LESSON 19.1

Finding Order in Biodiversity

KEY QUESTIONS

- *What are the goals of binomial nomenclature and taxonomy?*
- *How did Linnaeus group species into larger taxa?*
- *What are the six kingdoms of life as they are now identified?*

VOCABULARY
taxonomy
binomial nomenclature
genus
taxon
family
order
class
phylum
kingdom

READING TOOL

In your **Biology Foundations Workbook**, order the events listed to describe the history of how scientists have organized and labeled living organisms.

As European scientists traveled the world, they discovered plants and animals they had never seen before. They were eager to communicate with each other about their discoveries. But the common names for organisms back then varied a lot from place to place. In fact, common names can still be confusing today. For example, in the United States, this big cat may be known as a cougar, a mountain lion, or a puma. Some of its Spanish common names are león Americano, león bayo, león Colorado, and onza bermeja! So, it isn't surprising that biologists need a scientific system to universally identify species.

Assigning Scientific Names

Biologists now identify and organize biodiversity through a standardized system. **Taxonomy** is a system of naming and classifying organisms based on shared characteristics and universal rules. Each scientific name must refer to one and only one species. Scientists must all agree to use the same name for that species.

At first, European scientists tried to assign Latin or Greek names to each species. Unhappily, that idea didn't work well. Early scientific names often described species in great detail, so names could be ridiculously 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.

Binomial Nomenclature In the 1730s, Swedish botanist Carolus Linnaeus developed a naming system called **binomial nomenclature**. The system proved very successful and popular, and is still in use today. ***In binomial nomenclature, each species is assigned a two-part scientific name.*** Scientific names are written in italics. The first word begins with a capital letter, and the second word is in lowercase.

For example, the scientific name of the polar bear shown in **Figure 19-1** is *Ursus maritimus*. The first part of that name—*Ursus*—is the genus to which the species belongs. A **genus** (plural: genera, JEN ur uh) is a group of similar species. The genus *Ursus* contains five other species of bears, such as *Ursus arctos*, the brown bear or grizzly bear, and *Ursus americanus*, the American black bear. The second part of a scientific 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.

VIDEO

Discover what it is like to find a new species.

Classifying Species into Larger Groups In addition to naming organisms, biologists classify living and fossil species into larger groups. Whether you realize it or not, you classify things all the time. You may, for example, talk about "teachers" or "mechanics." Sometimes you refer to a 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.

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).

READING CHECK **Synthesize** What are the parts of a scientific name for an organism?

Figure 19-1

Binomial Nomenclature

Different species within the same genus, such as these bears, lemurs, and oak trees, share many characteristics in common, but differ from each other in distinctive ways.

Ursus arctos

Eulemur coronatus

Quercus robur

Ursus maritimus

Eulemur macaco

Quercus virginiana

The Linnaean Classification System

Linnaeus developed a classification system that organized species into taxa based on similarities and differences he could see. ***Over time, Linnaeus's original classification system expanded to include seven hierarchical taxa: species, genus, family, order, class, phylum, and kingdom.***

INTERACTIVITY

Explore classification using the Linnaean system.

Species and Genus Let's explore this classification system using camels as our subject. The scientific name of a camel with two humps is *Camelus bactrianus*. The second part of the name refers to Bactria, an ancient country in Asia. As you can see in **Figure 19-2**, the genus *Camelus* also includes another species, *Camelus dromedarius*, the dromedary, which has only one hump.

Family Bactrian camels and dromedaries resemble llamas, which live in South America. But llamas are more similar to other South American species than they are to Asian and African camels. Therefore, llamas are placed in a different genus, *Lama*, and their species name is *Lama glama*. The genera *Camelus* and *Lama* are grouped with other genera that share many similarities into a larger taxon, the **family** Camelidae.

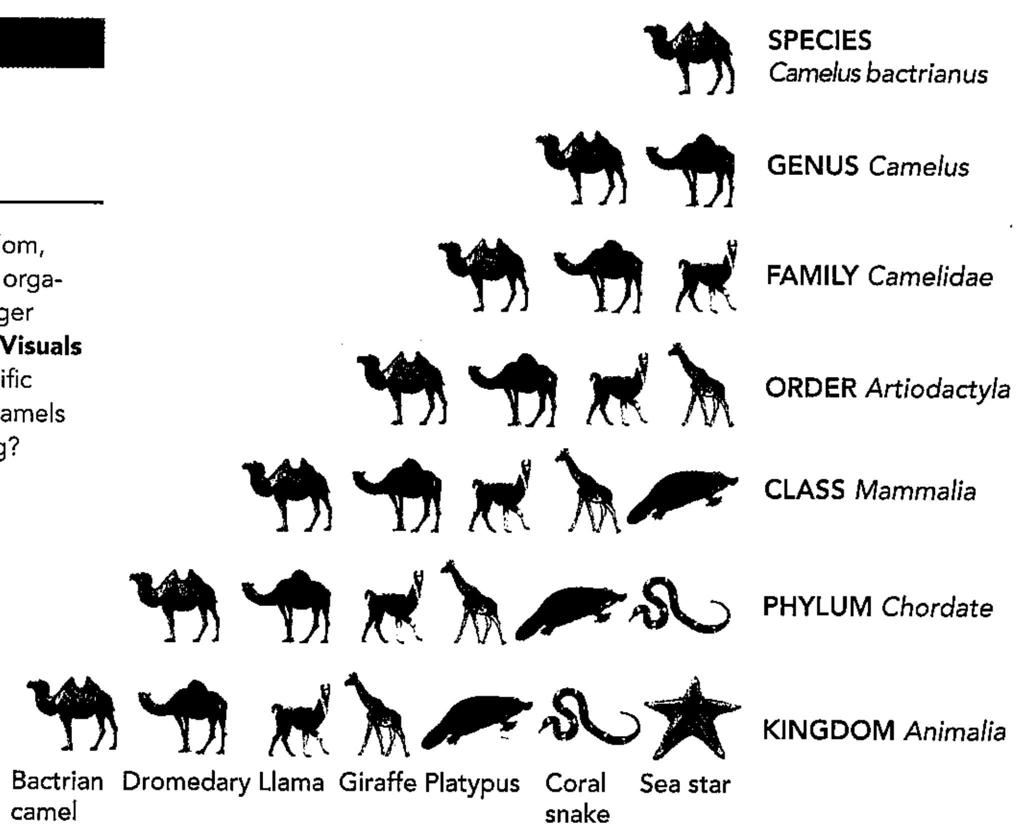
Order Closely related families are grouped into the next larger taxon, called an **order**. Camels and llamas (family Camelidae) are grouped with several other animal families, including deer (family Cervidae) and cattle (family Bovidae). They form the order Artiodactyla, which includes hoofed animals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

CASE STUDY

Figure 19-2

From Species to Kingdom

From species to kingdom, *Camelus bactrianus* is organized in larger and larger groups. **Interpret Visuals** What is the most specific group to which both camels and platypuses belong?



