UNIT 5

Evolution

Kingfisher male with courtship gift

Insect of the newly named order Mantophasmatodea

Poison dart frogs

Evolution and Life on Earth

1753

Carolus Linnaeus publishes the first of two volumes containing the classification of all known species. In doing so, Linnaeus establishes a consistent system for naming and classifying species. The system is widely used thereafter.

1859

Charles Darwin suggests that natural selection is the mechanism of evolution. Within months, public debates regarding the truth and significance of his theory ensue.

Galápagos tortoises

1907

In his book, *Plant Breeding,* Hugo de Vries, Dutch botanist, joins Mendel's laws of heredity with the newer theory of mutation. De Vries asserts that inheritable mutations are the mechanism by which species change and new species form.

1960

Mary and Jonathan Leakey discover fossil bones of a human ancestor, *Homo habilis,* in Olduvai Gorge, Tanzania.

Mary Leakey, paleoanthropologist

1974

Donald Johansen discovers a fossilized skeleton of one of the first hominids, *Australopithecus afarensis*. This specimen was nicknamed "Lucy."

Skull of *A. afarensis*

1980

Walter and Luis Alvarez, Frank Asaro, and Helen Michel publish a paper providing evidence that 65 million years ago, an asteroid collided with Earth and caused severe environmental changes. The changes may have led to the extinction of the majority of species that lived during that time.

1994

Reinhardt Kristensen and Peter Funch discover a tiny animal living on the lips of lobsters. They name the new species *Symbion pandora*. This species is so different from other animals that scientists classify it within a new phylum, Cycliophora, within kingdom Animalia.

2006

A team of biologists announces a study of Camiguin Island, the smallest island of the Philippines. They find 54 species of birds and 24 of species of mammals.

As-yet-unnamed parrot species

Beetles—one of the most diverse groups of animals on Earth

BIOLOGY CAREER

Museum Curator

Rob DeSalle

Rob DeSalle is a curator in the Division of Invertebrate Zoology at the American Museum of Natural History in New York City. He is an adjunct professor at Columbia University and City University of New York and is a Distinguished Research Professor at New York University. His current research focuses on molecular evolution in various organisms, including pathogenic bacteria and insects.

DeSalle enjoys being a scientist because he can investigate the diversity of life every day. He also enjoys the opportunity to serve as a mentor to students. Most of all, he enjoys the thrill of discovering something that no one else on the planet has found.

He considers his most significant accomplishment in science to be his work communicating scientific ideas through his writing and museum exhibitions.

Besides his work, DeSalle loves baseball and is a passionate fan of the Chicago Cubs.

Fossil and eggs of dinosaur called *oviraptor*

UNIT 5

Chapter Planner 18

Classification

	Standards	Teach Key Ideas
CHAPTER OPENER, pp. 420–421 — 15 min.	*National Science Education Standards*	
SECTION 1 The Importance of Classification, pp. 423–426 — 30 min. ❯ The Need for Systems ❯ Scientific Nomenciature ❯ The Linnaean System	LSEvol 5, UCP1, SI2, HNS1, HNS2, HNS3	**Bellringer Transparency** **Transparencies** D29 Biological Hierarchy of Classification • D30 Classification of a Bee **Visual Concepts** Classification • Linnaeus's Levels of Classification • Species Name • Species
SECTION 2 Modern Systematics, pp. 427–432 — 45 min. ❯ Traditional Systematics ❯ Phylogenetics ❯ Cladistics ❯ Inferring Evolutionary Relatedness	LSEvol 3, LSEvol 4, LSEvol 5, UCP2, SI2, HNS2, HNS3	**Bellringer Transparency** **Transparencies** D31 Evolutionary Systematics and Cladistic Taxonomy **Visual Concepts** Analogous features • Phylogeny • Cladistics • Cladogram • Systematics
SECTION 3 Kingdoms and Domains, pp. 433–439 — 90 min. ❯ Updating Classification Systems ❯ The Three-Domain System	LSCell 1, LSCell 5, LSCell 6, LSEvol 2, LSEvol 4, LSEvol 5, UCP1, SI2, HNS2, HNS3	**Bellringer Transparency** **Transparencies** D27 Six Kingdoms • D28 Kingdom and Domain Characteristics **Visual Concepts** Kingdoms of Life • Kingdom Characteristics • Parts of a Cell Wall • Comparing Prokaryotes and Eukaryotes • Comparing Organisms That Are Unicellular and Multicellular • Comparing Autotrophs and Heterotrophs • Origin of Eukaryotic Cells • Bacteria • Characteristics of Bacteria

See also PowerPoint® Resources

Chapter Review and Assessment Resources

- SE Super Summary, p. 440
- SE Chapter Review, p. 441
- SE Standardized Test Prep, p. 443
- Review Resources
- Chapter Tests A and B
- Holt Online Assessment

CHAPTER Fast Track *Thorough instruction will require the times shown.*

Basic Learners

- TE Making Analogies, p. 424
- Directed Reading Worksheets*
- Active Reading Worksheets*
- Lab Manuals, Level A*
- Study Guide* ■
- Note-taking Workbook*
- Special Needs Activities and Modified Tests*

Advanced Learners

- TE Analogous Structures, p. 428
- TE Classification Characteristics, p. 433
- TE Types of Archaebacteria, p. 435
- Critical Thinking Worksheets*
- Concept Mapping Worksheets*
- Science Skills Worksheets*
- Lab Datasheets, Level C*

Key
- SE Student Edition
- TE Teacher's Edition
- Chapter Resource File
- Workbook
- Transparency
- CD or CD-ROM
- * Datasheet or blackline master available
- ■ Also available in Spanish

All resources listed below are also available on the Teacher's One-Stop Planner.

Why It Matters	Hands-On	Skills Development	Assessment
Build student motivation with resources about high-interest applications.	SE **Inquiry Lab** What Is Your System?, p. 421*■	TE **Reading Toolbox** Assessing Prior Knowledge, p. 420 SE **Reading Toolbox,** p. 422	
TE **Binomial Nomenclature,** p. 424 TE **Naming Species,** p. 425	**Inquiry Lab** Identifying Unknown Organisms*	SE **Reading Toolbox** Mnemonic Devices, p. 426 TE **Reading Toolbox** Mnemonic Devices, p. 426	SE **Section Review** TE **Formative Assessment Spanish Assessment***■ **Section Quiz**■
TE **Demonstration** Using the Linnaean System, p. 427 TE **DNA Analysis,** p. 430 SE **New Species,** p. 432	SE **Quick Lab** Cladogram Construction, p. 430*■	SE **Reading Toolbox** Word Origins, p. 429 TE **Reading Toolbox** Word Origins, p. 429	SE **Section Review** TE **Formative Assessment Spanish Assessment***■ **Section Quiz**■
TE **Demonstration** Classification Systems, p. 433 TE **Alternate Classification,** p. 434 TE **Demonstration** Observing Protists, p. 436	SE **Quick Lab** Field Guides, p. 435*■ SE **Skills Practice Lab** Dichotomous Keys, p. 438*■ **Skills Practice Lab** Analyzing Amino-Acid Sequences*	TE **Math Skills** Average Bacterial Cell, p. 435 SE **Reading Toolbox** Phylogenetic Tree, p. 436 TE **Reading Toolbox** Phylogenetic Tree, p. 436	SE **Section Review** TE **Formative Assessment Spanish Assessment***■ **Section Quiz**■

See also Lab Generator

See also Holt Online Assessment Resources

Resources for Differentiated Instruction

English Learners
- TE Making Analogies, p. 424
- TE Word Origins, p. 434
- Directed Reading Worksheets*
- Active Reading Worksheets*
- Lab Manuals, Level A*
- Study Guide*■
- Note-taking Workbook*
- Multilingual Glossary

Struggling Readers
- TE Note-Taking, p. 427
- Directed Reading Worksheets*
- Active Reading Worksheets*
- Lab Manuals, Level A*
- Study Guide*
- Note-taking Workbook*
- Special Needs Activities and Modified Tests*

Special Education Students
- TE Common Names, p. 424
- Directed Reading Worksheets*
- Active Reading Worksheets*
- Lab Manuals, Level A*
- Study Guide*■
- Note-taking Workbook*
- Special Needs Activities and Modified Tests*

Alternative Assessment
- TE Constructing Cladograms, p. 429
- Science Skills Worksheets*
- Section Quizzes*■
- Chapter Tests A, B, and C*■

Chapter 18

Overview

The purpose of this chapter is to explain how living organisms are classified and to identify the traits biologists use to classify them. Students will learn how scientists have developed classification schemes to organize their knowledge of life's diversity and to represent inferences about the evolutionary relationships among organisms.

READING TOOLBOX

Assessing Prior Knowledge Students should understand the following concepts:

- cellular basis of life
- evolutionary theory

Visual Literacy Tell students that these butterflies are part of a collection in the Milan Natural History Museum in Italy and that they show common European examples. Discuss with students whether they think the butterflies are all the same species. (They are not, but accept all reasonable answers.)

Chapter 18 Classification

Preview

Why It Matters

More than one million species on Earth have been given scientific names, but many more species exist that have not been identified.

These butterflies look similar, but does that mean they are related? There is more to that answer than meets the eye.

InquiryLab

15 min

What Is Your System?

Often, more than one way exists to organize or group things. In this lab, you will work with others to decide on a system.

