18 Classification

Big idea: Unity and Diversity of Life

Q: What is the goal of biologists who classify living things?

The National Museum of Natural History houses one of the largest collections of bird species in the world. The collection represents about 80 percent of the world's diversity of birds.

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CHAPTER **MYSTERY**

GRIN AND BEAR IT

If you simply looked at a polar bear and brown bear, you would probably never doubt that they are members of different species. Polar bears grow much larger than brown bears, and their paws have adapted to swimming long distances and to walking on snow and ice. Their white fur camouflages them, but the coats on brown bears are, well, brown—and their paws aren't adapted to water.

Clearly polar bears and brown bears are very different physically. But do physical characteristics tell the whole story? Remember the definition of *species:* "a group of similar organisms that can breed and produce fertile offspring." Well, polar bears and brown bears can mate and produce fertile offspring. They must be members of the same species, then. But are they? As you read this chapter, look for clues to whether polar bears are a separate species. Then, solve the mystery.

Never Stop Exploring Your World. Solving the mystery of scientific classification is only the beginning. Take a video field trip with the ecogeeks of Untamed Science to see where the mystery leads.

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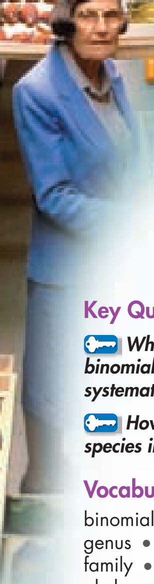


18.1 Finding Order in Diversity

Key Questions

What are the goals of binomial nomenclature and systematics?

How did Linnaeus group species into larger taxa?

Vocabulary

binomial nomenclature • genus • systematics • taxon • family • order • class • phylum • kingdom

Taking Notes

Preview Visuals Before you read, look at **Figure 18–5.** Notice all the levels of classification. As you read, refer to the figure again.

THINK ABOUT IT Scientists have been trying to identify, name, and find order in the diversity of life for a long time. The first scientific system for naming and grouping organisms was set up long before Darwin. In recent decades, biologists have been completing a changeover from that older system of names and classification to a newer strategy that is based on evolutionary theory.

Assigning Scientific Names

What are the goals of binomial nomenclature and systematics?

The first step in understanding and studying diversity is to describe and name each species. To be useful, each scientific name must refer to one and only one species, and everyone must use the same name for that species. But what kind of name should be used? Common names can be confusing, because they vary among languages and from place to place. The animal in **Figure 18–1,** for example, can be called a cougar, a puma, a panther, or a mountain lion. Furthermore, different species may share a common name. In the United Kingdom, the word *buzzard* refers to a hawk, whereas in the United States, *buzzard* refers to a vulture.

Back in the eighteenth century, European scientists recognized that these kinds of common names were confusing, so they agreed to assign Latin or Greek names to each species. Unhappily, that didn't do much to clear up the confusion. Early scientific names often described species in great detail, so the names could be long. For example, the English translation of the scientific name of a tree might be "Oak with deeply divided leaves that have no hairs on their undersides and no teeth around their edges." It was also difficult to standardize these names, because different scientists focused on different characteristics. Many of these same characteristics can still be used to identify organisms when using dichotomous keys, as you can see in **Figure 18–2.**

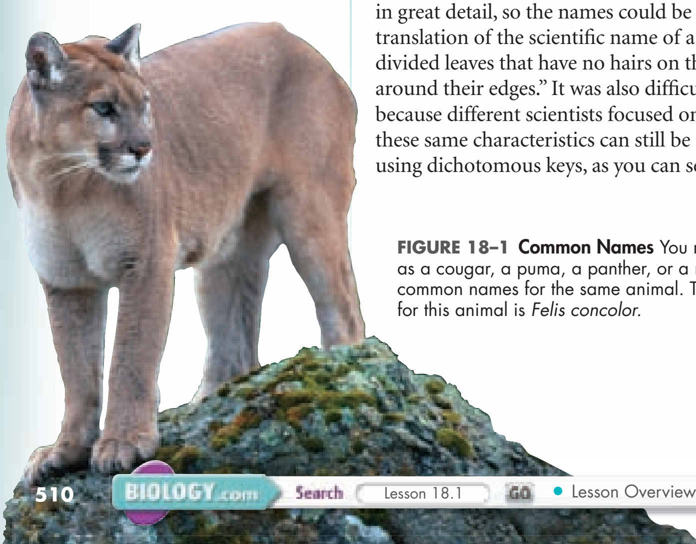
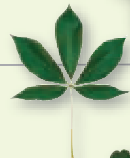
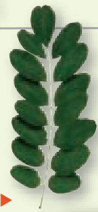
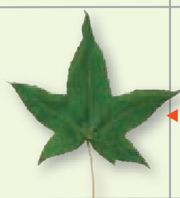


FIGURE 18–1 Common Names You might recognize this as a cougar, a puma, a panther, or a mountain lion—all common names for the same animal. The scientific name for this animal is *Felis concolor.*

USING A DICHOTOMOUS KEY

FIGURE 18–2 A dichotomous key is used to identify organisms. It consists of a series of paired statements or questions that describe alternative possible characteristics of an organism. The paired statements usually describe the presence or absence of certain visible characteristics or structures. Each set of choices is arranged so that each step produces a smaller subset.

Suppose you found a leaf that you wanted to identify. The leaf looks like the one shown here. Use the key to identify this leaf.

Step	Leaf Characteristics	Tree
1a	Compound leaf (leaves divided into leaflets) . . . go to Step 2	
1b	Simple leaf (leaf not divided into leaflets) . . . go to Step 4	
2a	Leaflets all attached at a central point	Buckeye 
2b	Leaflets attached at several points . . . go to Step 3	
3a	Leaflets tapered with pointed tips	 Pecan
3b	Leaflets oval with rounded tips	Locust 
4a	Veins branched out from one central point . . . go to Step 5	
4b	Veins branched off main vein in middle of the leaf . . . go to Step 6	
5a	Heart-shaped leaf	Redbud 
5b	Star-shaped leaf	 Sweet gum
6a	Leaf with jagged edges	Birch
6b	Leaf with smooth edges	Magnolia 

Because your leaf is a simple leaf, you skip ahead to Step 4.

Continue reading the statements until you determine the identity of your leaf.

Because your leaf has jagged edges, you determine that it's from a birch tree.

MYSTERY CLUE

Polar bears and brown bears interbreed and produce fertile hybrids in zoos, but they very rarely interbreed in nature. What do you think this means about the relationship between them?

Binomial Nomenclature In the 1730s, Swedish botanist Carolus Linnaeus, developed a two-word naming system called **binomial nomenclature.** **In binomial nomenclature, each species is assigned a two-part scientific name.** Scientific names are written in italic. The first word begins with a capital letter, and the second word is lowercased.

The polar bear in **Figure 18–3** is called *Ursus maritimus*. The first part of the name—*Ursus*—is the genus to which the organism belongs. A **genus** (plural: genera, JEN ur uh) is a group of similar species. The genus *Ursus* contains five other species of bears, including *Ursus arctos*, the brown bear or "grizzly."

The second part of a scientific name—in these examples, *maritimus* or *arctos*—is unique to each species. A species, remember, is generally defined as a group of individuals capable of interbreeding and producing fertile offspring. The species name is often a description of an important trait or the organism's habitat. The Latin word *maritimus*, refers to the sea, because polar bears often live on pack ice that floats in the sea.

In Your Notebook *The word* binomial *means "having two names." How does this meaning apply to binomial nomenclature?*

Classifying Species Into Larger Groups In addition to naming organisms, biologists also try to organize, or classify, living and fossil species into larger groups that have biological meaning. In a useful classification system, organisms in a particular group are more similar to one another than they are to organisms in other groups. The science of naming and grouping organisms is called **systematics** (sis tuh MAT iks). **The goal of systematics is to organize living things into groups that have biological meaning.** Biologists often refer to these groups as **taxa** (singular: taxon).

Whether you realize it or not, you use classification systems all the time. You may, for example, talk about "teachers" or "mechanics." Sometimes you refer to a smaller, more specific group, such as "biology teachers" or "auto mechanics." When you do this, you refer to these groups using widely accepted names and characteristics that many people understand. In the same way, when you hear the word *bird*, you immediately think of an animal with wings and feathers.

FIGURE 18–3 Binomial Nomenclature The scientific name of the polar bear is *Ursus maritimus*, which means "marine bear." The scientific name of the red maple is *Acer rubrum*. The genus *Acer* consists of all maple trees. The species *rubrum* describes the red maple's color.