Class Similar orders, in turn, are grouped into the next larger rank, a **class.** The order Artiodactyla is placed in the class Mammalia. The mammals include 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 can look different, but share important characteristics. The class Mammalia is placed in the phylum Chordata. The chordates are animals that share a body feature called a nerve cord along the back and other important body features. Phylum Chordata includes mammals, birds (class Aves), reptiles (class Reptilia), amphibians (class Amphibia), and all classes of fishes.

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

Classification Changes with New Discoveries In a sense, organisms determine on their own who belongs to their species. How? By deciding with whom they mate! If individuals living under natural conditions mate and produce fertile offspring, those parents and offspring are members of the same species. That's a simple "natural" way to define species, the smallest important taxon.

Higher taxa, on the other hand, are defined by rules created by researchers like Linnaeus. He classified organisms according to rules based on similarities and differences he could see. But that can get tricky. Look at the animals in **Figure 19-3.** Adult barnacles and limpets both live attached to rocks, and have similar-looking shells. Adult crabs, on the other hand, scramble around on jointed legs. Based on these easily visible characteristics, would you classify limpets and barnacles together, and put crabs in a different group?

As biologists attempted to classify more and more organisms, these kinds of questions arose frequently. Which characteristics are most important? In addition, ongoing discoveries in genetics, cell biology, and development revealed scores of new and different characteristics. Rules for ranking the importance of those characteristics in forming higher taxa groups have changed over time. In addition, biologists today want classification to reflect Darwinian theory by grouping organisms into taxa that reflect how closely related they are to each other.

READING CHECK **Synthesize** What are the seven taxa in hierarchical order, from most general to most specific?

BUILD VOCABULARY

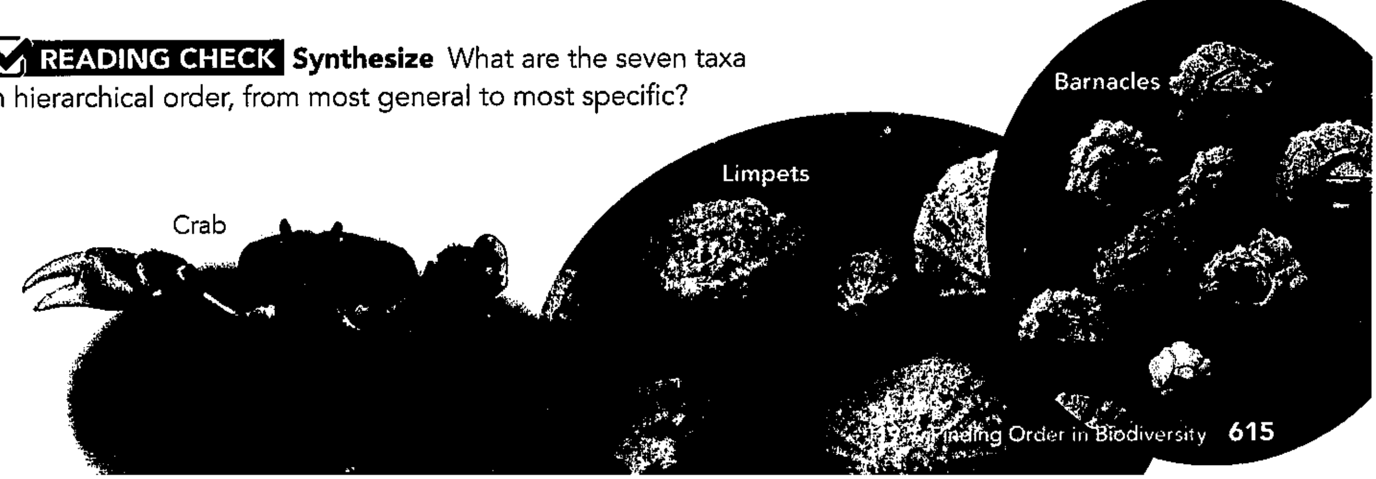
Multiple Meanings The words *family, order, class,* and *kingdom* all mean something different in everyday usage than they do in biological classification. For example, in everyday usage, a *family* is a group of people who are related to one another. In systematics, a *family* is a group of genera.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

INTERACTIVITY

Figure 19-3

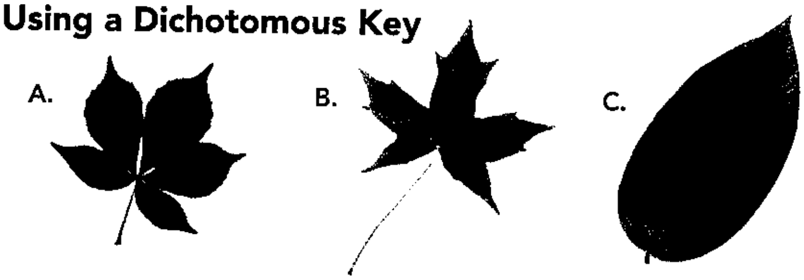
Classifying Organisms by Appearance

Barnacles may appear similar to limpets, but their interiors show more structural similiarity to crabs. These animals show the difficulty of classifying organisms by appearances alone.



Quick Lab — Guided Inquiry

Using a Dichotomous Key



A dichotomous key is a series of steps that lead to a classification of an organism. It consists of a series of paired statements that describe alternative characteristics of organisms. Use the key to identify the type of tree that produced each leaf. Begin with Step 1. Your answer to each step will either bring you to the next step or identify the tree. The results will show either the next step or the name of the tree.

ANALYZE AND CONCLUDE

1. **Classify** Identify the type of tree that produced leaves A, B, and C.
2. **Identify Patterns** Use the objects provided by your teacher to make your own dichotomous key.

Dichotomous Key for Classifying Leaves

Step	Leaf Characteristics	Result
1a	Compound leaf, divided into leaflets	Go to step 2
1b	Simple 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	Oval leaf	Magnolia

Changing Ideas About Kingdoms

During Linnaeus's time, the only known fundamental differences among living things were the characteristics that separated animals from plants. For this reason, the two kingdoms of this time were Animalia and Plantae. Over time, biologists learned more about the natural world. The classification systems have changed dramatically, as shown in **Figure 19-4**.