Procedure

1. Work with a partner. Examine the **assortment of objects** provided by your teacher.
2. Sort your objects into groups of "related" objects. Try to get every object into a group with at least one other object.
3. Choose a name for each group.
4. Choose one object from your collection, and trade it with an object from another pair of students.
5. Try to fit the new object into one of your groups.

Analysis

1. **List** and define each of your group names from step 3.
2. **Describe** how you classified the new object in step 4.
3. **Predict** whether another person would be able to "correctly" classify one of your objects by using your list of groups. Explain your reasoning.

InquiryLab

Teacher's Notes Students are likely to disagree with one another during steps 2 and 3. Tell them that there is no "correct" system, but that they do need to come to agreement.

Materials
10–20 loosely related everyday objects, such as hardware (nuts, bolts, screws) or office supplies (paper clips, rubber bands, binder clips)

Answers to Analysis

1. Students should have several groups with names and definitions; each group should include at least two items from the initial assortment of items.
2. Students may have revised their scheme to incorporate the new object.
3. Students should analyze how easy their scheme is for others to understand and use.

READING TOOLBOX

Using Words

1. arrange things in order using a system; name an arrangement or order
2. giving names to things in the system

Using Language

1. Answers will vary.
2. Sample answer (JFMAMJJASOND): Jimmy Finds Money And Makes Jane Jump After Sleeping Over Nine Days

Using Science Graphics

1. birds
2. turtles

READING TOOLBOX

These reading tools can help you learn the material in this chapter. For more information on how to use these and other tools, see **Appendix: Reading and Study Skills.**

Using Words

Word Origins Many scientific words derive their parts from Greek or Latin words. Learning the meanings of some Greek and Latin word parts can help you understand the meaning of many scientific words.

Your Turn Answer the following questions.

1. What do taxonomists probably do?
2. What role might nomenclature have in taxonomy?

Word Parts

Word part	Origin	Meaning
tax	Greek	arrangement, order, movement
nom	Greek; Latin	law, order, system; name
clatur	Latin	calling, naming
clad	Greek	shoot, branch, twig
phyl	Greek	tribe, race, class, clan
gram	Greek	write, a written record
gen	Greek, Latin	birth, descent, origin, creation
morph	Greek	shape, form, appearance

Using Language

Mnemonics Mnemonic devices are tools that help you remember lists or parts in their proper order. Use the first letter of every word that you want to remember as the first letter of a new word in a memorable sentence. You may be more likely to remember the sentence if the sentence is funny.

Your Turn Create mnemonic devices that could help you remember all of the parts of the following groups of items.

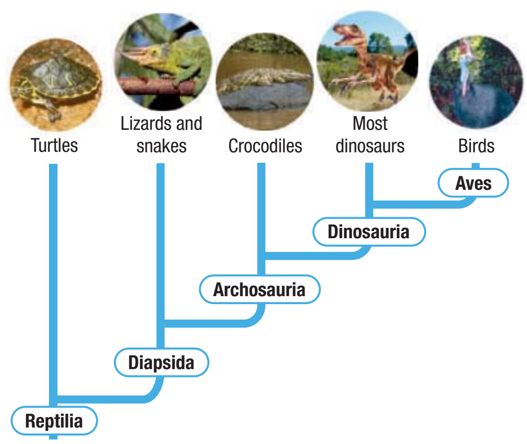
1. the names of all of your teachers
2. the 12 months of the year

Using Science Graphics

Phylogenetic Tree A phylogenetic tree shows the relationships of different groups of organisms to each other. The groups that are most closely related appear on branches that lie close together. Branch points represent a point in time where groups became separated and speciation began. Time is represented as moving forward from the bottom (or trunk) toward the top (or branches) of the tree.

Your Turn Use this phylogenetic tree to answer the following questions.

1. Which group is most closely related to extinct dinosaurs?
2. Which group existed before the other groups did?



Section 1

The Importance of Classification

Key Ideas	Key Terms	Why It Matters
› Why do biologists have taxonomic systems? › What makes up the scientific name of a species? › What is the structure of the modern Linnaean system of classification?	taxonomy genus binomial nomenclature	In order to study and make use of living things, we need a name for each specific thing.

The number of species that exist in the world is much greater than the number known. About 1.7 million species have been named and described by scientists. But scientists think that millions more are undiscovered. We have little knowledge of Earth's variety of species.

The Need for Systems

In biology, the practice of naming and classifying organisms is called **taxonomy.** Scientists use a logical system of classification to manage large amounts of information. Similarly, a library uses a system for organizing books. › **Biologists use taxonomic systems to organize their knowledge of organisms. These systems attempt to provide consistent ways to name and categorize organisms.**

Common names of organisms are not organized into a system. One species may have many common names, and one common name may be used for more than one species. For example, the bird called a *robin* in Great Britain is a different bird from the bird called a *robin* in North America. To avoid confusion, biologists need a way to name organisms that does not depend on language or location.

Biologists also need a way to organize lists of names. A system that has categories is more efficient than a simple list. So, biologists group organisms into large categories as well as smaller and more specific categories. The general term for any one of these categories is a *taxon* (plural, *taxa*).

› **Reading Check** *What is the problem with common names of species? (See the Appendix for answers to Reading Checks.)*

taxonomy (taks AHN uh mee) the science of describing, naming, and classifying organisms

Figure 1 Museums are full of biological specimens, yet only a fraction of Earth's species have been scientifically named.

Section 1

› Focus

This section describes Linnaeus's role in developing the modern system of biological classification and discusses the eight level scheme used by scientists today.

Bellringer

Use the Bellringer transparency to prepare students for this section.

› Teach

Teaching Key Ideas

Differentiating Individuals Ask students if they have ever heard of two people who have the same name. Have them consider what kinds of problems could arise from this situation. Ask how two people could differentiate themselves if they had the same name. (possible answers: social security number, address, age, nickname) LS **Interpersonal**

Key Resources

Transparencies
D29 Biological Hierarchy of Classification
D30 Classification of a Bee

Visual Concepts
Classification
Linnaeus's Levels of Classification
Species Name
Species

Teach, *continued*

Teaching Key Ideas

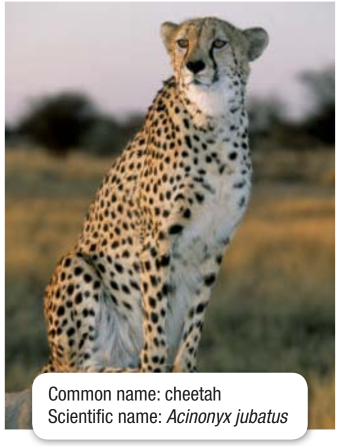
Scientific Names Write the following scientific names on the board: *Carnegiea gigantea* (giant saguaro cactus), *Nymphaea odorata* (fragrant water lily), *Canis familiaris* (domestic dog), *Viola tricolor* (pansy with three-colored flowers), and *Peromyscus californicus* (a common California mouse). Have students look for descriptive clues in each name. Have them predict the common name for each before telling them the names. **LS Verbal**

Why It Matters

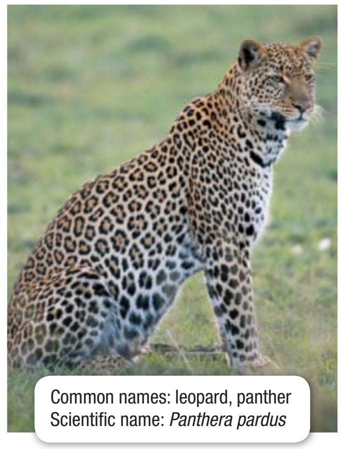
Binomial Nomenclature Tell students that Linnaeus did not invent binomial nomenclature but popularized its use. Swiss scientist Gaspard Bauhin pioneered the use of two-word names about 200 years before Linnaeus. **LS Logical**

Answers to Caption Questions

Figure 2: *Panthera*



Common name: cheetah
Scientific name: *Acinonyx jubatus*



Common names: leopard, panther
Scientific name: *Panthera pardus*

Common names: lion, African lion
Scientific name: *Panthera leo*

Figure 2 Each species may have many common names but only one scientific name. The scientific name is made up of a genus name and a species identifier. Each genus is a group of closely related species. **To what genus do both lions and leopards belong?**

genus (JEE nuhs) a level of classification that contains similar species

binomial nomenclature (bie NOH mee uhl NOH muhn KLAY chuhr) a system for giving each organism a two-word scientific name that consists of the genus name followed by the species name

SCILINKS.
www.scilinks.org
Topic: Carl Linnaeus
Code: HX80226

Scientific Nomenclature

As biology became established as a science, biologists began to create systems for naming and classifying living things. A major challenge was to give each species a unique name.

Early Scientific Names In the early days of European biology, various naming systems were invented. Some used long, descriptive Latin phrases called *polynomials*. Names for taxa were inconsistent between these systems. The only taxon that was somewhat consistent was the **genus,** which was a taxon used to group similar species.

A simpler and more consistent system was developed by the Swedish biologist Carl Linnaeus in the 1750s. He wanted to catalog all known species. He wrote books in which he used the polynomial system but added a two-word Latin name for each species. His two-word system is called **binomial nomenclature.** For example, his two-part name for the European honeybee was *Apis mellifera*, the genus name followed by a single descriptive word for each species. **Figure 2** shows the binomial names of three other animals.

Naming Rules In the years since Linnaeus created his system, his basic approach has been universally adopted. The unique two-part name for a species is now called a *scientific name*. Scientific names must conform to rules established by an international commission of scientists. No two species can have the same scientific name.