Quick Lab
GUIDED INQUIRY

Classifying Fruits

1. Obtain five different fruits.
2. Use a knife to cut each fruit open and examine its structure. **CAUTION:** *Be careful with sharp instruments. Do not eat any of the cut fruits.*

3. Construct a table with five rows and four columns. Label each row with the name of a different fruit.
4. Examine the fruits, and choose four characteristics that help you tell the fruits apart. Label the columns in your table with the names of these characteristics.
5. Record a description of each fruit in the table.

Analyze and Conclude

1. **Classify** Based on your table, which fruits most closely resemble one another?

The Linnaean Classification System

How did Linnaeus group species into larger taxa?

In addition to creating the system of binomial nomenclature, Linnaeus also developed a classification system that organized species into taxa that formed a hierarchy or set of ordered ranks. Linnaeus's original system had just four levels. **Over time, Linnaeus's original classification system expanded to include seven hierarchical taxa: species, genus, family, order, class, phylum, and kingdom.**

We've already discussed the two smallest categories, species and genus. Now let's work our way up to the rank of kingdom by examining how camels are classified. The scientific name of a camel with two humps is *Camelus bactrianus.* (Bactria was an ancient country in Asia.) As you can see in **Figure 18–5,** the genus *Camelus* also includes another species, *Camelus dromedarius,* the dromedary, which has only one hump. In deciding how to place organisms into these larger taxa, Linnaeus grouped species according to anatomical similarities and differences.

FIGURE 18–4 Carolus Linnaeus

▶ ***Family*** The South American llama bears some resemblance to Bactrian camels and dromedaries. But the llama is more similar to other South American species than it is to European and Asian camels. Therefore, llamas are placed in a different genus, *Lama;* their species name is *Lama glama.* Several genera that share many similarities, like *Camelus* and *Lama,* are grouped into a larger category, the **family**—in this case, Camelidae.

▶ ***Order*** Closely related families are grouped into the next larger rank—an **order.** Camels and llamas (family Camelidae) are grouped with several other animal families, including deer (family Cervidae) and cattle (family Bovidae), into the order Artiodactyla, hoofed animals with an even number of toes.

BUILD Vocabulary

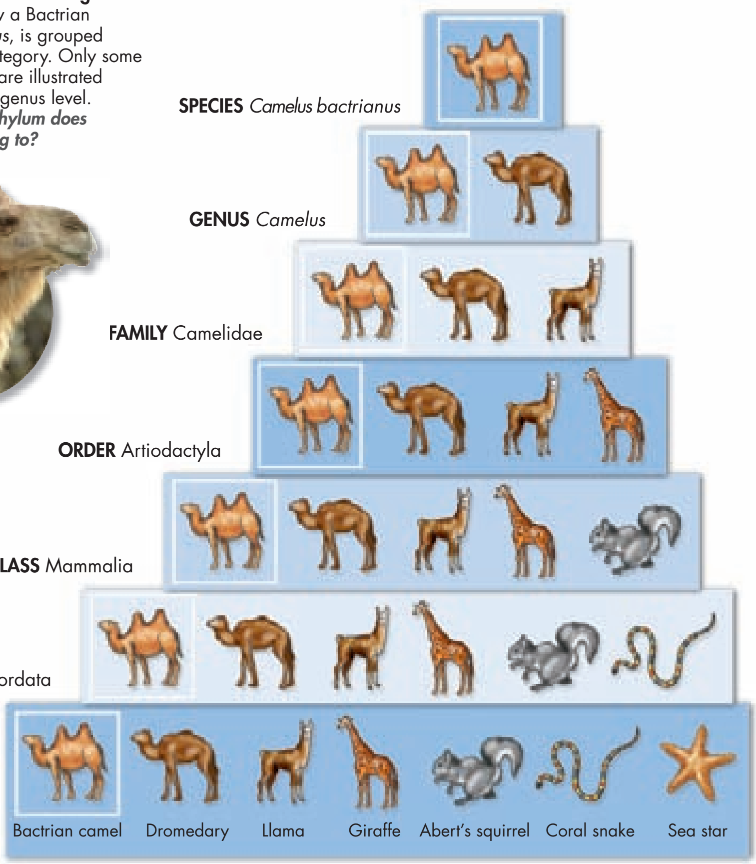
MULTIPLE MEANINGS The words **family, order, class,** and **kingdom** all have different meanings in biology than they do in common usage. For example, in systematics, a *family* is a group of genera. In everyday usage, a *family* is a group of people who are related to one another. Use a dictionary to find the common meanings of *order, class,* and *kingdom.*

▶ ***Class*** Similar orders, in turn, are grouped into the next larger rank, a **class.** The order Artiodactyla is placed in the class Mammalia, which includes all animals that are warmblooded, have body hair, and produce milk for their young.

▶ ***Phylum*** Classes are grouped into a **phylum.** A phylum includes organisms that are different but share important characteristics. The class Mammalia is grouped with birds (class Aves), reptiles (class Reptilia), amphibians (class Amphibia), and all classes of fish into the phylum Chordata. These organisms share important body-plan features, among them a nerve cord along the back.

▶ ***Kingdom*** The largest and most inclusive of Linnaeus's taxonomic categories is the **kingdom.** All multicellular animals are placed in the kingdom Animalia.

FIGURE 18–5 From Species to Kingdom This illustration shows how a Bactrian camel, *Camelus bactrianus*, is grouped within each taxonomic category. Only some representative organisms are illustrated for each taxon above the genus level. **Interpret Visuals** ***What phylum does*** **Camelus bactrianus** ***belong to?***



Problems With Traditional Classification In a sense, members of a species determine which organisms belong to that species by deciding with whom they mate and produce fertile offspring. There is thus a "natural" definition of species. Researchers, on the other hand, define Linnaean ranks above the level of species. Because, over time, systematists have emphasized a variety of characteristics, some of these groups have been defined in different ways at different times.

For example, Linnaeus's strategy of classifying organisms according to visible similarities and differences seems simple at first. But how should scientists decide which similarities and differences are most important? If you lived in Linnaeus's time, for example, how would you have classified the animals shown in **Figure 18–6**? Adult barnacles and limpets live attached to rocks and have similar-looking shells. Adult crabs look quite unlike both barnacles and limpets. Based on these features, would you place limpets and barnacles together, and crabs in a different group? As biologists attempted to classify more organisms over time, these kinds of questions arose frequently.

Linnaeus was a good scientist, and he chose his characteristics carefully. Many of his groups are still valid under modern classification schemes. But Linnaeus worked more than a century before Darwin published his ideas about descent with modification. Modern systematists apply Darwin's ideas to classification and try look beyond simple similarities and differences to ask questions about evolutionary relationships. Linnaeus grouped organisms strictly according to similarities and differences. Scientists today try to assign species to a larger group in ways that reflect how closely members of those groups are related to each other.

FIGURE 18–6 Barnacles, Limpets, and Crabs Problems can arise when species are classified based on easily observed traits. Look closely at the barnacles (top), the limpets (bottom), and the crab (left). Notice their similarities and differences. **Compare and Contrast** *Which animals seem most alike? Why?*

18.1 Assessment

Review Key Concepts

1. a. Review Identify two goals of systematics.

b. Explain Why do the common names of organisms—like *daisy* or *mountain lion*—often cause problems for scientists?

c. Classify The scientific name of the sugar maple is *Acer saccharum*. What does each part of the name designate?

2. a. Review List the ranks in the Linnaean system of classification, beginning with the smallest.

b. Explain In which group of organisms are the members more closely associated—all of the organisms in the same kingdom or all of the organisms in the same order? Explain your answer.

c. Apply Concepts What do scientists mean when they say that species is the only "natural" rank in classification?

Apply the Big idea

Unity and Diversity of Life

3. Which category has more biological meaning—all brown birds or all birds descended from a hawklike ancestor? Why?

18.2 Modern Evolutionary Classification

Key Questions

What is the goal of evolutionary classification?

What is a cladogram?

How are DNA sequences used in classification?

Vocabulary

phylogeny
clade
monophyletic group
cladogram
derived character

Taking Notes

Outline Make an outline of this lesson using the green headings as the main topics and the blue headings as subtopics. As you read, fill in details under each heading.

THINK ABOUT IT Darwin's ideas about a "tree of life" suggests a new way to classify organisms—not just based on similarities and differences, but instead based on evolutionary relationships. Under this system, taxa are arranged according to how closely related they are. When organisms are rearranged in this way, some of the old Linnaean ranks fall apart. For example, the Linnaean class reptilia isn't valid unless birds are included—which means birds are reptiles! And not only are birds reptiles, they're also dinosaurs! Wondering why? To understand, we need to look at the way evolutionary classification works.