From Two to Six Kingdoms Researchers found faults with the two-kingdom system when they began to study microorganisms. They discovered that single-celled organisms were significantly different from plants and animals. At first, they placed all microorganisms in a single kingdom, called Protista. Then yeasts, molds, and multicellular mushrooms were placed in the new kingdom Fungi.

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

By the 1990s, researchers had learned enough about bacteria to realize that some organisms lumped together as Monera were very different from one another genetically and biochemically. As a result, monerans were separated into two kingdoms, Eubacteria and Archaebacteria. The total number of kingdoms is now 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 the chart in **Figure 19-4**.

Visual Summary

Figure 19-4

Kingdoms Over Time

This diagram shows some of the ways in which organisms have been classified into kingdoms since the 1700s.

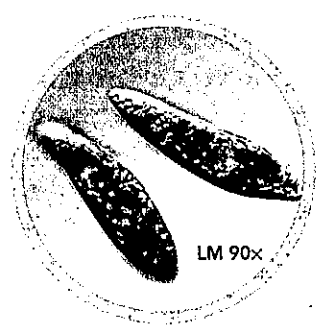
Kingdoms of Life, 1700s–1990s

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

Eubacteria

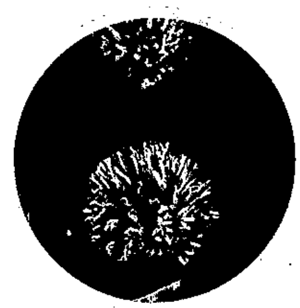
Lactobacillus acidophilus

"Protista"



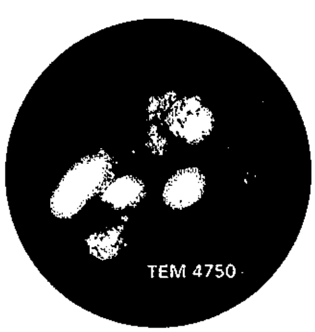
Euglena viridis

Plantae



Paeonia lactiflora

Archaebacteria



Halobacterium mediterranei

Fungi

Amanita muscaria

Animalia

Symphorichthys spilurus

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

Figure 19-5

Three Domains

Today, organisms are commonly grouped into three domains and six kingdoms. This table summarizes the key characteristics used to classify organisms into these higher taxa.

Three Domains Still more recent 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 even larger than a kingdom. The three are Bacteria (the old kingdom Eubacteria), Archaea (the old kingdom Archaebacteria), and Eukarya (kingdoms Fungi, Plantae, Animalia, and "Protista"), as shown in **Figure 19-5**.

Why do we put quotation marks around the old kingdom Protista? Recent research shows that there is no way to put all unicellular eukaryotes into a taxon that contains a single common ancestor, all of its descendants, and only those descendants. Since only that kind of taxon is valid under evolutionary classification, quotation marks are used to show that this is not a taxon of the sort modern biologists prefer.

LESSON 19.1 Review

KEY QUESTIONS

1. Identify two goals of systematics.
2. In which group of organisms are the members more closely related—all of the organisms in the same kingdom or all of the organisms in the same order? Explain your answer.
3. How do the six kingdoms fit into the three domains?

CRITICAL THINKING

4. **Define the Problem** What problem is solved by the Linnaean system of classification?
5. **Identify Patterns** A starfish and a sea cucumber are both members of the same phylum, called Echinodermata. From this information, what other taxa can you conclude that they share?
6. **CASE STUDY** The platypus is the only living member of the family Ornithorhynchidae. Based on this information, what conclusion can you make about its genus?

LESSON 19.2

Modern Evolutionary Classification

🔑 KEY QUESTIONS

- *What is the goal of evolutionary classification?*
- *What is a cladogram?*
- *How are DNA sequences used in classification?*
- *What does the tree of life show?*

HS-LS4-1: Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence.

VOCABULARY
phylogeny
clade
cladogram
derived character

READING TOOL

As you read, define and give examples of derived characters and lost traits. Fill in the table in your **Biology Foundations Workbook.**

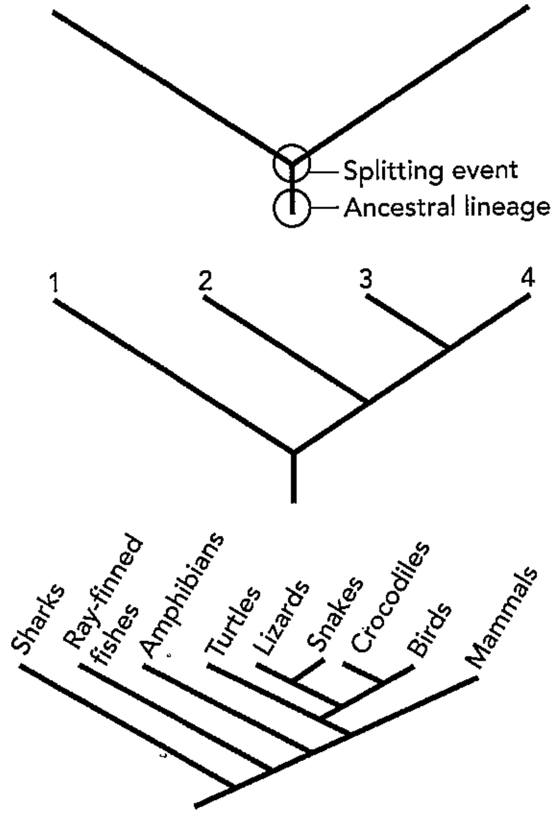
Darwin's "tree of life" suggests a way to classify organisms based on how closely related they are. When taxa are rearranged this way, some old Linnaean ranks fall apart. For example, the Linnaean class Reptilia isn't valid unless birds are included—which means birds are reptiles! And not only are birds reptiles, they are also descended from dinosaurs! Wondering why? To understand, we need to look at the way evolutionary classification works.

Evolutionary Classification

The core Darwinian concept of descent with modification revolutionized classification. First, Darwinian theory gave birth to the field of phylogeny. **Phylogeny** (fy LAHJ uh nee) is the study of the evolutionary history of lineages of organisms. Advances in phylogeny, in turn, led to evolutionary classification. 🔑 ***The goal of evolutionary classification is to group species into larger categories that reflect lines of evolutionary descent, rather than overall similarities and differences.***

Evolutionary classification 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—the domains described in the last lesson.

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. Some of the old higher taxa fit those requirements well. Other old taxa are not proper clades. Certain taxa fail the "clade test" because they include species descended from more than one different ancestor. Others (like the Linnaean class Reptilia) are not valid because they exclude some descendants of a single common ancestor (like birds).



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.

2 The relationship of lineages to each other is based on how recently they share a common ancestor. 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.

Figure 19-6
Building a Cladogram

A cladogram shows relative degrees of relatedness among lineages.