All scientific names for species are made up of two Latin or Latin-like terms. All of the members of a genus share the genus name as the first term. The second term is called the *species identifier* and is often descriptive. For example, in the name *Apis mellifera,* the term *mellifera* derives from the Latin word for "honey." When you write the scientific name, the genus name should be capitalized and the species identifier should be lowercased; both terms should be italicized.

Reading Check *Why did Linnaeus devise a new naming system?*

Differentiated Instruction

English Learners/Basic Learners

Making Analogies Explain that a useful classification system should include both broad and specific categories. In geography, categories might be continent, country, region, state, and city. An extension of this scheme could be to add the mail delivery system with zip code, street name, and house number. Work with students to develop a list of other things that are categorized in this way. **LS Logical**

Special Education Students

Common Names Help developmentally delayed students understand how common names can be misleading when describing an organism. Use examples such as the starfish (not a fish), sea horse (not a horse), silverfish (not a fish), horseshoe crab (not a crab), and ringworm (not a worm). Review the characters that usually define a fish, horse, crab, and worm. **LS Verbal**

The Linnaean System

In trying to catalog every known species, Linnaeus devised more than just a naming system. He devised a system to classify all plants and animals that were known during his time. His system formed the basis of taxonomy for centuries. **In the Linnaean system of classification, organisms are grouped at successive levels of a hierarchy based on similarities in their form and structure.** Since Linnaeus's time, many new groups and some new levels have been added, as **Figure 3** shows. **The eight basic levels of modern classification are domain, kingdom, phylum, class, order, family, genus, and species.**

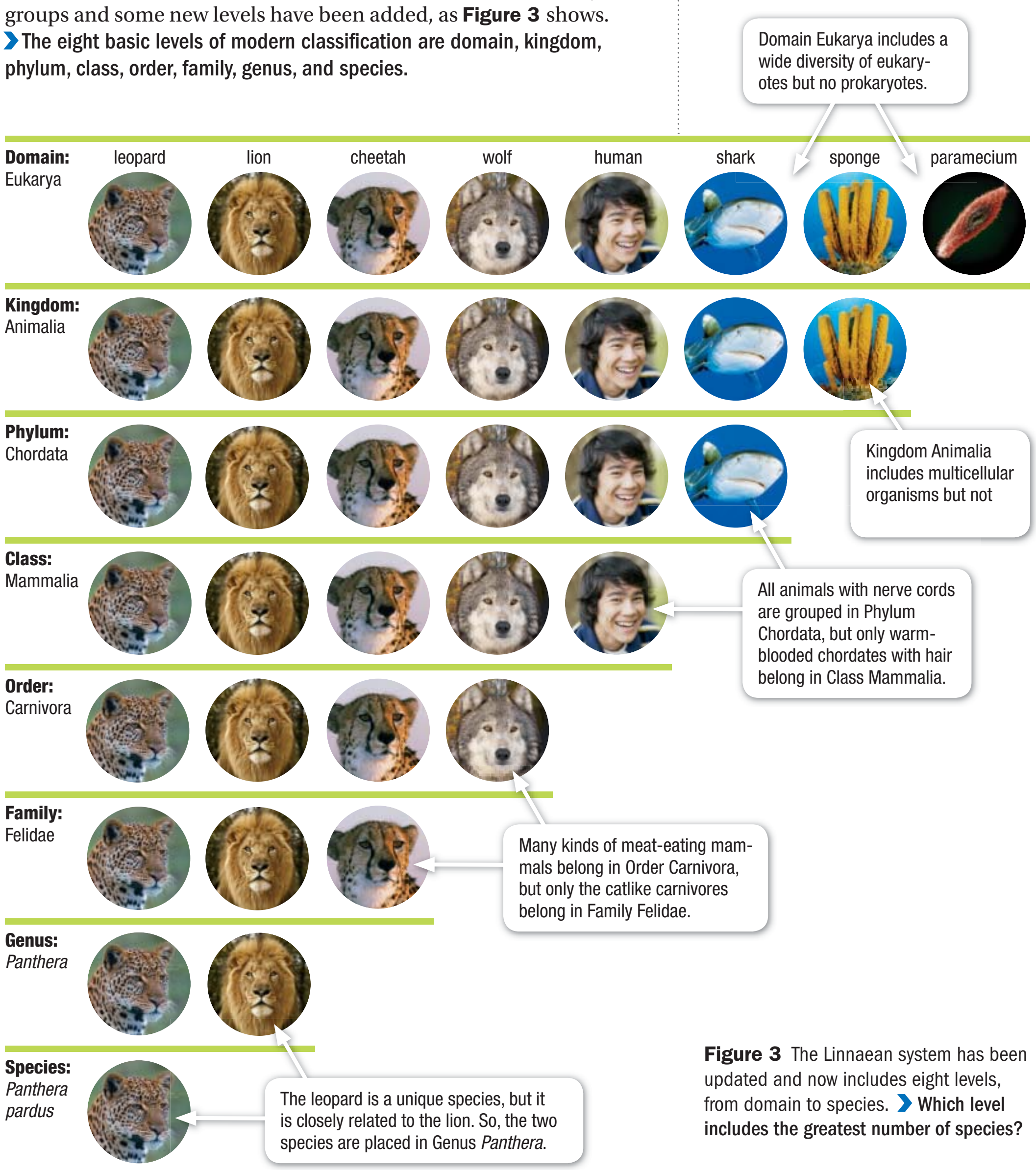


Figure 3 The Linnaean system has been updated and now includes eight levels, from domain to species. **Which level includes the greatest number of species?**

Why It Matters

Naming Species Some names are given to honor people, and some names are deliberately playful. For example, *Arthurdactylus conandoylensis* is a Brazilian pterosaur named after Arthur Conan Doyle and his novel *The Lost World.* Some names have accidental origins. The 18th century French naturalist Pierre Sonnerat gave the name *Indri indri* to a species of Malagasy lemur because he thought that the natives called it that, but they were just saying "Look! Look!"

Teaching Key Ideas

A Changing System Emphasize that the Linnaean system changes as scientists discover new information. For example, in his original work Linneaus recognized three broad categories that he named the Three Kingdoms of Nature: Animal, Vegetable, and Mineral.

Teaching Key Ideas

Reviewing Taxa Tell students that the term *taxon* applies to all categories. At the domain level, Archaea, Bacteria, and Eukarya are taxa relative to one another. At the species level, *Homo sapiens, Pan paniscus, Pan troglodytes,* and *Gorilla gorilla* are taxa. **LS Logical**

Answers to Caption Questions

Figure 3: domain

Teach, *continued*

READING TOOLBOX

Mnemonic Devices sample answer: Dear King Phillip Came Over For Ginger Snaps

Close

Formative Assessment

In the Linnaean system, scientists classify organisms based on _____.

A. external characteristics (Incorrect. Internal characteristics are also important.)

B. similarities in form and structure (Correct! The more similarities in form and structure, the more closely two organisms are probably related.)

C. where organisms live (Incorrect. Organisms located very far apart can be very closely related.)

D. species name (Incorrect. The process of classification results in the species name.)

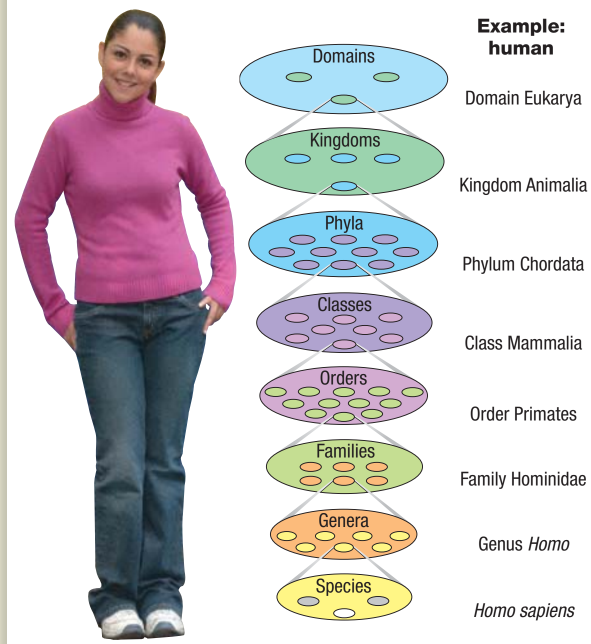


Figure 4 A species can be classified at each level of the Linnaean system.

READING TOOLBOX

Mnemonics To remember the eight levels in their proper order, use a phrase, such as “Do Kindly Pay Cash Or Furnish Good Security,” to represent *Domain, Kingdom, Phylum, Class, Order, Family, Genus,* and *Species*.

Levels of the Modern Linnaean System

Each level has its own set of names for taxa at that level. Each taxon is identified based on shared traits. Similar species are grouped into a genus; similar genera are grouped into a family; and so on up to the level of domain. **Figure 4** shows the classification of humans in this system.

- **Domain** Since Linnaeus’s time, the category *domain* has been invented in order to recognize the most basic differences among cell types. All living things are now grouped into one of three domains. For example, humans belong to the domain Eukarya.
- **Kingdom** The category *kingdom* encompasses large groups such as plants, animals, or fungi. Six kingdoms fit within the three domains.
- **Phylum** A *phylum* is a subgroup within a kingdom. Many phyla exist within each kingdom. Humans belong to the phylum Chordata.
- **Class** A *class* is a subgroup within a phylum.
- **Order** An *order* is a subgroup within a class.
- **Family** A *family* is a subgroup within an order. Humans belong to the family Hominidae.
- **Genus** A *genus* (plural, *genera*) is a subgroup within a family. Each genus is made up of species with uniquely shared traits, such that the species are thought to be closely related. Humans belong to the genus *Homo*.
- **Species** A *species* is usually defined as a unique group of organisms united by heredity or interbreeding. But in practice, scientists tend to define species based on unique features. For example, *Homo sapiens* is recognized as the only living primate species that walks upright and uses spoken language.

