.

Archaea

- Archaea are unicellular organisms without nuclei.
- Archaea cells have different chemicals than bacteria.
- Archaea can live in extreme conditions.



Bacteria

- Bacteria are unicellular organisms.
- A bacterial cell has no nucleus.
- Bacteria reproduce by dividing in two.

Six Kingdoms

The classification system that many scientists use today has six kingdoms. Every known species on Earth is included in one of these six kingdoms.

- Kingdom **Plantae** (PLAN-TEE) includes plants such as trees, grass, and moss.
- Kingdom **Animalia** (AN-uh-MAL-yuh) includes animals, from lions and tigers and bears to bugs and multicellular microbes.
- Kingdom **Protista** (pruh-TIHS-tuh) includes organisms that don't fit easily into animals, plants, or fungi. They are either unicellular organisms or have a simple multicellular structure.
- Kingdom **Fungi** (FUHN-jy) includes mushrooms, molds, and yeasts.
- Kingdom **Archaea** (AHR-kee-uh) contains organisms that are similar to bacteria, but have a cell structure that is so different that scientists separate them into their own kingdom.
- Kingdom **Bacteria** (bak-TIHR-ee-uh) are unicellular organisms with no nucleus.

This system may change as scientists learn more about the species in each kingdom. Before 1990, most scientists preferred a five-kingdom system that combined Archaea and Bacteria into a single kingdom. However, as scientists learned of chemical differences between the cells of the species, they arranged them into two kingdoms. Today, some scientists suggest that the kingdom Protista should be arranged into smaller kingdoms because of the many differences among its species. Many scientists agree on a three domain and six kingdom system similar to the one summarized on pages 317–319.

CHECK YOUR READING Which of the six kingdoms include unicellular organisms?

VOCABULARY
Add description wheels for *Plantae, Animalia, Protista, Fungi, Archaea,* and *Bacteria* to your notebook. You may want to add to your diagrams as you read the section.

The two most familiar kingdoms are plants and animals.

Carolus Linnaeus divided all of the species he identified into two large groups: plants and animals. People still use these groups to describe most living things today. But these two kingdoms also include unfamiliar organisms.

It might seem odd that living things that are so different from each other—humans, elephants, termites, ducks, fish, worms—are all part of the same group. However, all of these organisms share some general traits, just as all plants share another set of general traits.

Clematis viticella
(Italian clematis)

Plantae

About 250,000 plant species live on Earth. They range from tiny mosses to the largest organisms on the planet, giant sequoia trees. The oldest living organism on our planet is a plant called the bristlecone pine. Some living bristlecone pines were growing when the Egyptians built the pyramids, about 4000 years ago.

All plants are multicellular and are eukaryotes, which means their DNA is stored in the nucleus of their cells. All plants are able to make sugars using the Sun's energy. Plants cannot move from place to place, but they can grow around objects, turn toward light, and grow upward. Plant cells are different from animal cells, because plant cells have tough walls outside their cell membranes.

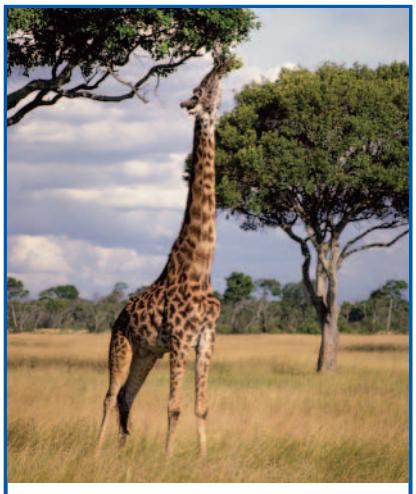
Animalia

Scientists have already named a million species in the kingdom Animalia. Many different types of animals inhabit the planet, but more than 90 percent of the named species are insects. The animal kingdom also includes familiar animals such as whales, sharks, humans, bears, dogs, and fish.

All animals get their energy by eating other organisms or by eating food made by other organisms. Animals have the ability to move around for at least part of their life. Most animals have mouths and some type of nervous system. Plant and animal cells are both eukaryotic, but animal cells have no cell walls.

CHECK YOUR READING What is the most abundant type of species in the animal kingdom?

Abracadabrella birdsville
(jumping spider)



Giraffa camelopardalis
(giraffe)

Octopus cyanea
(day octopus)

Other organisms make up four more kingdoms.