INTERACTIVITY

Complete a cladogram that shows the evolutionary history of plants.

Cladograms

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 current hypotheses about 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 and look at part 1 of **Figure 19-6**. Part 1 represents how one ancestral species branches into two species, each of which could found a new lineage. Now look at part 2. The bottom, or "root" of this cladogram, represents the common ancestor shared by all organisms in the cladogram. The branching pattern shows how closely related various lineages are. Each branch point represents the last point at which species in lineages above that point shared a common ancestor. Lineages 3 and 4 share a common ancestor more recently with each other than they do with lineage 2. So 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. All three of these groups are more closely related to each other than any of them is to lineage 1. Now look at part 3 of the figure. Does it surprise you that amphibians are more closely related to mammals than they are to ray-finned fish?

Derived Characters Cladistic analysis focuses on certain kinds of characters, called <u>derived</u> characters. A **derived character** is a trait that arose in the most recent common ancestor of a lineage and was passed 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 19-7** shows several traits shared by coyotes and lions, members of the clades Tetrapoda, Mammalia, and Carnivora. Four limbs is a derived character for the entire clade Tetrapoda, because the common ancestor of all tetrapods had four limbs. But if we look just at mammals, four limbs is *not* a derived character. If it were, *only* mammals would have four limbs. Hair, on the other hand, is a derived character for the clade Mammalia. But neither four limbs nor hair is a derived character for clade Carnivora. Why? Other species not in this clade also have four limbs (i.e. frogs) or hair (i.e. rodents). Specialized shearing teeth, however, is a derived character for Carnivora. 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, a subgroup of Carnivora that consists of cats.

Losing Traits As stated, four limbs is a derived character for clade Tetrapoda. But what about snakes? Snakes are reptiles, which are tetrapods. But snakes 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 can sometimes lose a 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.

READING CHECK **Classify** Are both coyotes and lions a member of the clade Carnivora? Explain.

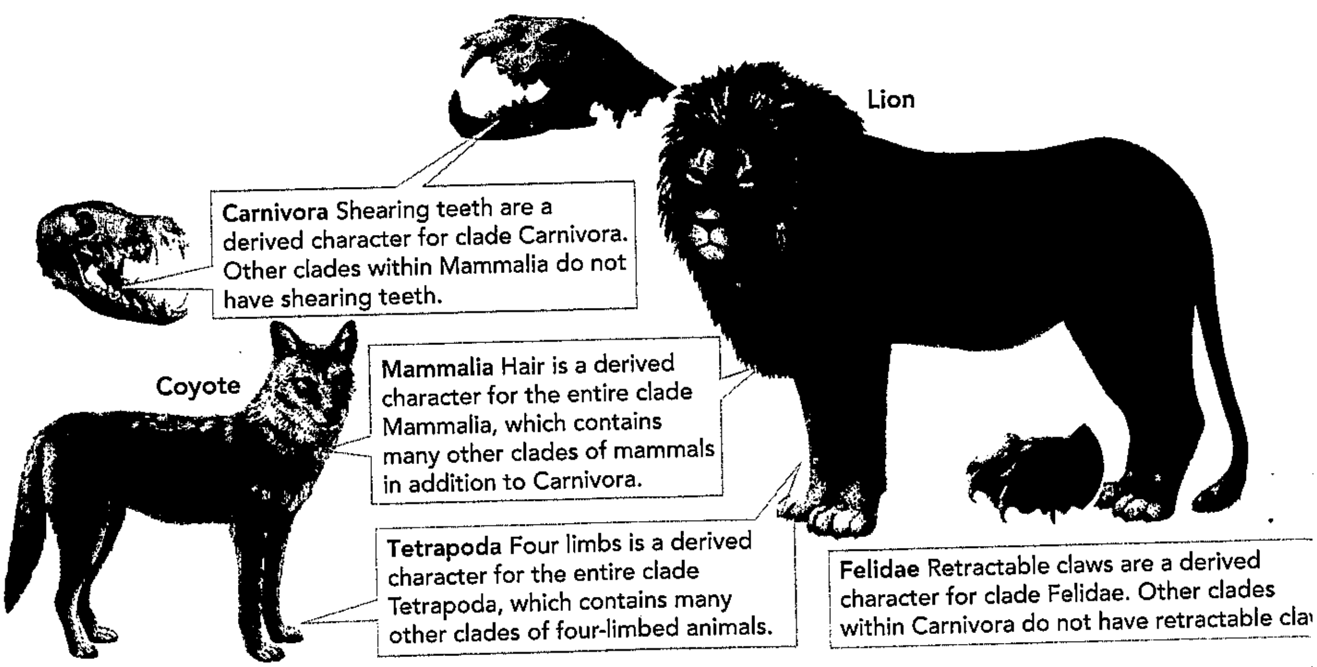
BUILD VOCABULARY

Academic Words The term <u>derived</u> refers to a beginning or origin. Some English words, for example, are derived from other languages. A **derived character** is a trait that has a common origin in a clade.

Figure 19-7

Derived Characters

Shared characters put both lions and coyotes in several clades, including Tetrapoda (four legs), Mammalia (hair), and Carnivora (shearing teeth Only the lion, however, has retractable claws, a derived character for the clade Felida



Interpreting Cladograms

Look at **Figure 19-8**, which shows a simplified phylogeny of the cat family. The lowest branching point represents the last common ancestor of all four-limbed animals, which are members of the clade Tetrapoda. The forks in this cladogram show the order in which various groups branched off from the tetrapod lineage. The positions of various characters in the cladogram reflect the order in which those characteristics arose. Hair, for example, is a defining character for the clade Mammalia. In the lineage leading to cats, specialized shearing teeth evolved before retractable claws.

Furthermore, each derived character listed along the main trunk of the cladogram defines a clade. 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. Note that hair is a derived character for the entire clade Mammalia, but it is not a derived character for the branch of mammals in the clade Carnivora.

CASE STUDY

Figure 19-8

Interpreting a Cladogram

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 is an amniotic egg a derived character? Is the duck-billed platypus a member of the clade Amniota? Explain.

Clades and Traditional Groups

Which Linnaean groupings form clades, and which do not? Remember that a true clade must contain an ancestral species and *all* of its descendants, with no exceptions. It also must exclude all species that are not descendants of the original ancestor. Cladistic analysis shows that many traditional taxonomic groups form valid clades. For example, Linnaean class Mammalia corresponds to clade Mammalia.