Reading Check *How many kingdoms are in the Linnaean system?*

Section 1 Review

KEY IDEAS

1. **Explain** why biologists have systems for naming and grouping organisms.
2. **Describe** the structure of a scientific name for a species.
3. **List** the categories of the modern Linnaean system of classification in order from general to specific.

CRITICAL THINKING

4. **Logical Reasoning** Describe additional problems that might occur for biologists without a logical taxonomic system.
5. **Anticipating Change** Although the basic structure of the system that Linnaeus invented is still in use, many aspects of this system have changed. Suggest some possible ways that the system may have changed.

ALTERNATIVE ASSESSMENT

6. **Classification Poster** Create a poster that shows the major levels of classification for your favorite organism. Write a description of the general characteristics of the organism at each level. For each level, include a list of other organisms that belong to the same taxon.

Answers to Section Review

1. Biologists use taxonomic systems to name and categorize organisms in consistent ways to prevent confusion.
2. All scientific names for species are made up of two Latin or Latin-like terms; no two species may have the same two-part name.
3. domain, kingdom, phylum, class, order, family, genus, species
4. Biologists might not realize that they are studying the same species; they might not see similarities and relationships between organisms.
5. Scientists might have added more levels or “in between” levels; names of taxa at each level might have changed; taxa might have been “promoted” or “demoted” among levels.
6. Posters should show the classification of an organism at all eight levels, as well as a general description of characteristics and a list of similar organisms in each taxon. Check that students capitalize and italicize taxon names as appropriate.

Section 2

Modern Systematics

Key Ideas	Key Terms	Why It Matters
❯ What problems arise when scientists try to group organisms by apparent similarities? ❯ Is the evolutionary past reflected in modern systematics? ❯ How is cladistics used to construct evolutionary relationships? ❯ What evidence do scientists use to analyze these relationships?	phylogeny cladistics	Modern systematics unites evolutionary science with traditional studies of anatomy.

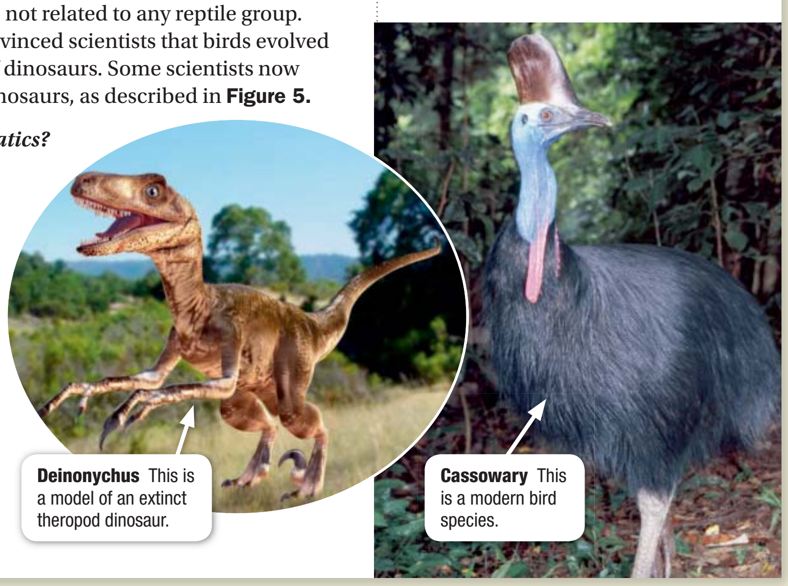
Have you ever wondered how scientists tell one species from another? For example, how can you tell a mushroom that is harmless from a mushroom that is poisonous? Identification is not easy, even for experts. The experts often revise their classifications as well as their procedures. This field of expertise is known as *systematics*.

Traditional Systematics

Linnaeus's system was based on his judgment of the importance of various similarities among living things. ❯ **Scientists traditionally have used similarities in appearance and structure to group organisms. However, this approach has proven problematic.** Some groups look similar but turn out to be distantly related. Other groups look different and turn out to be closely related. Often, new data or new analyses suggest relationships between organisms that were not apparent before.

For example, dinosaurs were once seen as a group of reptiles that became extinct millions of years ago. And birds were seen as a separate, modern group that was not related to any reptile group. However, fossil evidence has convinced scientists that birds evolved from one of the many lineages of dinosaurs. Some scientists now classify birds as a subgroup of dinosaurs, as described in **Figure 5.**

❯ **Reading Check** ***What is systematics?***



Deinonychus This is a model of an extinct theropod dinosaur.

Cassowary This is a modern bird species.

Figure 5 In a sense, birds are dinosaurs. Scientists think that modern birds are descended from a subgroup of dinosaurs called *theropods.* This inference is based on thorough comparisons of modern birds and fossilized theropods.

Section 2

❯ Focus

This section identifies problems with traditional classification and describes the relationship between an organism's classification and its evolutionary history.

Bellringer

Use the Bellringer transparency to prepare students for this section.

❯ Teach

Demonstration

Using the Linnaean System Tell students that Linnaeus classified all living things into two groups—plants and animals. Show pictures of plants and animals and ask students into which of the two groups they would place each organism. Then show students pictures of unicellular organisms. Ask students to classify them according to Linnaeus' system. Students probably will not be able to classify most of the organisms. Point out that Linnaeus did not include unicellular organisms in his system because he didn't know they existed; the microscope had not yet been invented. Tell students that today scientists use more than obvious similarities to classify organisms. **LS Logical**

Differentiated Instruction

Struggling Readers

Note-Taking Have students fold a sheet of paper in half vertically, creating four columns. Ask them to list each of the four headings in this section at the top of a column (*Problems with Traditional Classification, Phylogenetics, Cladistics,* and *Analyzing Evolutionary Relatedness*). As they read, have students add pertinent details and note any material that they do not understand. **LS Verbal**

Key Resources

Transparencies
D31 Evolutionary Systematics and Cladistic Taxonomy

Visual Concepts
Analogous features
Phylogeny
Cladistics
Cladogram
Systematics

Teach, *continued*

Teaching Key Ideas

Dolphin Evolution Tell students that Aristotle recognized that dolphins and whales differed from fishes in their respiration and reproduction, among other characteristics. This fact was overlooked for over 2,000 years. Today we know that whales show many similarities with early land mammals and probably share ancestry with most hoofed mammals. Emphasize to students that all phylogenies represent hypotheses and are subject to revision any time that new data, such as fossils, embryology, or molecular evidence, does not fit the previously established criteria.

Answers to Caption Questions

Figure 6: The Linnaean system simply puts groups into boxes based on a lists of characters; modern phylogenetics puts successively more-inclusive groups onto a "tree" based on inferences of relatedness.

phylogeny the evolutionary history of a species or taxonomic group

cladistics a phylogenetic classification system that uses shared derived characters and ancestry as the sole criterion for grouping taxa

Phylogenetics

Today, scientists who study systematics are interested in **phylogeny,** or the ancestral relationships between species. **Grouping organisms by similarity is often assumed to reflect phylogeny, but inferring phylogeny is complex in practice.** Reconstructing a species' phylogeny is like trying to draw a huge family tree that links ancestors and descendants across thousands or millions of generations.

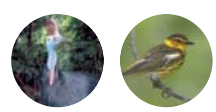
Misleading Similarities Inferring phylogenies from similarities can be misleading. Not all similar characters are inherited from a common ancestor. Consider the wings of a bird and of an insect. Both types of wings enable flight, but the structures of the two kinds of wings differ. Moreover, fossil evidence shows that insects with wings existed long before birds with wings appeared. Through the process called *convergent evolution*, similarities may evolve in groups that are not closely related to one another, often because the groups become adapted to similar habitats or lifestyles. Similarities that arise through convergent evolution are called *analogous* characters.

Judging Relatedness Another problem is that grouping organisms by similarities is subjective. Are all characters equally important, or are some more important than others? Often, different scientists may give different answers to these questions.

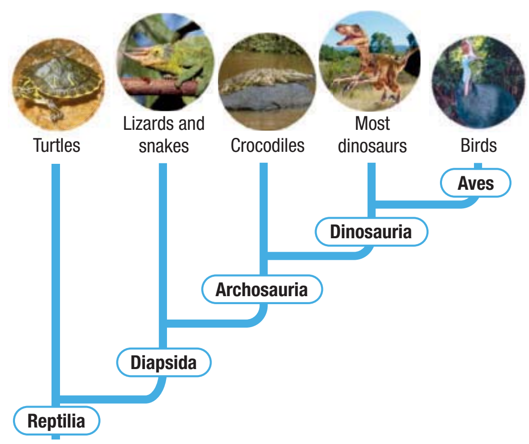
For example, systematists historically placed birds in a separate class from reptiles, giving importance to characters such as feathers, as **Figure 6** shows. But more recently, fossil evidence and detailed studies of bird and dinosaur anatomy have changed the view of these groups. **Figure 6** shows that birds are now considered part of the "family tree" of dinosaurs. This family tree, or *phylogenetic tree,* represents a hypothesis of the relationships between several groups.