Evolutionary Classification

What is the goal of evolutionary classification?

The concept of descent with modification led to **phylogeny** (fy LAHJ uh nee)—the study of how living and extinct organisms are related to one another. Advances in phylogeny, in turn, led to phylogenetic systematics. **The goal of phylogenetic systematics, or evolutionary classification, is to group species into larger categories that reflect lines of evolutionary descent, rather than overall similarities and differences.**

Common Ancestors

Phylogenetic systematics places organisms into higher taxa whose members are more closely related to one another than they are to members of any other group. The larger a taxon is, the farther back in time all of its members shared a common ancestor. This is true all the way up to the largest taxa.

Clades

Classifying organisms according to these rules places them into groups called clades. A **clade** is a group of species that includes a single common ancestor and all descendants of that ancestor—living and extinct. How are clades different from Linnaean taxa? A clade must be a monophyletic (mahn oh fy LET ik) group. A **monophyletic group** includes a single common ancestor and *all* of its descendants.

Some groups of organisms defined before the advent of evolutionary classification are monophyletic. Some, however, are paraphyletic, meaning that the group includes a common ancestor but excludes one or more groups of descendants. These groups are invalid under evolutionary classification.

In Your Notebook *In your own words, explain what makes a clade monophyletic or paraphyletic.*

BUILD Vocabulary

WORD ORIGINS The word **cladogram** comes from two Greek words: *klados*, meaning "branch," and *gramma*, meaning "something that is written or drawn." A cladogram is an evolutionary diagram with a branching pattern.

Cladograms

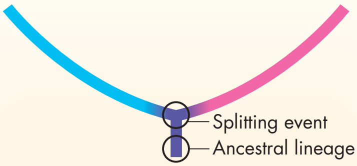
What is a cladogram?

Modern evolutionary classification uses a method called cladistic analysis. Cladistic analysis compares carefully selected traits to determine the order in which groups of organisms branched off from their common ancestors. This information is then used to link clades together into a diagram called a **cladogram.** **A cladogram links groups of organisms by showing how evolutionary lines, or lineages, branched off from common ancestors.**

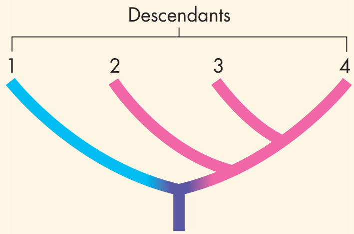
Building Cladograms To understand how cladograms are constructed, think back to the process of speciation. A speciation event, in which one ancestral species splits into two new ones, is the basis of each branch point, or node, in a cladogram. That node represents the last point at which the two new lineages shared a common ancestor. As shown in part 1 of **Figure 18–7,** a node splits a lineage into two separate lines of evolutionary ancestry.

Each node represents the last point at which species in lineages above the node shared a common ancestor. The bottom, or "root" of a cladogram, represents the common ancestor shared by all of the organisms in the cladogram. A cladogram's branching patterns indicate degrees of relatedness among organisms. Look at part 2 of **Figure 18–7.** Because lineages 3 and 4 share a common ancestor more recently with each other than they do with lineage 2, you know that lineages 3 and 4 are more closely related to each other than either is to lineage 2. The same is true for lineages 2, 3, and 4. In terms of ancestry, they are more closely related to each other than any of them is to lineage 1. Look at the cladogram shown in part 3 of **Figure 18–7.** Does it surprise you that amphibians are more closely related to mammals than they are to ray-finned fish? In terms of ancestry, it's true!

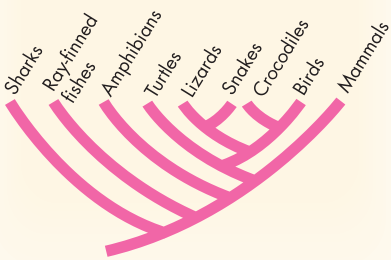
FIGURE 18–7 Building a Cladogram A cladogram shows relative degrees of relatedness among lineages.



1 Cladograms are diagrams showing how evolutionary lines, or lineages, split from each other over time. This diagram shows a single ancestral lineage splitting into two. The point of splitting is called a "node" in the cladogram.



2 How recently lineages share a common ancestor reflect how closely the lineages are related to one another. Here, lineages 3 and 4 are each more closely related to each other than any of them is to any other lineage.



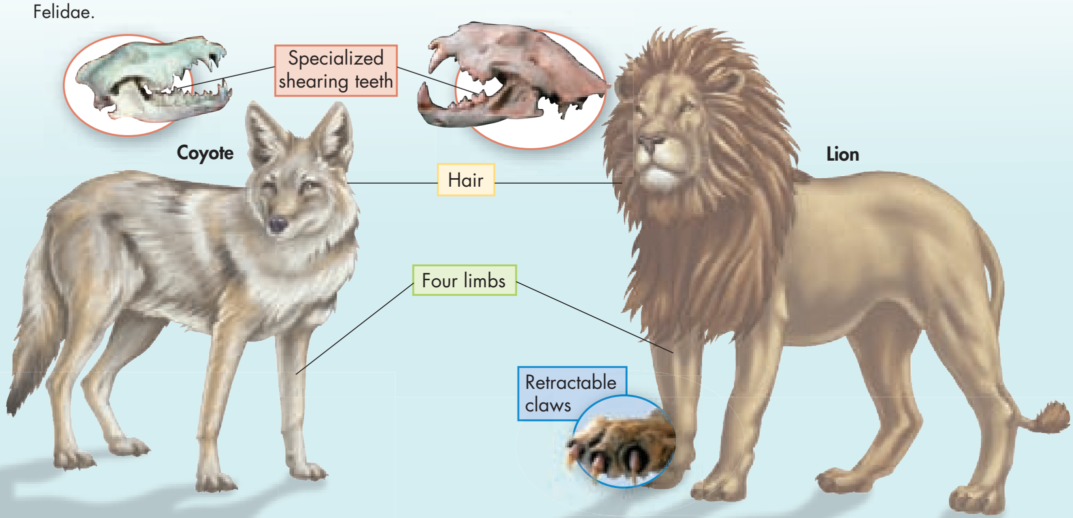
3 This cladogram shows the evolutionary relationships among vertebrates, animals with backbones.

Derived Characters In contrast to Linnaean taxonomy, cladistic analysis focuses on certain kinds of characters, called derived characters, when assigning organisms into clades. A **derived character** is a trait that arose in the most recent common ancestor of a particular lineage and was passed along to its descendants.

Whether or not a character is derived depends on the level at which you're grouping organisms. Here's what we mean. **Figure 18–8** shows several traits that are shared by coyotes and lions, both members of the clade Carnivora. Four limbs is a derived character for the entire clade Tetrapoda because the common ancestor of all tetrapods had four limbs, and this trait was passed to its descendants. Hair is a derived character for the clade Mammalia. But for mammals, four limbs is *not* a derived character—if it were, only mammals would have that trait. Nor is four limbs or hair a derived character for clade Carnivora. Specialized shearing teeth, however, is. What about retractable claws? This trait is found in lions but not in coyotes. Thus, retractable claws is a derived character for the clade Felidae—also known as cats.

Losing Traits Notice above that four limbs is a derived character for clade Tetrapoda. But what about snakes? Snakes are definitely reptiles, which are tetrapods. But snakes certainly don't have four limbs! The *ancestors* of snakes, however, did have four limbs. Somewhere in the lineage leading to modern snakes, that trait was lost. Because distantly related groups of organisms can sometimes lose the same character, systematists are cautious about using the *absence* of a trait as a character in their analyses. After all, whales don't have four limbs either, but snakes are certainly more closely related to other reptiles than they are to whales.