Carolus Linnaeus's classification systems included the organisms he knew about in the late 1700s. Some of the organisms Linnaeus called plants—the mushrooms, molds, and their relatives—turned out to have some characteristics very different from those of plants. Biologists now put fungi in a kingdom of their own.

Three other kingdoms consist mainly of microscopic organisms. These are Protista, Archaea, and Bacteria. Most organisms on Earth are classified as bacteria or archaea. These are prokaryotic organisms, which have small, simple cells and no nuclei.

CHECK YOUR READING What are the four kingdoms besides Plantae and Animalia?

Protista

The kingdom Protista includes a wide variety of organisms. Most protists are unicellular. Protists that are multicellular have structures that are too simple to be classified as animals, plants, or fungi. All protists have large, complex cells with a true nucleus (eukaryotes). Some eat other organisms as animals do; some get energy from sunlight as plants do. Some protists resemble fungi. However, protists that are multicellular do not have as many specialized cells or structures as plants, animals, and fungi.

Many protists live in pond water or sea water. The largest of the unicellular species are barely visible without a microscope. However, large organisms such as seaweeds are also classified as Protista. Some seaweeds can grow hundreds of feet in a single year.

Different groups of protists evolved from different ancestors. Scientists still debate whether kingdom Protista should be classified as one kingdom or should be split into several kingdoms.

Macrocystis pyrifera (giant kelp)

Fungi

Every time a loaf of bread is baked, a fungus is responsible for the rising dough. One group of fungi called yeasts makes it possible for us to make bread and many other food products. Another type of fungi that people eat includes some mushrooms. A mushroom grows in thin threads underground, and only the small cap breaks above the ground.

READING TiP
Fungi is the plural form of *fungus.*

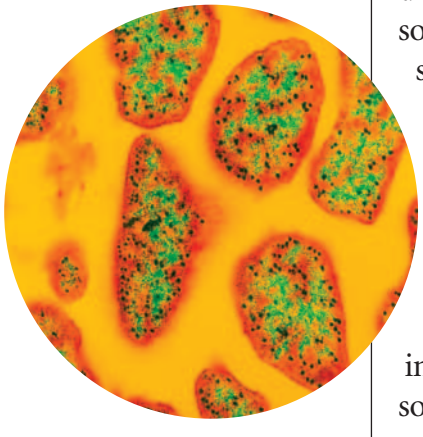
Fungi are usually divided into three categories: mushrooms, molds, and yeasts. The trait that separates fungi from other organisms is that fungi take in nutrients from their surroundings instead of eating other organisms or using sunlight. Both plants and fungi remain rooted in one place. Most fungi have cell walls similar to the cell walls of plants. Unlike plants, however, many fungi act as decomposers, breaking down dead or decaying material into simpler parts that can be absorbed or recycled by other organisms.

Penicillium
(bread mold)

Lepiota procera
(parasol mushroom)

Archaea

In the mid-1990s a researcher studying the genes of some bacteria discovered that although they resembled bacteria in size and cell type, some species had very specific genetic differences. After more study, scientists decided to call these organisms archaea. They differ so much that scientists now classify archaea in the separate kingdom or domain of Archaea.



Methanococcoides burtonii

In some ways, archaea appear to be more related to eukaryotes—organisms with complex cells containing nuclei—than to bacteria. Archaea do not have nuclei, but their cell structure is different from that of bacteria. Like bacteria, archaea live in many environments, especially in the ocean. But they also live in some very extreme environments, such as boiling mud near geysers, hot vents at the bottom of the ocean, salty ponds, and deep under the sand.

CHECK YOUR READING Which traits classify an organism as part of the kingdom Archaea?

Bacteria

Bacteria live nearly everywhere on Earth. This kingdom includes organisms that cause human disease and spoil food, but most of these organisms are helpful members of biological communities.

All bacteria are unicellular organisms. They have small, simple cells without a nucleus. Most bacteria have a cell wall outside the cell membrane, but this wall is not the same as the cell wall of plants. Bacteria reproduce by dividing in two, and can produce many new generations in a short period of time.

Escherichia coli (E. coli)

Species and environments change.

In the last chapter you read about the ways species change over time. You have also read how the evolutionary history of species helps scientists classify living things.