Figure 6 Traditional systematics grouped birds separately from other reptiles by emphasizing the unique features of birds. However, modern phylogenetics places birds as a subgroup of reptiles on a phylogenetic tree. **How do these two systems differ in structure?**

Linnaean Classification

Classes of Animals	
Class Reptilia	Class Aves
egg-laying, exothermic, scales	egg-laying, endothermic, feathers
lizards, snakes, turtles, crocodiles, and dinosaurs 	birds 

Modern Phylogeny



Differentiated Instruction

Advanced Learners

Analogous Structures Ask students to research a list of analogous structures that are found in organisms. (Examples: insect wing/bird wing; platypus bill/duck bill) Have them hypothesize about the adaptive value of each structure.
LS Logical

Cladistics

To unite systematics with phylogenetics, scientists need an objective way to sort out relatedness. Today, the preferred method is cladistics. **Cladistics** is a method of analysis that infers phylogenies by careful comparisons of shared characters. **Cladistic analysis is used to select the most likely phylogeny among a given set of organisms.**

Comparing Characters Cladistics focuses on finding characters that are *shared* between different groups of organisms because of shared ancestry. With respect to two groups, a shared character is defined as *ancestral* if it is thought to have evolved in a common ancestor of both groups. In contrast, a *derived* character is one that evolved in one group but not in the other group. Cladistics infers relatedness by identifying shared derived and shared ancestral characters among groups while avoiding the use of analogous characters.

For example, consider the relationship between flowering plants and conifers. The production of seeds is a character that is present in all living conifers and flowering plants and in some prehistoric plants. So, it is a shared ancestral character among these groups. The production of flowers, however, is a derived character that is shared only among flowering plants. Flowers evolved in some ancestor of flowering plants but did not evolve in the group that led to conifers.

Constructing Cladograms Cladistics uses a strict comparison of many characters among several groups in order to construct a cladogram. A *cladogram* is a phylogenetic tree that is drawn in a specific way, as **Figure 7** shows. Organisms are grouped together through identification of their shared derived characters. All groups that arise from one point on a cladogram belong to a clade. A *clade* is a set of groups that are related by descent from a single ancestral lineage.

Each clade in a tree is usually compared with an *outgroup,* or group that lacks some of the shared characters. For example, **Figure 7** shows that flowering plants and conifers share a character with each other that they do not share with ferns. So, conifers and flowering plants form a clade, and ferns form the outgroup.

Reading Check *What does a cladogram show?*

Characters in Plants

Type of plants	Vascular tissue	Seeds	Flowers
Mosses	no	no	no
Ferns	yes	no	no
Conifers	yes	yes	no
Flowering plants	yes	yes	yes

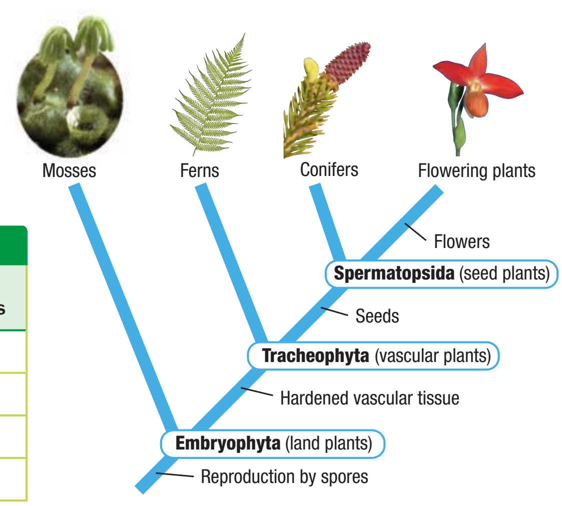


Figure 7 This cladogram organizes plants by using a strict comparison of the characters shown in the table. Each clade is united by a specific shared derived character. **Which groups are united by having seeds?**

Academic Vocabulary

objective independent of the mind; without bias

Reading Toolbox

Word Origins The word root *clad* means "shoot, branch or twig" and the word root *gram* means "to write or record." Use this information to analyze the meaning of the term *cladogram.*

Teaching Key Ideas

Comparing Tools A key difference between cladistics and Linnaean taxonomy is that cladistics allows for an infinite number of nested levels. Cladograms can be "zoomed in" (or out) almost infinitely, with each node leading to more detailed branches. Also, some branches may have many more sub-branches (evolutionary radiations or diversifications) than others.

Reading Toolbox

Word Origins a record showing how groups of organisms branch off from one another

Answers to Caption Questions

Figure 7: conifers and flowering plants

Differentiated Instruction

Alternative Assessment

Constructing Cladograms Using the same collection of materials from the Inquiry Lab at the beginning of the chapter, have students construct charts of characteristics and corresponding cladograms to show the relationship among the objects. **LS Logical**

Teach, *continued*

QuickLab

Teacher's Notes Note that after the initial outgroup is chosen, the remaining characters (those not found in the outgroup) are the derived characters of the remaining groups.

Answers to Analysis

1. The first outgroup should be tuna and should appear on the first branch from the base.
2. The most common character among the rest is *Four legs.* This label should appear just above the branch that leads to *Tuna* on the part of the tree that leads to the remaining three groups.
3. The next branch should lead to *Frog,* with *Amniotic egg* leading to the remaining two groups; then a branch to *Lizard,* with *Hair* leading only to *Cat.*
4. amniotic egg
5. four legs

Data

QuickLab

10 min

Cladogram Construction

Use this table of shared characters to construct a cladogram. Use the other cladograms in this section to help you draw your cladogram.

Characters in Vertebrates

	Four legs	Amniotic egg	Hair
Tuna	no	no	no
Frog	yes	no	no
Lizard	yes	yes	no
Cat	yes	yes	yes

Analysis

1. **Identify** the outgroup. The outgroup is the group that does not share any of the characters in this list. Draw a diagonal line and then a single branch from its base. Write the outgroup at the tip of this first branch.
2. **Identify** the most common character. Just past the "fork" of the first branch, write the most common derived character. This character should be present in all of the subsequent groups added to the tree.
3. **Complete** the tree. Repeat step 2 for the second most-common character. Repeat until the tree is filled with all of the groups and characters from the table.
4. CRITICAL THINKING **Applying Concepts** What is a shared derived character of cats and lizards?
5. CRITICAL THINKING **Applying Concepts** What character evolved in the ancestor of frogs but not in that of fish?

SCILINKS.
www.scilinks.org
Topic: Phylogenetic Tree
Code: HX81141

Inferring Evolutionary Relatedness

As you have seen, phylogenetics relies heavily on data about characters that are either present or absent in taxa. But other kinds of data are also important. **Biologists compare many kinds of evidence and apply logic carefully in order to infer phylogenies.** They constantly revise and add details to their definitions of taxa.

Morphological Evidence *Morphology* refers to the physical structure or anatomy of organisms. Large-scale morphological data are most obvious and have been well studied. For example, the major characters used to define plant groups—vascular tissue, seeds, and flowers—were recognized long ago. But because convergent evolution can lead to analogous characters, scientists must consider many characters and look carefully for similarities and differences. For example, many animals have wings that are merely analogous.

An important part of morphology in multicellular species is the pattern of development from embryo to adult. Organisms that share ancestral genes often show additional similarities during the process of development. For example, in all vertebrate species, the jaw of an adult develops from the same part of an embryo. In many cases, studies of embryos bring new information to phylogenetic debates.

Molecular Evidence In recent decades, scientists have used genetic information to infer phylogenies. Recall that as genes are passed on from generation to generation, mutations occur. Some mutations may be passed on to all species that descend from a common ancestor. So, DNA, RNA, and proteins can be compared in the same manner as morphology is compared to infer phylogenies.

Reading Check ***What is an example of morphological data?***

MISCONCEPTION ALERT

Teleology Evolution is often mistakenly described in terms of purposefulness; that wings, for example, evolved so an organism could fly. This view of evolution is based on teleology (Greek *telos*, "end"; *logos*, "discourse"), or the doctrine that explains phenomena in terms of ends or final causes. Make sure students understand that the process of natural selection only determines whether a new characteristic is advantageous in a given time and place and thus whether it may be passed on to offspring in that context.

Why It Matters

DNA Analysis Point out that DNA analysis is changing some long-held beliefs about evolutionary relationships (beliefs that were based on anatomical traits alone). For example, an American cheetah-like cat found in the west is more closely related to pumas than to the African cheetah that it more closely resembles. The genetic data indicates that the similarities in the American and African species are an example of parallel evolution as a result of similar ecological pressures.

Sequence Data Today, genetic sequence data are widely used for cladistic analysis. First, the sequence of DNA bases in a gene (or of amino acids in a protein) is determined for several species. Then, each letter (or amino acid) at each position in the sequence is compared. Such a comparison can be laid out in a large table, but computers are best able to calculate the relative similarity of many sequences.

Genomic Data At the level of genomes, alleles may be added or lost over time. So, another form of molecular evidence is the presence or absence of specific alleles—or the proteins that result from them. Finally, the relative timing between genetic changes can be inferred.

Evidence of Order and Time Cladistics can determine only the relative order of divergence, or branching, in a phylogenetic tree. To infer the actual time when a group may have begun to "branch off," extra information is needed. Often, this information comes from the fossil record. For example, by using cladistics, scientists have identified lancelets as the closest relative of vertebrates. The oldest known fossils of vertebrates are about 450 million years old, but the oldest lancelet fossils are 535 million years old. So, these two lineages must have diverged more than 450 million years ago.