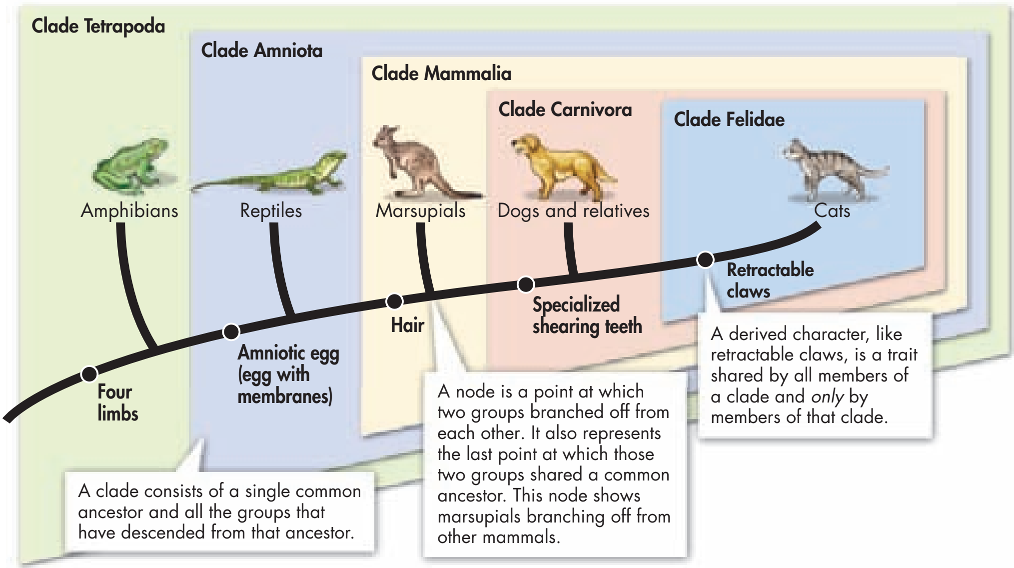
FIGURE 18–8 Derived Characters The coyote and lion share several characters—hair, four limbs, and specialized shearing teeth. These shared characters put them in the clades Tetrapoda, Mammalia, and Carnivora. The lion, however, has retractable claws. Retractable claws is the derived character for the clade Felidae.



VISUAL SUMMARY

INTERPRETING A CLADOGRAM

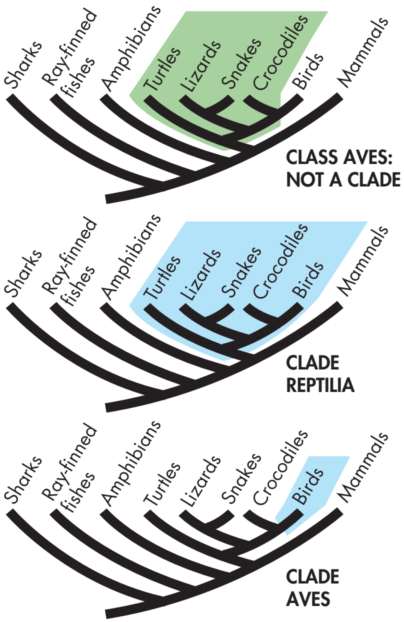
FIGURE 18–9 This cladogram shows the evolutionary history of cats. In a cladogram, all organisms in a clade share a set of derived characters. Notice that smaller clades are nested within larger clades. **Interpret Visuals** ***For which clade in this cladogram is an amniotic egg a derived character?***



Interpreting Cladograms We can now put this information together to "read" a cladogram. **Figure 18–9** shows a simplified phylogeny of the cat family. The lowest node represents the last common ancestor of all four-limbed animals—members of the clade Tetrapoda. The forks in this cladogram show the order in which various groups branched off from the tetrapod lineage over the course of evolution. The positions of various characters in the cladogram reflect the order in which those characteristics arose in this lineage. In the lineage leading to cats, for example, specialized shearing teeth evolved before retractable claws. Furthermore, each derived character listed along the main trunk of the cladogram defines a clade. Hair, for example, is a defining character for the clade Mammalia. Retractable claws is a derived character shared only by the clade Felidae. Derived characters that occur "lower" on the cladogram than the branch point for a clade are not derived for that particular clade. Hair, for example, is not a derived character for the clade Carnivora.

In Your Notebook *List the derived characters in* ***Figure 18–9*** *and explain which groups in the cladogram have those characters.*

FIGURE 18–10 Clade or Not? A clade includes an ancestral species and all its descendants. Linnaean class Reptilia is not a clade because it does not include modern birds. Because it leaves this descendant group out, the class is paraphyletic. Clades Reptilia and Aves, however, are monophyletic and, therefore, valid clades. **Apply Concepts** ***Would a group that included all of clade Reptilia plus amphibians be monophyletic or paraphyletic? Explain.***



Clades and Traditional Taxonomic Groups

Which of the Linnaean groupings form clades, and which do not? Remember that a true clade must be monophyletic, which means that it contains an ancestral species and *all* of its descendants—it can't leave any out. It also cannot include any species which are not descendants of that original ancestor. Cladistic analysis shows that many traditional taxonomic groups do form valid clades. For example, Linnaean class Mammalia corresponds to clade Mammalia (shown in **Figure 18–9**). Members of this clade include all vertebrates with hair and several other important characteristics.

In other cases, however, traditional groups do not form valid clades. **Figure 18–10** shows why. Today's reptiles are all descended from a common ancestor. But birds, which have traditionally not been considered part of the Linnaean class Reptilia, are also descended from that same ancestor. So, class Reptilia, without birds, is not a clade. However, several valid clades *do* include birds: Aves (the birds themselves), Dinosauria, and the clade named Reptilia. So, is it correct to call birds reptiles? An evolutionary biologist would say yes!

You may be wondering: class Reptilia, clade Reptilia, who cares? But the resulting names aren't as important as the concepts behind the classification. Evolutionary biologists look for links between groups, figuring out how each is related to others. So the next time you see a bird, thinking of it as a member of a clade or class isn't as important as thinking about it not just as a bird, but also as a dinosaur, a reptile, a tetrapod, and a chordate.

Quick Lab
GUIDED INQUIRY

Constructing a Cladogram

1. Identify the organism in the table that is least closely related to the others.

2. Use the information in the table to construct a cladogram of these animals.

Derived Characters in Organisms

Organism	Derived Character		
	Backbone	**Legs**	**Hair**
Earthworm	Absent	Absent	Absent
Trout	Present	Absent	Absent
Lizard	Present	Present	Absent
Human	Present	Present	Present

Analyze and Conclude

1. Interpret Tables What trait separates the least closely related animal from the other animals?

2. Apply Concepts Do you have enough information to determine where a frog should be placed on the cladogram? Explain your answer.

3. Draw Conclusions Does your cladogram indicate that lizards and humans share a more recent common ancestor than either does with an earthworm? Explain your answer.

DNA in Classification

How are DNA sequences used in classification?

The examples of cladistic analysis we've discussed so far are based largely on physical characteristics like skeletons and teeth. But the goal of modern systematics is to understand the evolutionary relationships of all life on Earth—from bacteria to plants, snails, and apes. How can we devise hypotheses about the common ancestors of organisms that appear to have no physical similarities?

Genes as Derived Characters Remember that all organisms carry genetic information in their DNA passed on from earlier generations. A wide range of organisms share a number of genes and show important homologies that can be used to determine evolutionary relationships. For example, all eukaryotic cells have mitochondria, and all mitochondria have their own genes. Because all genes mutate over time, shared genes contain differences that can be treated as derived characters in cladistic analysis. For that reason, similarities and differences in DNA can be used to develop hypotheses about evolutionary relationships. **In general, the more derived genetic characters two species share, the more recently they shared a common ancestor and the more closely they are related in evolutionary terms.**

New Techniques Suggest New Trees The use of DNA characters in cladistic analysis has helped to make evolutionary trees more accurate. Consider, for example, the birds in **Figure 18–11.** The African vulture in the top photograph looks a lot like the American vulture in the middle photograph. Both were traditionally classified in the falcon clade. But American vultures have a peculiar behavior: When they get overheated, they urinate on their legs, relying on evaporation to cool them down. Storks share this behavior, while African vultures do not. Could the behavior be a clue to the real relationships between these birds?

Biologists solved the puzzle by analyzing DNA from all three species. Molecular analysis showed that the DNA from American vultures is more similar to the DNA of storks than to the DNA of African vultures. DNA evidence therefore suggests that American vultures and storks share a more recent common ancestor than the American and African vultures do. Molecular analysis is a powerful tool that is now routinely used by taxonomists to supplement data from anatomy and answer questions like these.

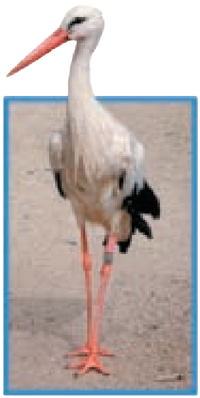


FIGURE 18–11 DNA and Classification Scientists use similarities in the genetic makeup of organisms to help determine classification. Traditionally African vultures and American vultures were classified together in the falcon family. But DNA analysis suggests that American vultures are actually more closely related to storks.

MYSTERY CLUE

DNA comparisons show that some populations of brown bears are more closely related to polar bears than they are to other brown bears. What do you think this means for the classification of polar bears?