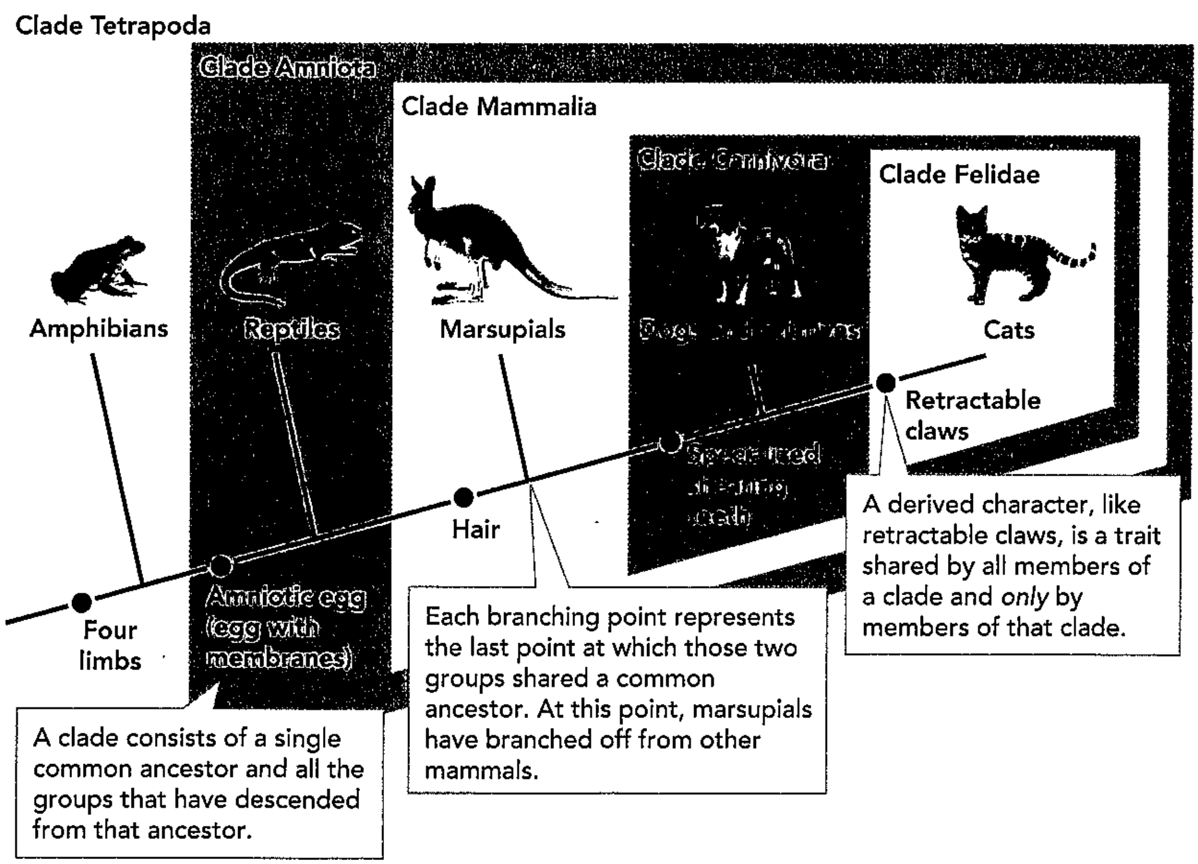
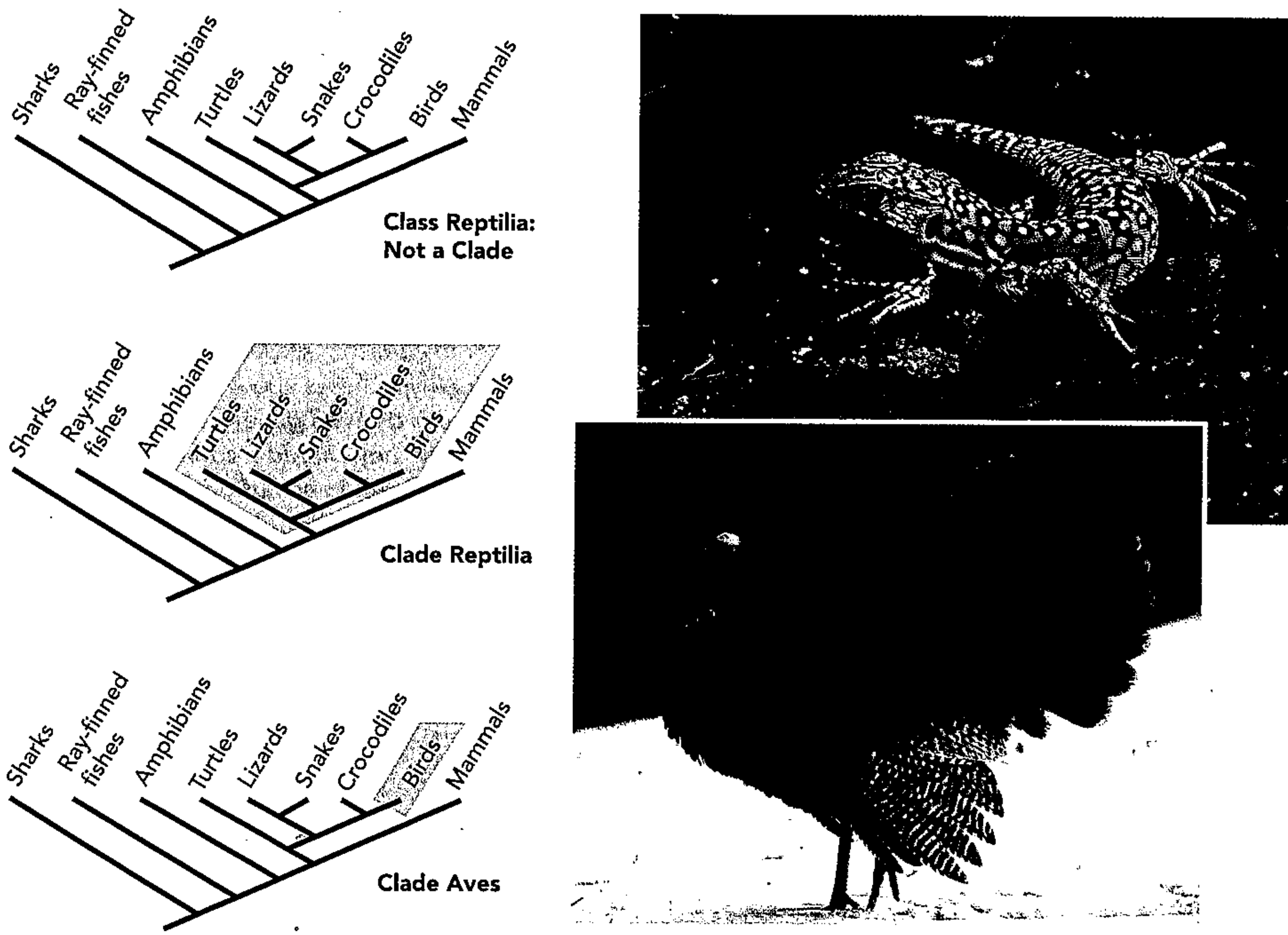


Figure 19-9

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. Clades Reptilia and Aves are valid clades. Note that these cladograms include living groups only.