Scientists have named over a million species and placed them into six kingdoms. In addition, scientists estimate that there are millions—maybe tens of millions—more species that haven't been discovered. Scientists have also discovered forms of life preserved in the fossil record. Some of those organisms are the ancestors of organisms that live today.

Species evolve over time as individual organisms and environments change. Individual organisms are faced with many other pressures that affect daily lives. These pressures may come from changes in their living space, in the availability of food or other resources, or from other organisms. In the next chapter, you will read about how groups of species are affected by changes in their surroundings.

9.3 Review

KEY CONCEPTS

1. What are the names of the six kingdoms used in the classification system?
2. How are species sorted into the various kingdoms?

CRITICAL THINKING

3. **Communicate** Make a table with columns headed Characteristics, Animalia, and Plantae. Using as many rows as needed, list characteristics that differ between these two kingdoms.
4. **Analyze** Explain how fungi differ from plants.

CHALLENGE

5. **Analyze** One bacterium has a membrane surrounding its DNA. Should this organism be classified with the eukaryotes? Why or why not?

CHAPTER INVESTIGATION

Making a Field Guide

OVERVIEW AND PURPOSE A field guide is an illustrated book that shows the differences and similarities among plant or animal organisms. In this activity you will

- observe and classify leaves
- prepare a field guide based on your observations

Question

Write It Up

A field guide helps scientists identify organisms. Can you successfully prepare such a field guide? What would you like to know about how field guides are used and made? Write a question that begins with *Which, How, Why, When,* or *What.*

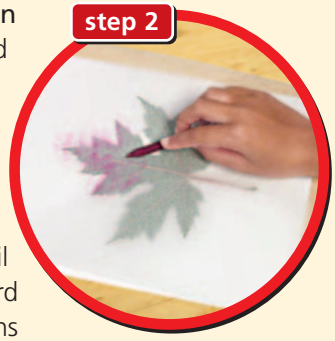
MATERIALS

- plastic gloves
- shoebox
- hand lens
- pencil
- paper
- tracing paper
- crayons

Procedure

1. Make 5 or more tables like the one shown on the sample science notebook on page 325. Gather at least 5 samples of different leaves from an area that your teacher chooses. **CAUTION: Wear protective gloves when handling plants. Be aware of any poisonous plants in your area. Place your samples in a shoebox and bring them back to the classroom for observation.**

2. **CAUTION: Wear plastic gloves when handling leaf samples.** Use the hand lens to study the leaves that you gathered. Make a sketch of each of the leaves. Create leaf rubbings by placing each leaf between two sheets of tracing paper and rubbing the top paper with the side of a pencil or crayon. Record your observations about each leaf in one of the data tables.



3 Use the information in your table to prepare your field guide. Start by dividing your leaves into two groups on the basis of one of the characteristics you observed. Then compare the leaves in each group. How are they similar or different? Continue to observe and divide the samples in each group until each leaf is in a classification by itself.

4 Use scientific field guides or other sources to identify your sample leaves. Find out the common and scientific name for each leaf and add that information to your table.

5 Describe the location of each sample and what effect the plant it represents has on its environment. For example, does the plant provide food or shelter for animals? Does it have a commercial use, or is it an important part of the environment?

6 Use your data tables, sketches, and leaf rubbings to prepare your field guide for the chosen area.

Observe and Analyze

Write It Up

1. **CLASSIFY** What characteristics did you choose for classifying your leaf samples? Explain why you grouped the leaves the way you did.

2. **ANALYZE** Which characteristics of the leaves you gathered were most useful in finding their scientific names and in identifying them?

Conclude

Write It Up

1. **INFER** Could you use the same characteristics you used to group your samples to classify leaves of other species?

2. **LIMITATIONS** Were there any leaves you could not classify? What would help you classify them?

3. **APPLY** How are field guides useful to scientists working on environmental studies? How are field guides useful to tourists or others who are exploring an environment?

INVESTIGATE Further

CHALLENGE Combine your field guide with those made by all the other members of your class to make one large field guide. Use all the sketches and observations to classify leaves into several large groups.

Making a Field Guide: Leaf 1

Characteristic	Observations
Simple leaf or several leaflets	
Number of lobes	
Texture	
Leaf edge	
Vein patterns	

Common name _____

Scientific name _____

Location where found _____

Uses/role in environment _____

9 Chapter Review

the BIG idea

Scientists have developed a system for classifying the great diversity of living things.