Often, scientists use DNA evidence when anatomical traits alone can't provide clear answers. Giant pandas and red pandas, for example, have given taxonomists a lot of trouble. These two species share anatomical similarities with both bears and raccoons, and both of them have peculiar wrist bones that work like a human thumb. DNA analysis revealed that the giant panda shares a more recent common ancestor with bears than with raccoons. DNA places red pandas, however, outside the bear clade. So pandas have been reclassified, placed with other bears in the clade Ursidae, as shown in **Figure 18–12.** What happened to the red panda? It is now placed in a different clade that also includes raccoons and other organisms such as seals and weasels.

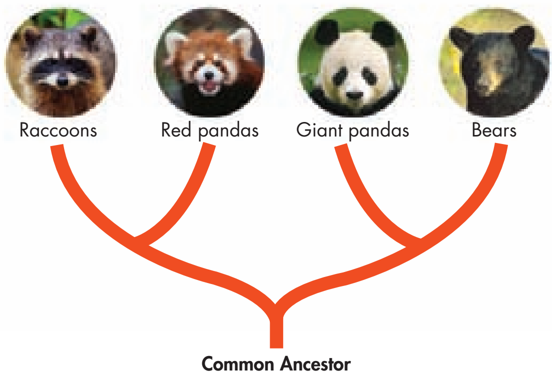


FIGURE 18–12 Classification of Pandas Biologists used to classify the red panda and the giant panda together. However, cladistic analysis using DNA suggests that the giant panda shares a more recent common ancestor with bears than with either red pandas or raccoons.

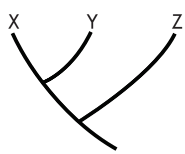
18.2 Assessment

Review Key Concepts

1. a. **Explain** How does evolutionary classification differ from traditional classification?
   b. **Apply Concepts** To an evolutionary taxonomist, what determines whether two species are in the same genus?
2. a. **Explain** What is a derived character?
   b. **Interpret Diagrams** Along any one lineage, what do the locations of derived characters on a cladogram show? In your answer, use examples from **Figure 18–9.**
3. a. **Review** How do taxonomists use the DNA sequences of species to determine how closely two species are related?
   b. **Relate Cause and Effect** Explain why the classification of American vultures has changed.

VISUAL THINKING

4. Examine the cladogram.
   a. **Interpret Diagrams** Which groups—X and Y, or X , Y, and Z—have the most recent common ancestor?
   b. **Infer** Which species—X and Y, or X and Z—share more derived characters?



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18.3 Building the Tree of Life

THINK ABOUT IT The process of identifying and naming all known organisms, living and extinct, is a huge first step toward the goal of systematics. Yet naming organisms is only part of the work. The real challenge is to group everything, from bacteria to dinosaurs to blue whales, in a way that reflects their evolutionary relationships. Over the years, new information and ways of studying organisms have produced major changes in Linnaeus's original scheme for organizing living things.

Key Questions

What are the six kingdoms of life as they are now identified?

What does the tree of life show?

Vocabulary

domain • Bacteria • Archaea • Eukarya

Taking Notes

Concept Map As you read, construct a concept map describing the characteristics of the three domains.

Changing Ideas About Kingdoms

What are the six kingdoms of life as they are now identified?

During Linnaeus's time, the only known differences among living things were the fundamental characteristics that separated animals from plants. Animals were organisms that moved from place to place and used food for energy. Plants were green organisms that generally did not move and got their energy from the sun.

As biologists learned more about the natural world, they realized that Linnaeus's two kingdoms—Animalia and Plantae—did not reflect the full diversity of life. Classification systems have changed dramatically since Linnaeus's time, as shown in **Figure 18–13.** And hypotheses about relationships among organisms are still changing today as new data are gathered.

Kingdoms of Life, 1700s–1990s

First Introduced	Names of Kingdoms					
1700s	Plantae					Animalia
Late 1800s	Protista			Plantae		Animalia
1950s	Monera		Protista	Fungi	Plantae	Animalia
1990s	Eubacteria	Archaebacteria	Protista	Fungi	Plantae	Animalia

FIGURE 18–13 From Two to Six Kingdoms This diagram shows some of the ways in which organisms have been classified into kingdoms since the 1700s.

Analyzing Data

Comparing the Domains

The table in **Figure 18–14** compares the three domains and six kingdoms. Use the information in the table to answer the following questions.

1. Interpret Tables Which kingdom has cells that lack cell walls?

2. Interpret Tables Which domain contains multicellular organisms?

3. Compare and Contrast On the basis of information in the table, how are the members of domain Archaea similar to those of domain Bacteria? How are organisms in domain Archaea similar to those in domain Eukarya?

Five Kingdoms As researchers began to study microorganisms, they discovered that single-celled organisms were significantly different from plants and animals. At first all microorganisms were placed in their own kingdom, named Protista. Then yeasts and molds, along with mushrooms, were placed in their own kingdom, Fungi.

Later still, scientists realized that bacteria lack the nuclei, mitochondria, and chloroplasts found in other forms of life. All prokaryotes (bacteria) were placed in yet another new kingdom, Monera. Single-celled eukaryotic organisms remained in the kingdom Protista. This process produced five kingdoms: Monera, Protista, Fungi, Plantae, and Animalia.

Six Kingdoms By the 1990s, researchers had learned a great deal about the genetics and biochemistry of bacteria. That knowledge made clear that the organisms in kingdom Monera were actually two genetically and biochemically different groups. As a result, the monerans were separated into two kingdoms, Eubacteria and Archaebacteria, bringing the total number of kingdoms to six. **The six-kingdom system of classification includes the kingdoms Eubacteria, Archaebacteria, Protista, Fungi, Plantae, and Animalia.** This system of classification is shown in the bottom row of **Figure 18–13** on the previous page.

FIGURE 18–14 Three Domains Today organisms are grouped into three domains and six kingdoms. This table summarizes the key characteristics used to classify organisms into these major taxonomic groups.

Classification of Living Things

DOMAIN	Bacteria	Archaea	Eukarya			
KINGDOM	Eubacteria	Archaebacteria	"Protista"	Fungi	Plantae	Animalia
CELL TYPE	Prokaryote	Prokaryote	Eukaryote	Eukaryote	Eukaryote	Eukaryote
CELL STRUCTURES	Cell walls with peptidoglycan	Cell walls without peptidoglycan	Cell walls of cellulose in some; some have chloroplasts	Cell walls of chitin	Cell walls of cellulose; chloroplasts	No cell walls or chloroplasts
NUMBER OF CELLS	Unicellular	Unicellular	Most unicellular; some colonial; some multicellular	Most multicellular; some unicellular	Most multicellular: some green algae unicellular	Multicellular
MODE OF NUTRITION	Autotroph or heterotroph	Autotroph or heterotroph	Autotroph or heterotroph	Heterotroph	Autotroph	Heterotroph
EXAMPLES	*Streptococcus, Escherichia coli*	Methanogens, halophiles	*Amoeba, Paramecium,* slime molds, giant kelp	Mushrooms, yeasts	Mosses, ferns, flowering plants	Sponges, worms, insects, fishes, mammals

Three Domains Genomic analysis has revealed that the two main prokaryotic groups are even more different from each other, and from eukaryotes, than previously thought. So biologists established a new taxonomic category—the domain. A **domain** is a larger, more inclusive category than a kingdom. Under this system, there are three domains—domain Bacteria (corresponding to the kingdom Eubacteria); domain Archaea (which corresponds to the kingdom Archaebacteria); and domain Eukarya (kingdoms Fungi, Plantae, and Animalia, and the "Protista").

Why do we put quotations around about the old kingdom Protista? Well, scientists now recognize that this is a paraphyletic group. This means that there is no way to put all unicellular eukaryotes into a clade that contains a single common ancestor, all of its descendants, and only those descendants. Since only monophyletic groups are valid under evolutionary classification, we use quotations to show that this is not a true clade. A summary of the three-domain system is shown in **Figure 18–14.**

The Tree of All Life

What does the tree of life show?

Remember that modern evolutionary classification is a rapidly changing science with a difficult goal—to present all life on a single evolutionary tree. As evolutionary biologists study relationships among taxa, they regularly change not only the way organisms are grouped, but also sometimes the names of groups. Remember that cladograms are visual presentations of hypotheses about relationships, and not hard and fast facts. **The tree of life shows current hypotheses regarding evolutionary relationships among the taxa within the three domains of life.**

Domain Bacteria Members of the domain **Bacteria** are unicellular and prokaryotic. Their cells have thick, rigid walls that surround a cell membrane. The cell walls contain a substance known as peptidoglycan (PEP tih doh gly kun). These bacteria are ecologically diverse, ranging from free-living soil organisms to deadly parasites. Some photosynthesize, while others do not. Some need oxygen to survive, while others are killed by oxygen. This domain corresponds to the kingdom Eubacteria.