In other cases, however, traditional groups are not valid clades, as **Figure 19-9** shows. Today's reptiles are all descended from a common ancestor. Birds were traditionally treated as a separate class, Aves. But birds are descended from that same common ancestor as reptiles. So class Reptilia, without birds, is not a clade. There are several valid clades that *do* include birds: Aves, Dinosauria, and the clade Reptilia. Can you now see why biologists say that birds are dinosaurs?

You may wonder: class Reptilia, clade Reptilia—who cares? But these names represent important concepts in classification. Remember that modern biologists want classification systems to represent the evolutionary relationships among organisms. Accurate understanding of those relationships can be very helpful in comparing and contrasting characteristics among and between clades.

READING CHECK **Compare** What do all clades have in common, regardless of their size?

INTERACTIVITY

Classify five shark species based on morphology and DNA analysis.

DNA in Classification

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

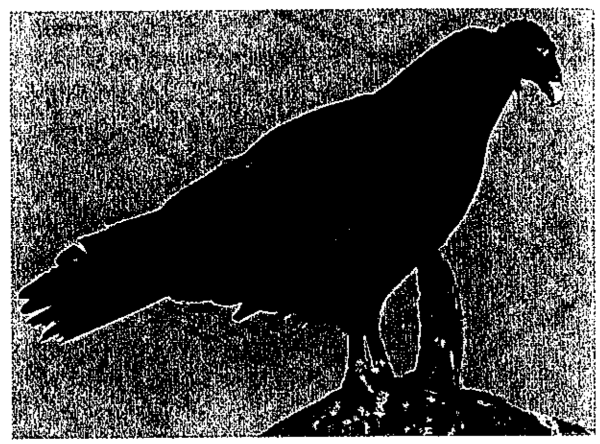
Genes as Derived Characters Remember that all organisms carry genetic information in DNA. They inherit genes from earlier generations. As scientists have discovered, a wide range of organisms share genes that can be used to determine evolutionary relationships.

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.***

Figure 19-10

DNA and Classification

The two vultures appear very different from the stork. However, DNA analysis suggests that American vultures, such as the turkey vulture, are more closely related to storks than they are to other vultures.



American turkey vulture (*Cathartes aura*)

African hooded vulture (*Necrosyrtes monachus*)

Saddle-billed stork (*Ephippiorhynchus senegalensis*)

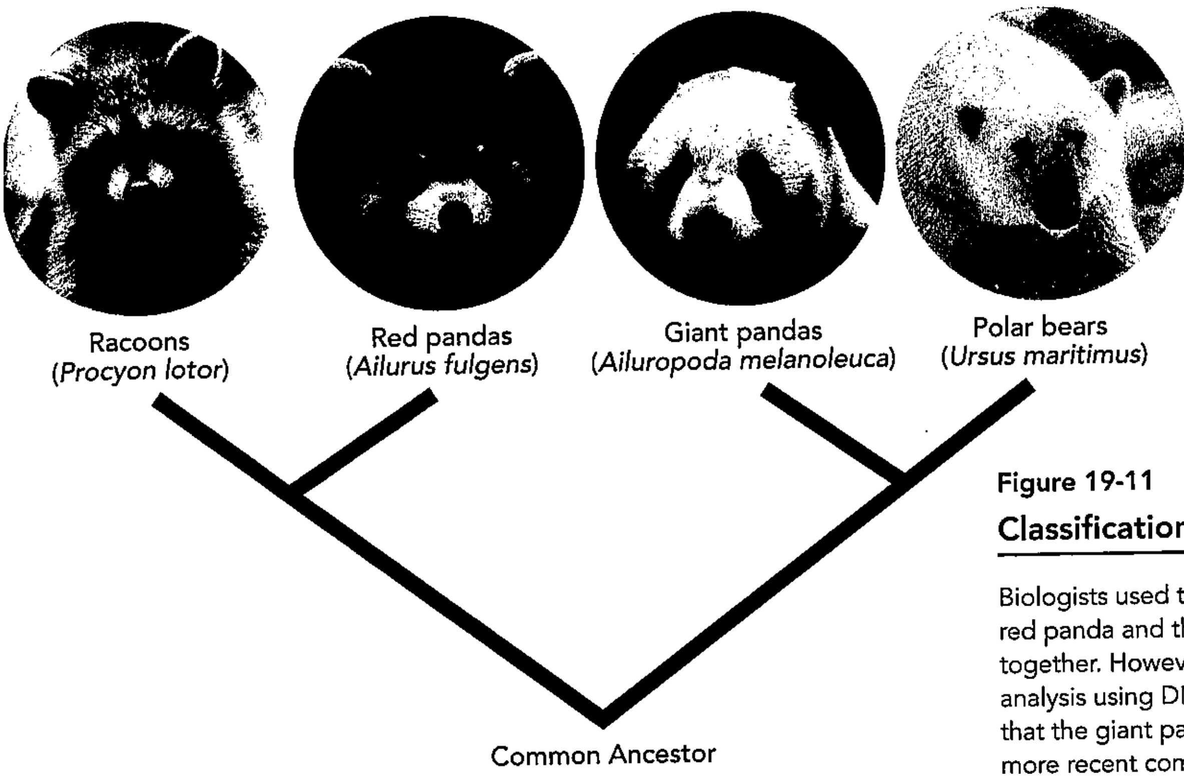


Figure 19-11

Classification of Pandas

Biologists used to classify the red panda and the giant panda together. However, cladistics analysis using DNA suggests that the giant panda shares a more recent common ancestor with bears than with either red pandas or raccoons.

New Techniques Suggest New Trees DNA analysis has helped to make evolutionary trees more accurate. Consider, for example, the birds shown in **Figure 19-10**. The hooded vulture from Africa looks a lot like the American turkey vulture. Both were traditionally classified in the Falcon clade. However, American vultures have a peculiar behavior: When they get overheated, they urinate on their legs, allowing evaporation to cool them down. Storks share this behavior, while hooded vultures and other vultures from Africa 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.