FLORIDA REVIEW
CLASSZONE.COM
Content Review and FCAT Practice

KEY CONCEPTS SUMMARY

1 Scientists develop systems for classifying living things.

- Living things are arranged in groups based on similarities.
- Classification is the process of arranging organisms into groups.
- Taxonomy involves classifying as well as naming species.

VOCABULARY
classification p. 300
taxonomy p. 300

2 Biologists use seven levels of classification.

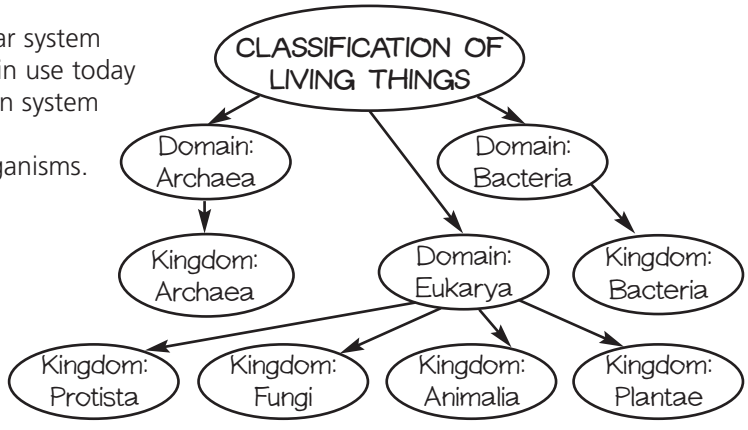
Spotted turtle
Clemmys guttata

Classification: Spotted turtle	
Kingdom	Animalia
Phylum	Chordata
Class	Reptilia
Order	Testudines
Family	Emydidae
Genus	*Clemmys*
Species	*guttata*

VOCABULARY
genus p. 308
binomial nomenclature p. 308
dichotomous key p. 312

3 Classification systems change as scientists learn more.

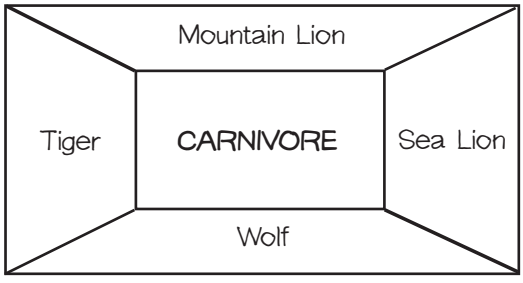
The most popular system of classification in use today is a three-domain system that includes six kingdoms of organisms.



VOCABULARY
domain p. 317
Plantae p. 319
Animalia p. 319
Protista p. 319
Fungi p. 319
Archaea p. 319
Bacteria p. 319

Reviewing Vocabulary

Make a frame like the one shown for each vocabulary word listed below. Write the word in the center. Decide what information to frame it with. Use definitions, examples, descriptions, parts, or pictures.



1. Plantae

2. Animalia

3. Protista

4. Fungi

Reviewing Key Concepts

Multiple Choice *Choose the letter of the best answer.*

5. The scientific process of arranging organisms into groups based on similarities is
- **a.** observation
- **b.** classification
- **c.** binomial nomenclature
- **d.** dichotomy

6. The system of naming organisms developed by Carolus Linnaeus is called
- **a.** binomial nomenclature
- **b.** taxonomy
- **c.** dichotomous nomenclature
- **d.** classification

7. Which group includes the most species?
- **a.** kingdom
- **b.** family
- **c.** domain
- **d.** phylum

8. The science of taxonomy allows scientists to
- **a.** identify unfamiliar organisms
- **b.** classify and name organisms
- **c.** refer to one specific type of organism
- **d.** determine similar traits of organisms

9. Which allows scientists to use genetic information to classify organisms?
- **a.** physical traits
- **b.** DNA
- **c.** fossil evidence
- **d.** habitats

10. A dichotomous key contains a series of questions that people use to
- **a.** find similar organisms
- **b.** identify organisms
- **c.** name organisms
- **d.** describe organisms

11. What are the names of the three domains?
- **a.** Plantae, Animalia, Protista
- **b.** Bacteria, Protista, Fungi
- **c.** Bacteria, Archaea, Eukarya
- **d.** Protista, Archaea, Eukarya

12. Which is an example of a trait?
- **a.** bone structure
- **b.** DNA information
- **c.** fossil records
- **d.** habitat

13. A group of species that have similar characteristics is called
- **a.** an order
- **b.** a family
- **c.** a phylum
- **d.** a genus

14. Which characteristic is common to animals, plants, protists, and fungi?
- **a.** ability to make their own food
- **b.** eukaryotic cells
- **c.** ability to move
- **d.** multicellular structure

Short Response *Write a short response to each question.*

15. What are the rules for creating a scientific name for an organism?

16. How is a field guide different from a dichotomous key?

17. What types of information caused scientists to add the level of domain to the system of classification?

Thinking Critically

18. **ANALYZE** How do scientists use fossils to classify organisms?