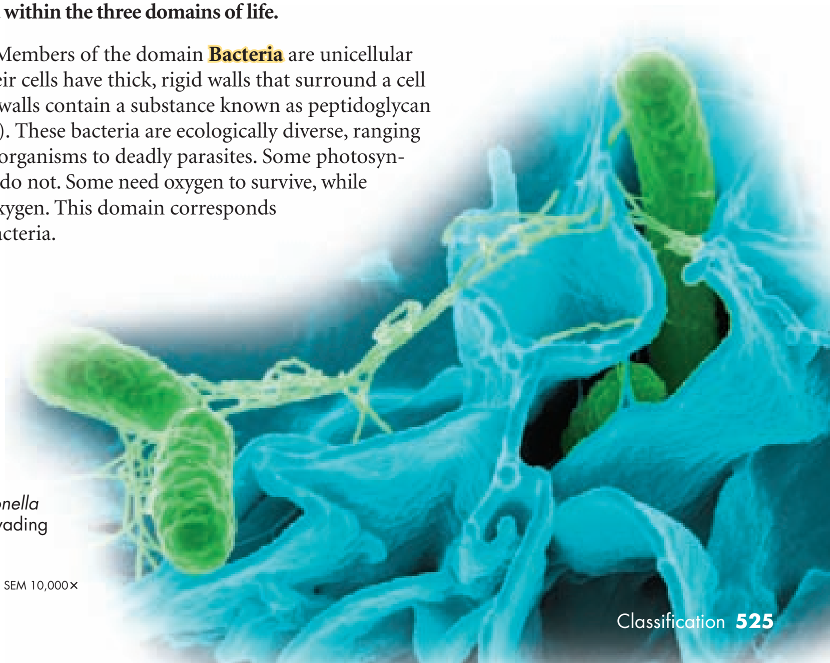

FIGURE 18–15 *Salmonella typhimurium* (green) invading human epithelial cells

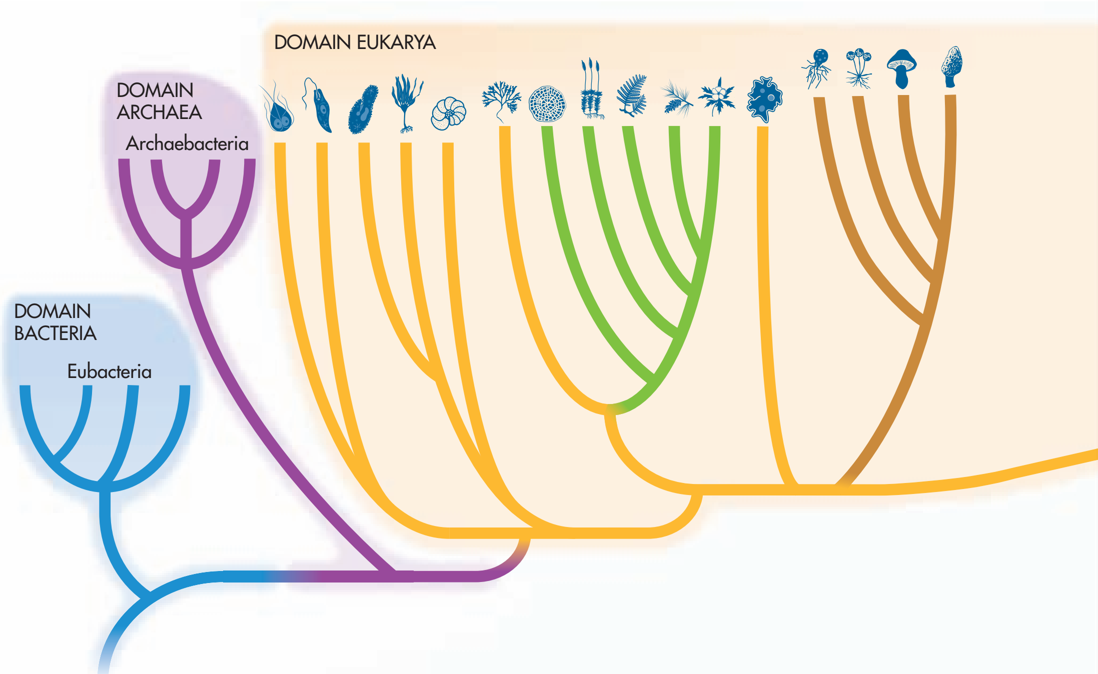

FIGURE 18–16 ***Sulfolobus*** This member of the domain Archaea is found in hot springs and thrives in acidic and sulfur-rich environments.

Domain Archaea Also unicellular and prokaryotic, members of the domain **Archaea** (ahr KEE uh) live in some of the most extreme environments you can imagine—in volcanic hot springs, brine pools, and black organic mud totally devoid of oxygen. Indeed, many of these bacteria can survive only in the absence of oxygen. Their cell walls lack peptidoglycan, and their cell membranes contain unusual lipids that are not found in any other organism. The domain Archaea corresponds to the kingdom Archaebacteria.

Domain Eukarya The domain **Eukarya** consists of all organisms that have a nucleus. It comprises the four remaining major groups of the six-kingdom system: "Protista," Fungi, Plantae, and Animalia.

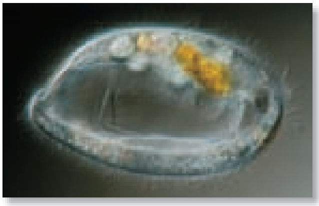

FIGURE 18–17 "Protists" "Protists" can live just about anywhere. This *Lembadion* is a freshwater ciliate.

▶ ***The "Protists": Unicellular Eukaryotes*** Recall that we are using quotations with this group to indicate that it is a paraphyletic group. Although some people still use the name "protists" to refer to these organisms, scientists who work with them have known for years that they do not form a valid clade. **Figure 18–18** reflects current cladistic analysis, which divides these organisms into at least five clades. The positions of these groups on the cladogram reflect its paraphyletic nature.

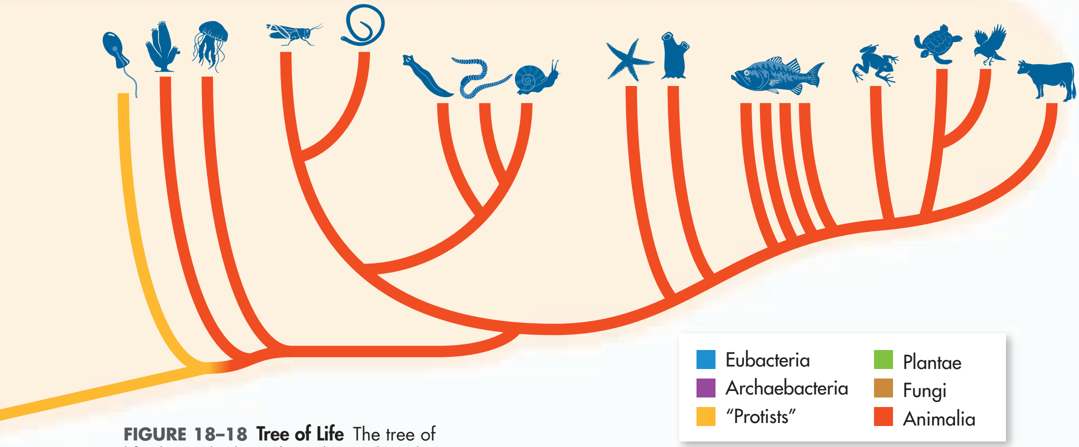

FIGURE 18–18 Tree of Life The tree of life shows the latest hypothesis about how major groups of organisms are related to one another. Note that both domain and kingdom designations are shown. **Classify** ***Which of the six kingdoms contains organisms that are not all in the same clade?***

Each group of "the eukaryotes formerly known as protists" is separate, and each shares closest common ancestors with other groups, rather than with each other. Most are unicellular, but one group, the brown algae, is multicellular. Some are photosynthetic, while others are heterotrophic. Some display characters that most closely resemble those of plants, fungi, or animals.

▶ ***Fungi*** Members of the kingdom Fungi are heterotrophs with cell walls containing chitin. Most feed on dead or decaying organic matter. Unlike other heterotrophs, fungi secrete digestive enzymes into their food source. After the digestive enzymes have broken down the food into smaller molecules, the fungi absorb the small molecules into their bodies. Mushrooms and other recognizable fungi are multicellular. Some fungi—yeasts, for example—are unicellular.

In Your Notebook *Explain why kingdom Protista is not valid under evolutionary classification.*

FIGURE 18–19
Ghost Fungus

FIGURE 18–20 Plants and Animals A sabre-wing hummingbird feeds on a pollinating ginger flower.