Often, scientists use DNA evidence when anatomical traits alone cannot provide clear answers. Giant pandas and red pandas, for example, puzzled taxonomists for many years. These species share anatomical similarities with both bears and raccoons, and both 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 giant pandas have been reclassified, and are now placed with other bears in the clade Ursidae, as shown in **Figure 19-11**. The red panda is now placed in a different clade that also includes raccoons, seals, and weasels.

READING CHECK **Summarize** Why is DNA analysis useful for classification?

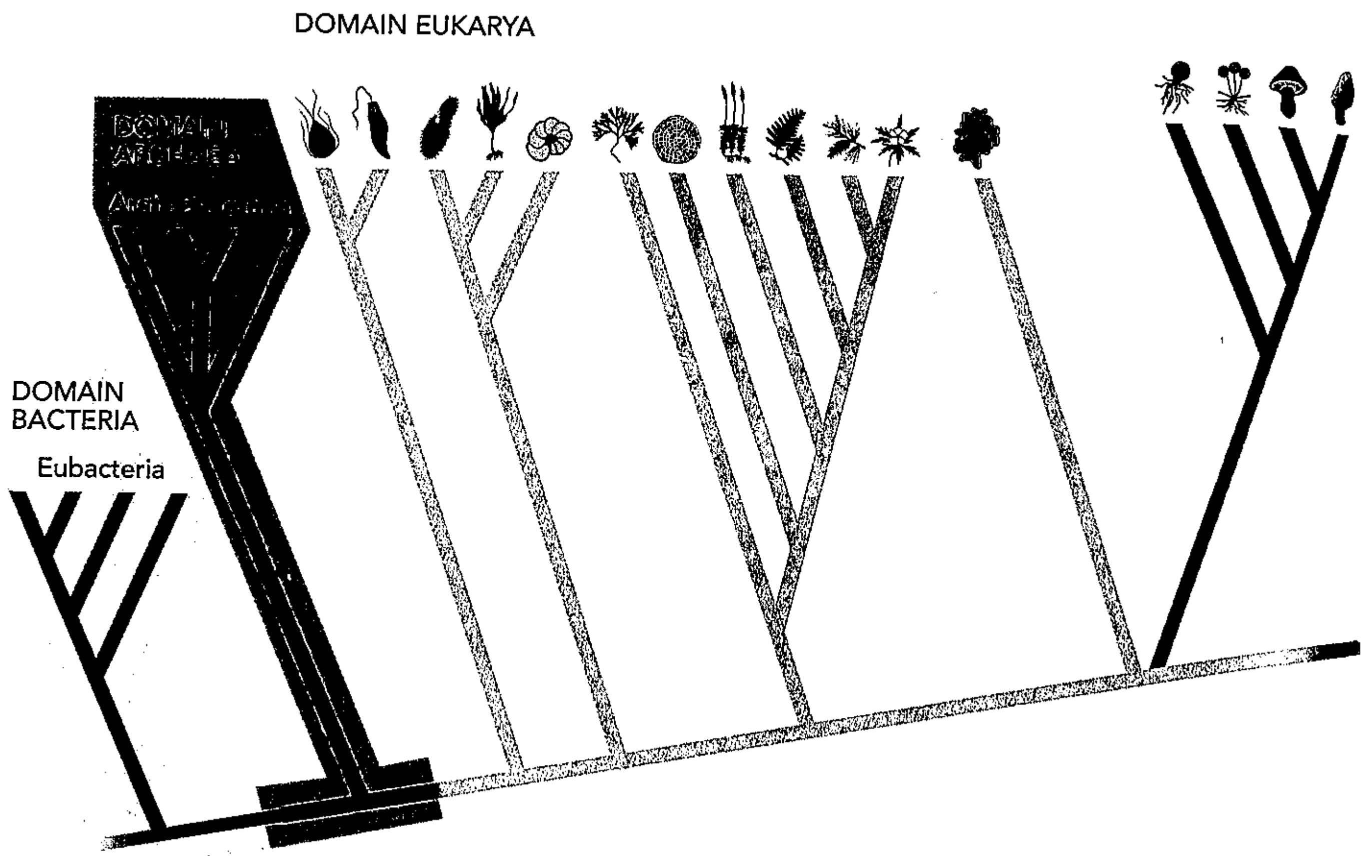


Figure 19-12
Tree of Life

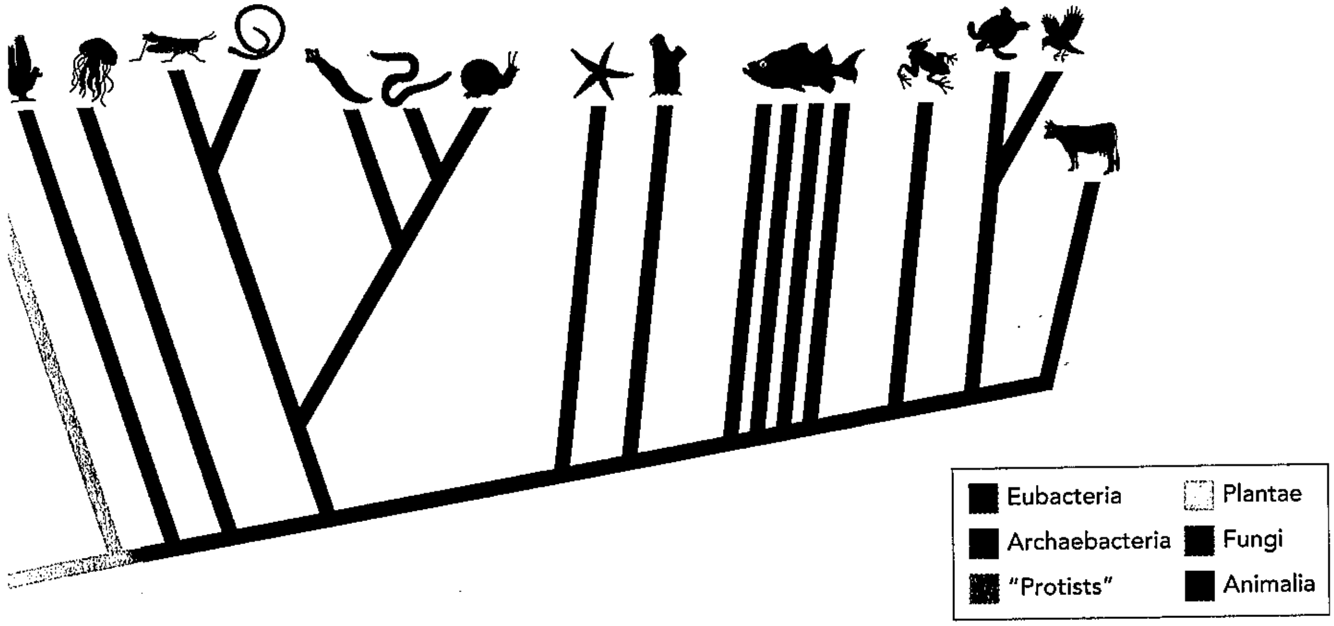
The tree of life shows the latest hypothesis about how major groups of organisms are related to one another. Note that both domain and kingdom designations are shown. **Classify** Which of the six kingdoms contains organisms that are not all in the same clade?