More recently, scientists have noticed that most DNA mutations occur at relatively constant rates. So, genetic change can be used as an approximate "molecular clock," as **Figure 8** shows. Scientists can measure the genetic differences between taxa and then estimate the time at which the taxa began to diverge.

Inference Using Parsimony Modern systematists use the *principle of parsimony* to construct phylogenetic trees. This principle holds that the simplest explanation for something is the most reasonable, unless strong evidence exists against the simplest explanation. So, given two possible cladograms, the one that implies the fewest character changes between branch points is preferred.

Reading Check *What kinds of molecular data inform cladistics?*

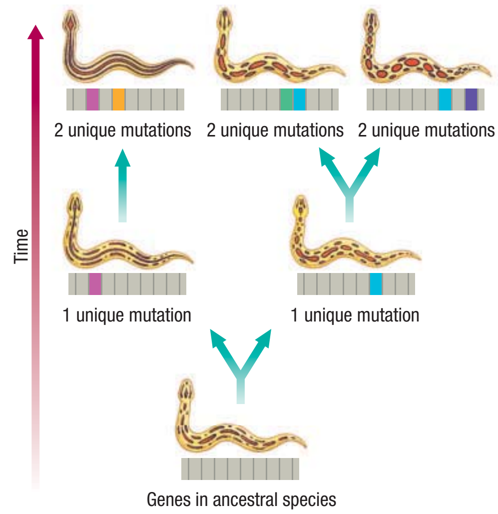


Figure 8 Because mutation occurs randomly at any time, an average rate of mutation can be measured and used as a "clock" to estimate the time any two species took to accumulate a number of genetic differences.

Section 2 Review

KEY IDEAS

1. **Identify** the kinds of problems that arise when scientists try to group organisms by similarities.
2. **Relate** classification to phylogeny.
3. **Describe** the method of cladistics.
4. **Identify** the kinds of evidence used to infer phylogenies.

CRITICAL THINKING

5. **Justifying Reasoning** Some scientists who study dinosaurs have stated that dinosaurs are not extinct. How could this statement be justified?
6. **Analyzing Relationships** Explain how the outgroup in a cladogram relates to the difference between ancestral and derived characters.

METHODS OF SCIENCE

7. **Taxonomic Challenge** In the past, mammals were identified as animals that have fur and give birth to live offspring, and reptiles were identified as animals that have scales and lay eggs. Then, an animal was found that has fur and lays eggs. How might this problem have been resolved?

Close

Formative Assessment

A cladogram shows several four-footed vertebrates: frog, turtle, alligator, kangaroo, armadillo, wolf, and dog. What would the character *presence of fur* tell you about the inferred relationship among these organisms?

A. The armadillo is more closely related to the alligator than the wolf because it does not have very much fur. (Incorrect. The *amount* of fur is not the defining characteristic.)

B. All these animals are related. (Incorrect. The derived character of fur shows that some are more closely related than others.)

C. The kangaroo, wolf, and dog are most closely related because they have the greatest amount of fur. (Incorrect. *Amount* of fur is not the defining characteristic.)

D. The frog, turtle, and alligator are not as closely related as are the other animals that have fur. (Correct! Fur is a derived character that divides this group into two subgroups.)

Answers to Section Review

1. Similarities can arise by convergent evolution, especially similarities in basic function or outward appearance.
2. Ideally, classification should reflect phylogeny.
3. Cladistics uses strict and careful comparisons of shared characters to decide between all possible relationships among several groups.
4. morphology, comparisons of biological molecules, fossil record, and parsimony
5. If birds are descendants of dinosaurs, then they are essentially a subgroup of dinosaurs. Using this reasoning, dinosaurs could be considered a living group.
6. Any characters that outgroup organisms have in common with ingroup organisms are ancestral. Characters that are unique to ingroup organisms are the derived characters of that clade only, and must have arisen in a lineage that was separate from the outgroup.
7. Scientists might have revised the list of defining characteristics of mammals or reptiles, or they might have created a new group that includes both mammals and reptiles.

Why It Matters

Teacher's Notes Scientists agree that many undiscovered species remain in all parts of the world. Yet some unidentified specimens are stored in museums, waiting for closer observation or information on their native habitat. Such was the case with specimens of Mantophasmatodea, an insect order only recently established.

READING TOOLBOX

Visual Literacy Have students research information about the animals shown.

- Lemur (in hand): *Microcebus lehilahytsara* or Goodman's mouse lemur. (named after researcher Steve Goodman; thought to be part of the lineage that led to early humans)
- Insect: Genus *Lobophasma*, order Mantophasmatodea (heelwalkers). (carnivores restricted to South Africa; eat other small insects)
- Monkey: *Callicebus bernhardi* or Prince Bernhard's titi monkey. (dark orange sideburns; named in honor of His Royal Highness Prince Bernhard of the Netherlands)
- Frog: *Philautua poppiae* or knuckles leaf-nesting frog. (one of many new frog species discovered in tropical forests)
- Bird: Smoky honeyeater. (about the size of a blue jay; lives only in the Foya Mountains of Indonesia)

Why It Matters

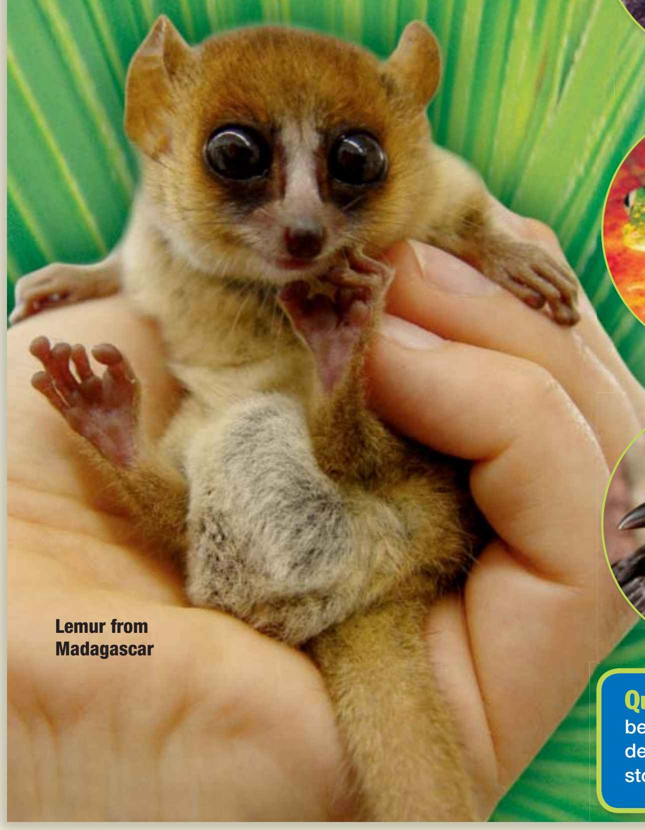
New Species

The work of biology is never finished. Indeed, the work of finding, naming, and classifying all living species has barely begun. Scientists have estimated that 1 km^2 of rain forest may contain hundreds or thousands of species, most of which are currently unknown to science. In fact, new species are "discovered" all of the time, all around the world.

Mantophasmatodea—
a new order of insects

When is a species "new"?

What does discovering a new species mean? Typically, it means collecting a specimen, giving it a name, and classifying it for the first time by using modern taxonomy. Although truly new species may be evolving at any time, most new species are simply new to science.


Lemur from Madagascar

Big, Small, Far, Near
Undiscovered species are everywhere! Even mammals, such as this monkey, are still being discovered. Of course, we may never find all of the tiny bugs and microbes in the world.

Biodiversity Hot Spots
Some parts of the world, such as tropical rain forests, contain an extreme diversity of species. This frog is from a region of Sri Lanka that is home to many amphibian species.

Undiscovered Worlds
In 2005, an expedition went into a "lost world" of rain forest in New Guinea that was previously unexplored by scientists. The expedition quickly found dozens of new species, such as this honeyeater bird.

Quick Project Find out if any new species have been discovered in your local area in the last few decades. Try to find the name of the new species, the story behind the name, and a photo of the species.

Answers to Research

Such information is most likely to be found on the Internet from the following sources: a state Department of Natural Resources, a large science or agricultural university or a science news service. The phrase "new species AND [state name]" should help narrow the search.

Section 3

Kingdoms and Domains

Key Ideas	Key Terms	Why It Matters
❯ Have biologists always recognized the same kingdoms? ❯ What are the domains and kingdoms of the three-domain system of classification?	bacteria archaea eukaryote	The three-domain system is one of the latest revolutions in biology.

If you read old books or stories, you might read about plants and animals, or "flora and fauna," but probably not "fungi" or "bacteria."

Updating Classification Systems

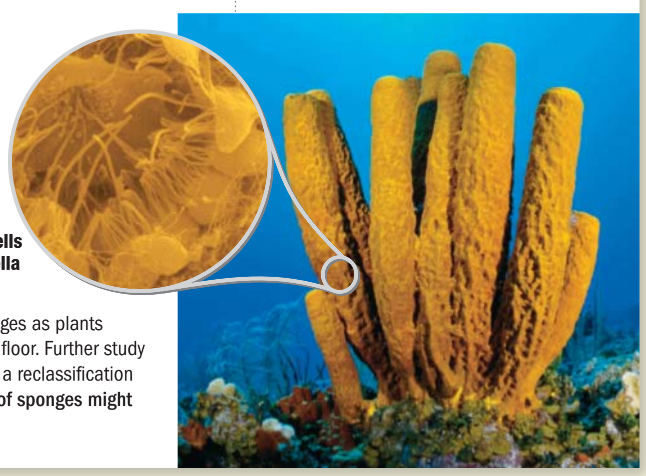
For many years after Linnaeus created his system, scientists recognized only two kingdoms: Plantae (plants) and Animalia (animals). Relatively few of Earth's species were known, and little was known about them. ❯ **Biologists have added complexity and detail to classification systems as they have learned more.** Throughout history, many new taxa have been proposed and some groups have been reclassified.