▶***Plantae*** Members of the kingdom Plantae are autotrophs with cell walls that contain cellulose. Autotrophic plants are able to carry on photosynthesis using chlorophyll. Plants are nonmotile—they cannot move from place to place. In this book, we follow the lead of the most current cladistic analysis, making the entire plant kingdom a sister group to the red algae, which are "protists." The plant kingdom, therefore, includes the green algae, along with mosses, ferns, cone-bearing plants, and flowering plants.

▶***Animalia*** Members of the kingdom Animalia are multicellular and heterotrophic. Animal cells do not have cell walls. Most animals can move about, at least for some part of their life cycle. As you will see in later chapters, there is incredible diversity within the animal kingdom, and many species of animals exist in nearly every part of the planet.

18.3 Assessment

Review Key Concepts

1. a. Review What are the six kingdoms of life as they are now identified?

b. Explain Why did systematists establish the domain?

c. Classify What were the monerans? Why did systematists split them into two kingdoms?

2. a. Review What are the three domains of life?

b. Explain Why are quotes used when describing the kingdom "Protista"?

c. Predict Do you think the tree of life cladogram will always stay the same as it is in **Figure 18–18?** Explain your answer.

ANALYZING DATA

3. The table compares some molecular characteristics of organisms in the three domains.

a. Interpret Tables Which domains have unbranched lipids in their cell membranes?

b. Interpret Tables Which domain has just one type of RNA polymerase?

c. Analyze Data On the basis of this table, how are archaea different from bacteria?

Molecular Characteristic	Domain		
	Bacteria	Archaea	Eukarya
Introns (parts of genes that do not code)	Rare	Sometimes present	Present
RNA polymerase	One type	Several types	Several types
Histones found with DNA	Not present	Present	Present
Lipids in cell membrane	Unbranched	Some branched	Unbranched

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Technology & BIOLOGY

Bar-Coding Life

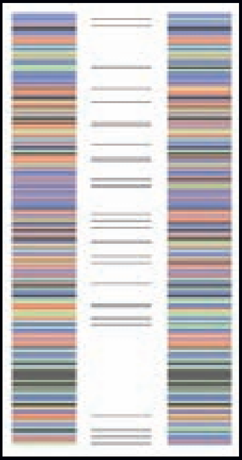
Until recently, classification has been a time-consuming process. A new project hopes to make identifying species as simple as scanning a supermarket bar code. It combines DNA sequencing with miniature computers, data processing, and the Internet.

To make this work, researchers picked a segment of DNA that all animals carry, the mitochondrial cytochrome oxidase (CO1) gene. (A chloroplast gene will probably be used for plants). Each base in the DNA sequence of CO1 is shown as a color-coded stripe, making it easy to spot differences between the barcodes of two specimens. The results are stored in a database.

Closely related species have similar bar codes. Species that are not closely related have bar codes that are very different from one another.

In the future, a researcher will be able to take a tiny sample of tissue or hair, analyze it using a portable device, and get a report on closest matches. Recent versions of this software even use maps to show where similar specimens have been collected before.

WRITING **Learn more about DNA bar-coding on the Internet. Then write a paragraph describing another possible use for the DNA bar-coding technology.**



▶ The bar code on the left belongs to the hermit thrush and the bar code on the right belongs to the American robin. Differences between the two bar codes, shown as lines in the middle column, show the genetic distance between the two species.

▶ **Hermit Thrush**

▶ **American Robin**

Design Your Own Lab

OPEN-ENDED INQUIRY

Pre-Lab: Dichotomous Keys

Problem Can you construct a dichotomous key that can be used to identify organisms?

Materials reference materials

Lab Manual Chapter 18 Lab

Skills Focus Observe, Classify, Compare and Contrast, Sequence

Connect to the Big idea Given the enormous variety of life on Earth, not even experts can identify every organism they observe. Both experts and amateurs use dichotomous keys to identify organisms. These keys are based on the appearance of organisms. A key is a series of paired statements. Readers select the statement that best describes an organism at each step until the organism is identified and named. In this lab, you will practice using a dichotomous key. Then you will construct your own key for a group of organisms.

Background Questions

a. **Review** Why do biologists prefer to identify an organism by its scientific name?

b. **Compare and Contrast** Explain how the way modern biologists group species into larger categories is different from the system that Linnaeus used.

c. **Review** How many choices does a dichotomous key provide at each step?

Pre-Lab Questions

Preview the procedure in the lab manual.

1. **Observe** Name three different physical traits that are used in the shark dichotomous key.
2. **Classify** Do all the sharks you will try to identify belong to the same genus? Explain your answer.
3. **Apply Concepts** After you make a list of physical traits that you can use in your dichotomous key, how will you decide which trait to pick for the first step?

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Visit Chapter 18 online to test yourself on chapter content and to find activities to help you learn.

Untamed Science Video Hop on board with the Untamed Science crew to find out how organisms are classified.

Art in Motion View a short animation that explains how to use a dichotomous key.

Art Review How well do you know the characteristics of the three domains? Test yourself in this activity.

InterActive Art Build your understanding of cladograms with this animation.

Data Analysis Investigate the problems involved in finding a mate for Lonesome George—the sole living member of his Galápagos tortoise species.

18 Study Guide

Big idea Unity and Diversity of Life

The goal of biologists who classify organisms is to construct a tree of life that shows how all organisms are related to one another.

18.1 Finding Order in Diversity

In binomial nomenclature, each species is assigned a two-part scientific name.

The goal of systematics is to organize living things into groups that have biological meaning.

Over time, Linnaeus's original classification system expanded to include seven hierarchical taxa: species, genus, family, order, class, phylum, and kingdom.

binomial nomenclature (512)
genus (512)
systematics (512)
taxon (512)
family (513)
order (513)
class (514)
phylum (514)
kingdom (514)

18.2 Modern Evolutionary Classification

The goal of phylogenetic systematics, or evolutionary classification, is to group species into larger categories that reflect lines of evolutionary descent, rather than overall similarities and differences.

A cladogram links groups of organisms by showing how evolutionary lines, or lineages, branched off from common ancestors.

In general, the more derived genetic characters two species share, the more recently they shared a common ancestor and the more closely they are related in evolutionary terms.

phylogeny (516)
clade (516)
monophyletic group (516)
cladogram (517)
derived character (518)

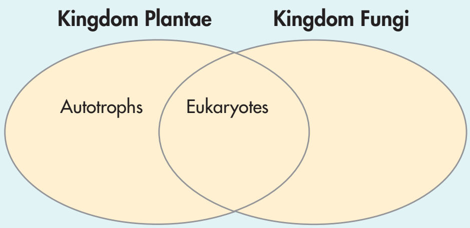
18.3 Building the Tree of Life

The six-kingdom system of classification includes the kingdoms Eubacteria, Archaebacteria, Protista, Fungi, Plantae, and Animalia.

The tree of life shows current hypotheses regarding evolutionary relationships among the taxa within the three domains of life.

domain (525)
Bacteria (525)
Archaea (526)
Eukarya (526)

Think Visually Using the information in this chapter, complete the following Venn diagram comparing members of kingdom Plantae and kingdom Fungi.



18 Assessment

18.1 Finding Order in Diversity

Understand Key Concepts

1. The science of naming and grouping organisms is called
   a. anatomy. **c.** botany.
   b. systematics. **d.** paleontology.

2. Solely from its name, you know that *Rhizopus nigricans* must be
   a. a plant. **c.** in the genus *Nigricans.*
   b. an animal. **d.** in the genus *Rhizopus.*

3. A useful classification system does NOT
   a. show relationships.
   b. reveal evolutionary trends.
   c. use different scientific names for the same organism.
   d. change the taxon of an organism based on new data.

4. In Linnaeus's system of classifying organisms, orders are grouped together into
   a. classes. **c.** families.
   b. species. **d.** genera.

5. The largest and most inclusive of the Linnaean taxonomic ranks is the
   a. kingdom. **c.** phylum.
   b. order. **d.** domain.

6. Why do biologists assign each organism a universally accepted name?

7. Why is species the only Linnaean rank defined "naturally"?

8. What features of binomial nomenclature make it useful for scientists of all nations?

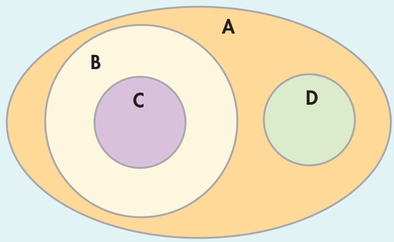
9. What is a taxon?