The Tree of All Life

Modern evolutionary classification is a rapidly changing science with a difficult goal—to present all life on a single evolutionary tree. As new discoveries are made, biologists change the way organisms are grouped. Sometimes they change the names of groups. Remember that cladograms are visual presentations of hypotheses about relationships, and not final. ***The tree of all life illustrates current hypotheses regarding evolutionary relationships among the taxa within the three domains of life.*** **Figure 19-12** shows a simplified version of the tree.

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 range 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 old kingdom Eubacteria.

Domain Archaea Like Bacteria, members of the domain Archaea (ahr KEE uh) are also unicellular and prokaryotic. However, Archaea live in some of Earth's most extreme environments, such as volcanic hot springs, brine pools, and black organic mud totally devoid of oxygen. Indeed, many archaea 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 organisms. The domain Archaea corresponds to the old kingdom Archaebacteria.



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

"Protists": Unicellular Eukaryotes Remember that this old kingdom is *not* a valid clade. People still use the name "protists" casually to refer to these organisms. However, scientists have known for years that many of these organisms are fundamentally different from one another, so the casual name has little meaning. Figure 19-12 shows that current cladistic analysis divides these organisms into at least five clades. The positions of these groups on the cladogram reflect current hypotheses about their evolutionary histories.

The protists are divided into several separate clades that also include other types of species. Most clades are unicellular, but one clade, the brown algae, is multicellular. Some are photosynthetic, while others are heterotrophic.

Fungi Members of the kingdom Fungi are heterotrophs with cell walls containing chitin. Mushrooms are multicellular. Some fungi, including yeasts, are unicellular. Fungal ecology is complicated, although most obtain nutrients from organic matter. Many fungi once thought to be just decomposers also act as symbionts with the roots of plants.

Plantae Members of the kingdom Plantae are autotrophs with cell walls that contain cellulose. Autotrophic plants photosynthesize using chlorophyll. The plant kingdom includes green algae, mosses, ferns, cone-bearing plants, and flowering plants. Some species of green algae are unicellular, and others are multicellular. All other types of plants are multicellular.

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. There is incredible diversity within the animal kingdom.

READING TOOL

Use the visual to explain why "Protists" do not form a valid clade.

Argument-Based Inquiry Guided Inquiry

Construct a Cladogram

Problem How can you use a cladogram to model the evolutionary relationship among species?

In this lab, you will make models of organisms to show evolutionary relationships. Then you will study a model made by another group. You will use your skills of observation and logical reasoning to identify the derived characters and construct a cladogram.

You can find this lab in your digital course.

A Revised Tree of Life The tree shown in Figure 19-12 is drawn to clearly illustrate current hypotheses about relationships among the groups of organisms that you are likely to know. That kind of tree, however, gives a couple of incorrect impressions. For one thing, its style of presentation suggests that mammals are the latest and greatest living things. It also misrepresents the relative numbers of organisms belonging to different clades. There are almost unimaginably large numbers of species in domains Eubacteria and Archaea, and equally overwhelming numbers of single-celled eukaryotes. Those clades literally dwarf the clades of multicellular fungi, plants, and animals that most people know best.

So what's the solution? What kind of cladogram could show a more accurate picture of the full diversity of life? To more accurately portray the living world, that kind of tree would spread organisms out to reflect the genetic diversity that underlies major differences in biochemistry and cell structure. The difficulty is that if we draw such a tree in the "normal" style for cladograms, it would spread out over several pages. One solution, proposed by biologist David Hillis, of the University of Texas at Austin, is shown in **Figure 19-13**. It provides a truer representation of the full diversity we know exists among living organisms.

HS-LS1-4

LESSON 19.2 Review

KEY IDEAS

1. How is the goal of evolutionary classification different from Linnaean classification?
2. What is the relationship between a clade and a cladogram?
3. How do taxonomists use the DNA sequences of species to determine how closely two species are related?
4. How is the tree of life related to the work of Charles Darwin?

CRITICAL THINKING

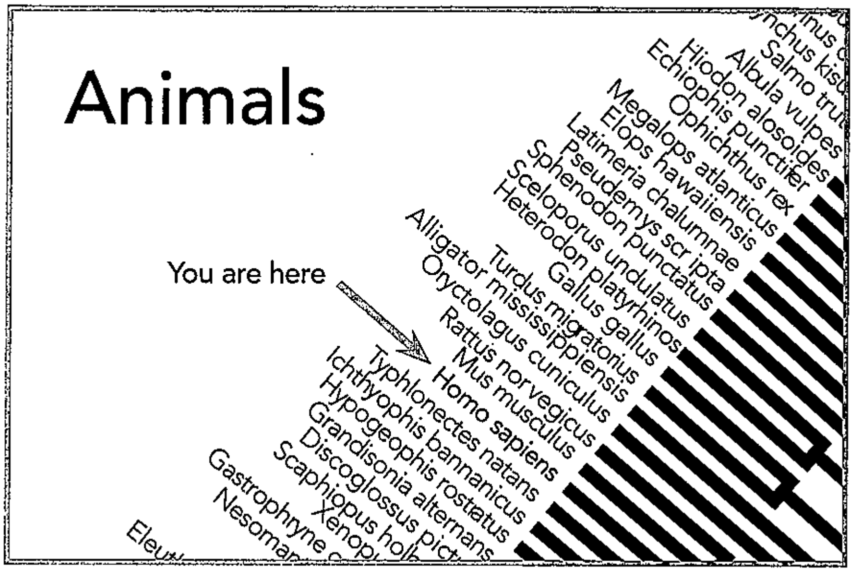
5. **Apply Scientific Reasoning** The family Camelidae includes camels and llamas. Do all the living members of the family form a clade? Explain.
6. **CASE STUDY** A scientist studies the DNA in corresponding genes of a platypus, a beaver, and a duck. The DNA from which two species are most likely to be most similar? Explain your answer.

INTERACTIVITY

Figure 19-13

Circular Model of the Diversity of Life

This circular model shows how the diversity of life has increased over time.



Source: David M. Hillis, Derrick Zwickl, and Robin Gutell, University of Texas