For example, **Figure 9** shows sponges, which were first classified as plants. Then, the invention of the microscope allowed scientists to look at cells. Scientists learned that sponges have cells that are much more like animal cells than like plant cells. So today, sponges are classified as animals. The microscope prompted many such changes.

From Two to Five Kingdoms In the 1800s, scientists added Kingdom Protista as a taxon for unicellular organisms. Soon, they noticed the differences between prokaryotic cells and eukaryotic cells. So, scientists created Kingdom Monera for prokaryotes and left single-celled eukaryotes in Kingdom Protista. By the 1950s, five kingdoms were used: Monera, Protista, Fungi, Plantae, and Animalia.

Six Kingdoms In the 1990s, Kingdom Monera came into question. Genetic data suggested two major groups of prokaryotes. So, Kingdom Monera was split into two new kingdoms: Eubacteria and Archaebacteria.

❯ **Reading Check** *What were the original Linnaean kingdoms?*



Sponge cells with flagella

Figure 9 Early scientists classified sponges as plants because sponges are attached to the sea floor. Further study and microscopic views in particular led to a reclassification of sponges as animals. ❯ **What features of sponges might have led to this reclassification?**

Section 3

❯ Focus

This section describes how classification systems change as scientists learn new information.

Bellringer

Use the Bellringer transparency to prepare students for this section.

❯ Teach

Demonstration

Classification Systems Give groups of students several colored plastic eggs. Place a small object, such as a coin, paper clip, or foil ball, inside each egg. On the inside surface, mark a plus or circle symbol. Challenge students to group the eggs without opening them and to give reasons for their system. Then have students open the eggs and reclassify them based on their internal characteristics. Have students explain how they changed their systems based on new information. Connect their explanations to how scientists revise the classification of organisms based on new information. **LS Logical**

Answers to Caption Questions

Figure 9: having flagella

Differentiated Instruction

Advanced Learners

Classification Characteristics Have students research the basic characteristics that differentiated the two-, three-, five-, and six-kingdom systems of classification. Have them document the discoveries that led to a change in the number of kingdoms. **LS Verbal**

Key Resources

Transparencies

D27 Six Kingdoms

D28 Kingdom and Domain Characteristics

Visual Concepts

Kingdoms of Life

Kingdom Characteristics

Parts of a Cell Wall

Comparing Prokaryotes and Eukaryotes

Comparing Organisms That Are Unicellular and Multicellular

Comparing Autotrophs and Heterotrophs

Origin of Eukaryotic Cells

Bacteria

Characteristics of Bacteria

Teach, *continued*

Teaching Key Ideas

Relationships and Characteristics Work with students to make comparisons between **Figure 10** and **Figure 11** on the next page. Make sure they understand how the presence or absence of the major characteristics are connected to the relationships shown in the tree. **LS Visual**

Why It Matters

Alternate Classification An alternate classification system—the PhyloCode—grew out of a Harvard workshop in 1998 and is the work of international scientists. It is designed to be used concurrently with the rank-based codes or (after rules governing species names are added) as the code governing the names of taxa. The intent is not to replace existing names but to provide an alternative system for governing the application of both existing and newly proposed names for clades and species. **LS Verbal**

Answers to Caption Questions

Figure 10: genetics

Characteristics of Domains and Kingdoms

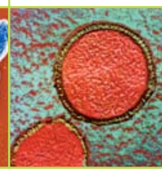
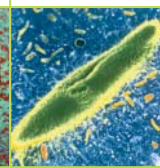
Domain	Bacteria	Archaea	Eukarya			
Kingdom	Eubacteria	Archaebacteria	Protista	Fungi	Plantae	Animalia
Example	*Streptococcus pneumoniae*	*Staphylothermus marinus*	paramecium	spore cap mushroom	Texas paintbrush	white-winged dove
						
Cell type	prokaryote		eukaryote			
Cell walls	cell walls with peptidoglycan	cell walls with unique lipids	some species with cell walls	cell walls with chitin	cell walls with cellulose	no cell walls
Number of cells	unicellular		unicellular or multicellular	mostly multicellular	mostly multicellular	multicellular
Nutrition	autotroph or heterotroph			heterotroph	autotroph	heterotroph

Figure 10 This table shows the major characteristics used to define the domains and kingdoms of the modern Linnaean system. **What other kind of characteristic differs between kingdoms?**

The Three-Domain System

As biologists began to see the differences between the two kinds of prokaryotes, they also saw the similarities among all eukaryotes. So, a new system was proposed that divides all organisms into three domains: Bacteria, Archaea, and Eukarya. **Today, most biologists tentatively recognize three domains and six kingdoms. Figure 10** shows the major characteristics of these taxa.

Major Characteristics Major taxa such as kingdoms are defined by major characteristics. These characteristics include:

- **Cell Type** The cells may be either *prokaryotic* or *eukaryotic*.
- **Cell Walls** The cells may either have a cell wall or lack a cell wall.
- **Body Type** An organism is either *unicellular* or *multicellular*.
- **Nutrition** An organism is either an *autotroph* (makes nutrients from inorganic materials) or a *heterotroph* (gets nutrients from other organisms). Some taxa have unique means of nutrition.
- **Genetics** As you have learned, related groups of organisms will have similar genetic material and systems of gene expression. So, organisms may have a unique system of DNA, RNA, and proteins.

Domain Bacteria **Domain Bacteria is equivalent to Kingdom Eubacteria.** The common name for members of this domain is *bacteria.* **Bacteria** are prokaryotes that have a strong exterior cell wall and a unique genetic system. However, bacteria have the same kind of cell membrane lipid as most eukaryotes do.

Differentiated Instruction

English Learners

Word Origins Review with students the prefixes that differentiate among the major characteristics discussed on this page: *pro-* (before), *eu-* (good, well, normal), *uni-* (one), *multi-* (many), *auto-* (by oneself), *hetero-* (other). Ask students to suggest other words that begin with these prefixes. (Sample answers: *pro-*: program, prologue, prohibit; *eu-*: eutropic, eubacteria, euglena; *uni-*: uniform, universe, unify; *multi-*: multiply, multicolor, multivitamin; *auto-*: automobile, automatic, autobiography, *hetero-*: heterogenous, heterozygote) **LS Verbal**

Hands-On

QuickLab

20 min

Field Guides

Have you ever used field guides to identify animals or plants? Do you know how these guides are organized? Take a few guides outside, and take a closer look.

Procedure

1. Gather **several different field guides** for plants or other organisms in your area. Also gather a **magnifying glass** and a **specimen jar.** Take these items with you to a **local natural area.**
2. **CAUTION: Do not touch or disturb any organisms without your teacher's permission; leave all natural items as you found them.** Try to find and identify at least two organisms that are listed in your field guides. Make notes to describe each organism.

Analysis

1. **Analyzing Methods** How difficult was identifying your organisms? How certain are you of your identification?
2. **Comparing Systems** How are the field guides organized? What other ways could they be organized?

All bacteria are similar in physical structure, with no internal compartments. Traditionally, bacteria have been classified according to their shape, the nature of their cell wall, their type of metabolism, or the way that they obtain nutrients. Bacteria are the most abundant organisms on Earth and are found in almost every environment.

Domain Archaea › **Domain Archaea is equivalent to Kingdom Archaebacteria.** The common name for members of this domain is *archaea.* **Archaea** have a chemically unique cell wall and membranes and a unique genetic system. The genetic systems of archaea share some similarities with those of eukaryotes that they do not share with those of prokaryotes. Scientists think that archaea began to evolve in a separate lineage from bacteria early in Earth's history and that some archaea eventually gave rise to eukaryotes.

Archaea were first found by scientists in extreme environments, such as salt lakes, the deep ocean, or hot springs that exceed 100°C. These archaea are called *extremophiles.* Other archaea called *methanogens* live in oxygen-free environments. However, some archaea live in the same environments as many bacteria do.

Domain Eukarya › **Domain Eukarya is made up of Kingdoms Protista, Fungi, Plantae, and Animalia.** Members of the domain Eukarya are **eukaryotes,** which are organisms composed of eukaryotic cells. These cells have a complex internal structure. This structure enabled the cells to become larger than the earliest cells and enabled the evolution of multicellular life. While eukaryotes vary in many fundamental respects, they share several key features.

› **Reading Check** *Which kingdoms are prokaryotic?*

bacteria (bak TIR ee uh) extremely small, single-celled organisms that usually have a cell wall and that usually reproduce by cell division; members of the domain Bacteria

archaea (ahr KEE uh) prokaryotes that are distinguished from other prokaryotes by differences in their genetics and in the makeup of their cell wall; members of the domain Archaea

eukaryote an organism made up of cells that have a nucleus enclosed by a membrane, multiple chromosomes, and a mitotic cycle; members of the domain Eukarya

QuickLab

Teacher's Notes Encourage students to make drawings to complement their written descriptions. Review appropriate guidelines for working outdoors and with live organisms. Emphasize that students should observe without touching. Students should wash their hands when they return to the classroom.