19. **APPLY** Scientists once classified American vultures and African vultures together in the falcon family. Now, scientists know that American vultures are more closely related to storks. What type of evidence might scientists have used to come to this conclusion? Explain your answer.

20. **EVALUATE** Which two of these species are more closely related: *Felis catus, Felis concolor, Picea concolor?* How do you know?

21. **INFER** A scientist is studying the following organisms. What conclusions can you draw about the organisms based on their scientific names?

- *Ursus americanus*
- *Ursus arctos*
- *Ursus maritimus*

22. **ANALYZE** Two organisms you are studying are in the same class, but in a different order. What does this information tell you about the two organisms?

23. **RANK** Which of these have more groups of organisms: phylum or family? Explain your answer.

24. **SUMMARIZE** Describe how you would use a dichotomous key to identify this leaf.

25. **SYNTHESIZE** Why was it necessary for scientists to create groups for classifying organisms other than the groups of plants and animals described by Linnaeus?

26. **CLASSIFY** Suppose you discover a new organism that is single celled, has a nucleus, lives in the water, and uses sunlight to produce its energy. In which kingdom would you classify this organism? Explain.

the BIG idea

27. **INFER** Look again at the picture on pages 296–297. Now that you have finished the chapter, how would you change or add details to your answer to the question on the photograph?

28. **PROVIDE EXAMPLES** Imagine that you are a scientist studying a variety of organisms in a South American rain forest. You have classified one organism in the kingdom Animalia and another organism in the kingdom Plantae. Give examples of the characteristics that would enable you to classify each organism in those kingdoms.

UNIT PROJECTS

If you are doing a unit project, make a folder for your project. Include in your folder a list of the resources you will need, the date on which the project is due, and a schedule to keep track of your progress. Begin gathering data.

FCAT Practice

Analyzing Graphics

Use the key to answer the following questions.

By following the steps in this dichotomous key, it is possible to find the type of tree to which a leaf belongs.

Step 1
1a) Leaves are needlelike . . . . . .Go to step 2
1b) Leaves are flat and scalelike . . . . . .Go to step 5
Step 2
2a) Needles are clustered . . . . . .Go to step 3
2b) Needles are not clustered . . . . . .Go to step 4
Step 3
3a) Clusters of 2–5 needles . . . . . .Pine
3b) Clusters greater than 10 . . . . . .Go to step 4
Step 4
4a) Needles soft . . . . . .Larch
4b) Needles stiff . . . . . .True cedar
Step 5
5a) Needles are short and sharp . . . . . .Giant sequoia
5b) Some needles are not sharp . . . . . .Go to Step 6

FCAT TiP

When using a dichotomous key, be sure to follow the directions carefully. If you lose your place, retrace your steps.

MULTIPLE CHOICE

1. Which type of tree has leaves with clusters of 2–5 needles?

A. pine tree
B. larch tree
C. true cedar tree
D. giant sequoia

2. If a tree has clusters of needles greater than 10, you would go to

F. step 1
G. step 2
H step 3
I. step 4

3. Each step on the key compares two

A. species
B. animals
C. traits
D. trees

4. A tree with soft needles that are not clustered is most likely a

F. pine tree
G. larch tree
H. true cedar tree
I. giant sequoia

SHORT RESPONSE

5. Use information from the key to describe the characteristics of a giant sequoia.

EXTENDED RESPONSE

6. A biologist has discovered and collected a number of unknown plant species from a rain-forest environment. Explain what type of evidence a biologist would rely on to determine if the plant species were new. Give specific examples of what a biologist would look for. What process would scientists go through to name the new species?

7. As you learned in the chapter, there are scientists who classify and name organisms. Explain why it is important for these taxonomists to study biological relationships. What may these relationships indicate about early life and modern life?