Think Critically

10. **Apply Concepts** What is a major problem with traditional classification? Give an example that demonstrates this problem.

11. **Use Analogies** Why is it important for a supermarket to have a classification scheme for displaying the foods that it sells?

12. **Classify** Venn diagrams can be used to make models of hierarchical classification schemes. A Venn diagram is shown below. Four groups are represented by circular regions—A, B, C, and D. Each region represents a collection of organisms or members of a taxonomic level. Regions that overlap, or intersect, share common members. Regions that do not overlap do not have members in common. Use the following terms to label the regions shown in the diagram: *kingdom Animalia, phylum Chordata, class Insecta,* and *class Mammalia.*



18.2 Modern Evolutionary Classification

Understand Key Concepts

13. A group that is limited to a common ancestor and all of its descendants is called a
    a. taxon. **c.** tree of life.
    b. phylogeny. **d.** monophyletic group.

14. A specific trait that is used to construct a cladogram is called a
    a. taxon. **c.** clade.
    b. structural feature. **d.** derived character.

15. A branch of a cladogram that consists of a single common ancestor and all the descendants of that ancestor is called
    a. cladistics. **c.** a clade.
    b. a kingdom. **d.** a class.

16. What does each individual node in a cladogram represent?

17. Why can differences in mitochondrial DNA be used as derived characters?

18. What is phylogeny?

Think Critically

19. **Apply Concepts** Both snakes and worms are tubular, with no legs. How could you determine whether their similarity in shape means that they share a recent common ancestor?

20. **Pose Questions** What questions would Linnaeus ask to determine a classification? What questions would a modern systematist ask?

21. **Apply Concepts** You are a biologist who is searching for new species in the Amazon jungle. You find two new species of beetles, beetle A and beetle B, that resemble each other closely but have somewhat different markings on their wings. In addition, both beetle A and beetle B resemble beetle C, a species that has already been identified. How could DNA similarities be used to help determine whether beetle A and beetle B are more closely related to each other or to beetle C?

22. **Infer** What is the relationship between natural selection and phylogeny?

23. **Apply Concepts** Explain why hair is a derived character for clade Mammalia but having four limbs is not. For which clade is four limbs a derived character?

18.3 Building the Tree of Life

Understand Key Concepts

24. The three domains are

a. Animalia, Plantae, and Archaebacteria.
b. Plantae, Fungi, and Eubacteria.
c. Bacteria, Archaea, and Eukarya.
d. Protista, Bacteria, and Animalia.

25. Which of the following kingdoms includes only heterotrophs?

a. Protista
b. Fungi
c. Plantae
d. Eubacteria

26. How do domains and kingdoms differ?

27. What characteristics are used to place an organism in the domain Bacteria?

solve the CHAPTER MYSTERY

GRIN AND BEAR IT

Most biologists classify the polar bear, *Ursus maritimus*, as a separate species from the brown bear, *Ursus arctos*. The teeth, body shape, metabolism, and behavior of polar bears are very different from those of brown bears. But some systematists are now questioning that classification.

Are polar bears and brown bears two distinct species? The answer depends on what a species is. The usual definition of *species* is "a group of similar organisms that can breed and produce fertile offspring." Polar bears and brown bears can, in fact, mate and produce offspring that are fertile. However, in the natural environment, polar bears and brown bears almost never mate.

The question is complicated by DNA analysis. There are different populations of brown bears, and these different populations have somewhat different genetic makeups. DNA analysis has shown that some populations of brown bears are more closely related to polar bears than they are to other populations of brown bears. According to DNA analysis, if polar bears are indeed a separate species, brown bears by themselves do not form a single clade.

1. **Classify** List the evidence that supports classifying polar bears and brown bears into two different species. Then list the evidence that indicates that polar bears and brown bears belong to the same species.

2. **Infer** What evidence indicates that different populations of brown bears belong to different clades?

3. **Connect to the Big idea** Do you think that the classic definition of *species*—"a group of similar organisms that can breed and produce fertile offspring"—is still adequate? Why or why not?

28. Which domain consists of prokaryotes whose cell walls lack peptidoglycan?

29. Describe the four kingdoms that make up the domain Eukarya.

30. What characteristic(s) differentiate the kingdom Fungi from the kingdom Eubacteria?

31. What do the branches of the tree of life try to show?

Think Critically

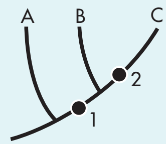
32. **Classify** In terms of cladistic analysis, what is the problem with placing all members of kingdom Protista into the same clade?

33. **Classify** Study the descriptions of the following organisms, and place them in the correct kingdom.
Organism A: Multicellular eukaryote without cell walls
Organism B: Its cell walls lack peptidoglycan, and its cell membranes contain certain lipids that are not found in other organisms. It lives in an extreme environment and can survive only in the absence of oxygen.
Organism C: Unicellular eukaryote with cell walls of chitin

Connecting Concepts

Use Science Graphics

The cladogram below shows the relationships among three imaginary groups of organisms—groups A, B, and C. Use the cladogram to answer questions 34–36.



34. **Interpret Visuals** Which groups share derived character 1?

35. **Apply Concepts** What does the node, or fork, between groups B and C represent?

36. **Apply Concepts** Which group split off from the other groups first?

Write About Science

37. **Explanation** Write a short explanation of the way in which taxonomists use similarities and differences in DNA to help classify organisms and infer evolutionary relationships. (*Hint:* Use a specific example to help clarify your explanation.)

38. **Assess the Big idea** Explain what the tree of life is and what its various parts represent. Also explain why the tree of life probably will change. (*Hint*: When you explain what the various parts represent, use the terms *base* and *branches*.)

Analyzing Data

Use the table to answer questions 39–41.

	Turtle	Lamprey	Frog	Fish	Cat
Hair	No	No	No	No	Yes
Amniotic egg	Yes	No	No	No	Yes
Four legs	Yes	No	Yes	No	Yes
Jaw	Yes	No	Yes	Yes	Yes
Vertebrae	Yes	Yes	Yes	Yes	Yes

39. **Interpret Tables** The first column lists derived characters that can be used to make a cladogram of vertebrates. Which characteristic is shared by the most organisms? Which by the fewest?

40. **Sequence** From the information given, place the animals in sequence from the most recently evolved to the most ancient.

41. **Draw Conclusions** Of the following pairs—lamprey-turtle, fish-cat, and frog-turtle—which are probably most closely related?

Standardized Test Prep

Multiple Choice

1. Which of the following is NOT a characteristic of Linnaeus's system for naming organisms?
A two-part name
B multipart name describing several traits
C name that identifies the organism's genus
D name that includes the organism's species identifier

2. In which of the following are the Linnaean ranks in correct order?
A phylum, kingdom, species
B genus, order, family
C kingdom, phylum, class
D order, class, family

3. In the six-kingdom system of classifying living things, which kingdoms contain unicellular organisms?
A Eubacteria only
B Eubacteria and "Protista" only
C Archaebacteria only
D Eubacteria, Archaebacteria, Plantae, and "Protista"

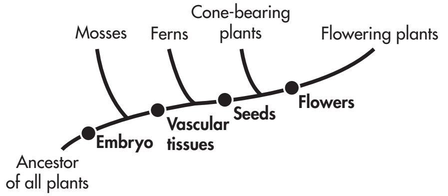
4. If species A and B have very similar genes, which of the following statements is probably true?
A Species A and B shared a relatively recent common ancestor.
B Species A evolved independently of species B for a long period.
C Species A and species B are the same species.
D Species A is older than species B.

5. The taxon called Eukarya is a(n)
A order.
B phylum.
C kingdom.
D domain.

6. Members of the kingdom "Protista" are classified into
A two domains.
B three domains.
C three species.
D three kingdoms.

Questions 7–9

The cladogram below shows the evolutionary relationships among four groups of plants.



7. Which of the following groups, taken by themselves, do NOT form a clade?
A cone-bearing plants and flowering plants
B ferns, cone-bearing plants, and flowering plants
C mosses and ferns
D mosses, ferns, cone-bearing plants, and flowering plants

8. Which of the following groups share the most recent common ancestor?
A cone-bearing plants and flowering plants
B mosses and ferns
C mosses and cone-bearing plants
D ferns and flowering plants

9. Which derived character appeared first during the course of the plants' evolution?
A seeds
B flowers
C embryo
D vascular tissues

Open-Ended Response

10. Why have biologists changed many of Linnaeus's original classifications of organisms?

If You Have Trouble With . . .										
Question	1	2	3	4	5	6	7	8	9	10
See Lesson	18.1	18.1	18.3	18.2	18.3	18.3	18.2	18.2	18.2	18.2