Materials
- field guides
- magnifying glasses
- plastic jars, for specimens
- binoculars (optional)

Answers to Analysis

1. Answers will vary. Identifying species with certainty is often difficult.
2. Sample answers: color, shape, habitat, geography, Linnaean taxa

Math Skills

Average Bacterial Cell Tell students that an average size for a bacterial cell is about 2 µm (micrometer). Explain that 1 µm is one-millionth of a meter. Ask students how large an image of an average bacterial cell would be if it were magnified one million times.
$(2\ \mu m \times \frac{m}{1{,}000{,}000\ \mu m} \times 1{,}000{,}000 = 2\ m)$
LS **Logical**

Differentiated Instruction

Advanced Learners

Types of Archaebacteria Have students find out more about methanogens and extremophiles. Methanogens often live deep in mud and release energy by combining hydrogen gas and carbon dioxide to form methane gas. Extremophiles live in extreme conditions, such as temperatures that can exceed 120°C, or water and acids with a pH below 1, close to that of battery acid. Others live under extreme pressures or in strongly chemical environments. LS **Verbal**

MISCONCEPTION ALERT

Viruses Students may wonder why viruses are not discussed in this chapter. Tell them that viruses do not meet the generally accepted definition of life. They are not made of cells, they do not carry out metabolic processes, and they cannot reproduce on their own. Thus, viruses are considered nonliving. However, because they affect living things in many ways, their characteristics and activities are discussed in biology texts.

Teach, *continued*

Teaching Key Ideas

Visual Literacy Discuss the evolutionary relationships shown in **Figure 11.** Help students to differentiate among the lineages that lead to each of the six kingdoms. Check that students understand the meaning of the branching. Ask: Are algae more closely related to bacteria or plants? (plants) Are fungi more like animals or plants? (animals) **LS Visual**

Demonstration

Observing Protists Set up microscope stations with various protists for students to observe. Ask students to compare what they see with the characteristics of plants and animals. Make sure that they understand that protists are grouped together because they lack the defining characteristics of fungi, plants, and animals, and that in the future their classification may change. **LS Visual**

Answers to Caption Questions

Figure 11: Because scientists are constantly revising and testing their hypotheses about the phylogenies of various groups. Many parts of the "tree" are rearranged often.

READING TOOLBOX

Phylogenetic Tree There is close relationship between plants and algae with chloroplasts. Birds are closely related to reptiles. Roundworms, arthropods, flatworms, segmented worms, mollusks, and echinoderms have a common cnidarian ancestor. Protista is the group that did not descend from a common single ancestor.

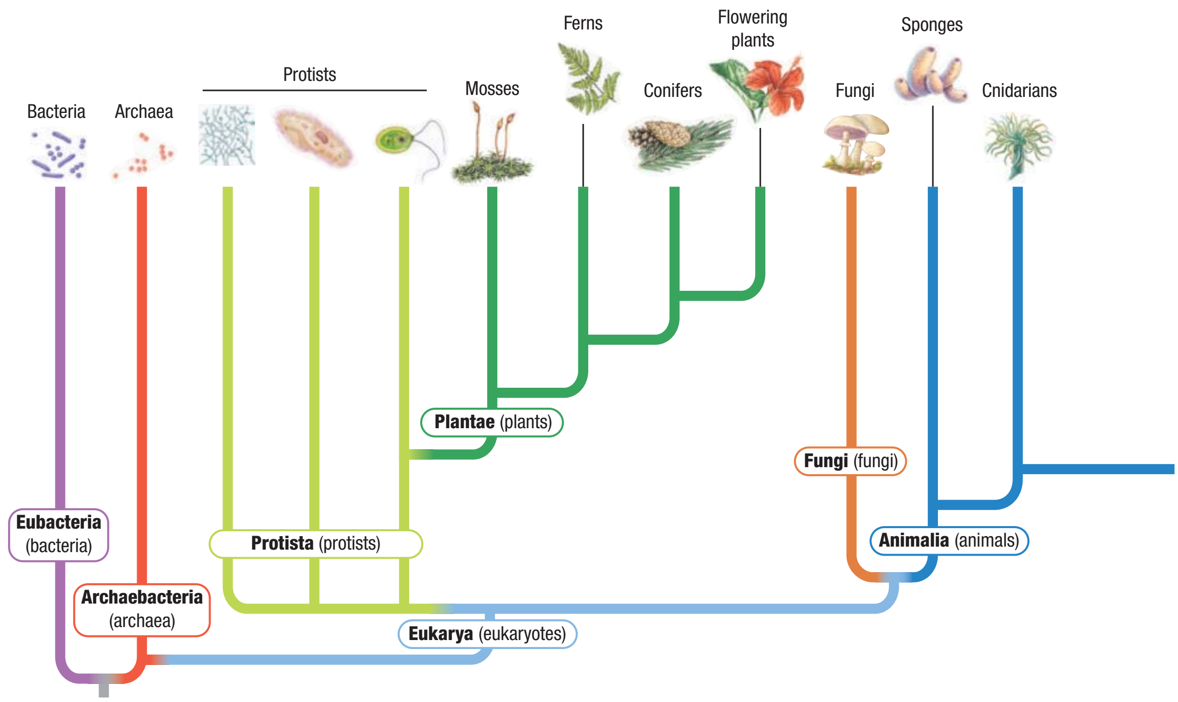


Figure 11 This tree of life shows current hypotheses of the relationships between all major groups of organisms. For updates on phylogenetic information, visit **go.hrw.com** and enter the keyword **HX8 Phylo.** **❯ Why might this type of model be revised?**

READING TOOLBOX

Phylogenetic Tree Look carefully at **Figure 11.** Try to identify which groups are most closely related to each other. Which label includes lineages that do not share a unique common ancestor?

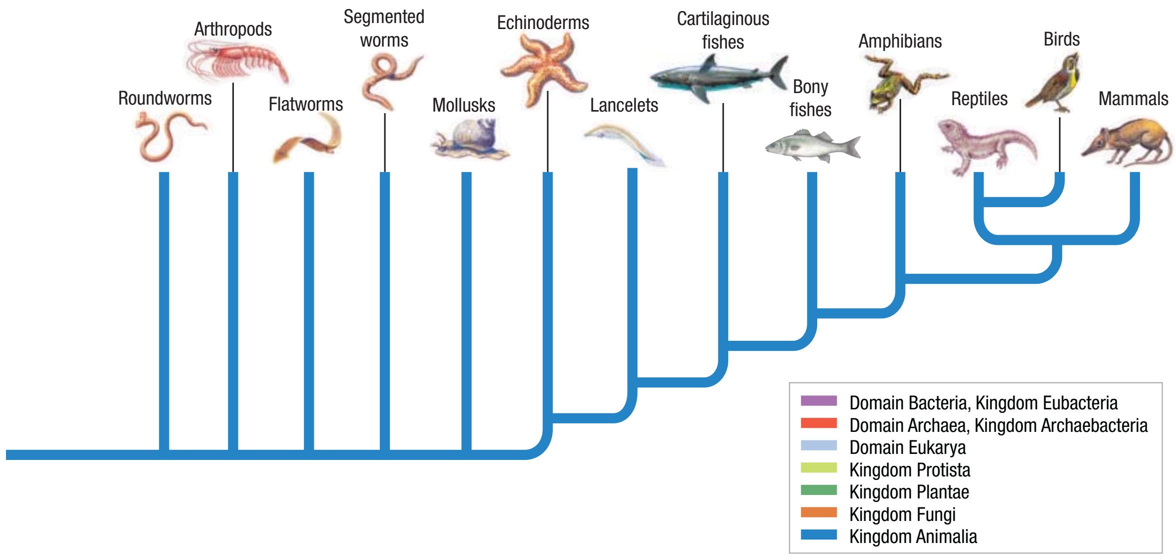
Characteristics of Eukaryotes Eukaryotes have highly organized cells. All eukaryotes have cells with a nucleus and other internal compartments. Also, true multicellularity and sexual reproduction occur only in eukaryotes. True multicellularity means that the activities of individual cells are coordinated and the cells themselves are in contact. Sexual reproduction means that genetic material is recombined when parents mate. Sexual reproduction is an important part of the life cycle of most eukaryotes.

Kinds of Eukaryotes The major groups of eukaryotes are defined by number of cells, body organization, and types of nutrition.

- **Plantae** Almost all plants are autotrophs that produce their own food by absorbing energy and raw materials from their environment. This process is *photosynthesis,* which occurs inside chloroplasts. The cell wall is made of a rigid material called *cellulose*. More than 270,000 known species of plants exist.
- **Animalia** Animals are multicellular heterotrophs. Their bodies may be simple collections of cells or highly complex networks of organ systems. Animal cells lack the rigid cell walls that plant cells have. More than 1 million known species of animals exist.
- **Fungi** Fungi are heterotrophs and are mostly multicellular. Their cell wall is made of a rigid material called *chitin*. Fungi are considered to be more closely related to animals than to any other kingdom. More than 70,000 known species of fungi exist.

MISCONCEPTION ALERT

Numbers of Individuals Make sure students understand that animals are not the most numerous organisms even though the animal kingdom takes up most of the branches on the tree. The animal kingdom includes the most known species, but the bacteria domain probably contains the most organisms.



- **Protista** Kingdom Protista is a diverse group. Unlike the other three Kingdoms of Eukarya, Protista is not a natural group but rather a "leftover" taxon. Any single-celled eukaryote that is *not* a plant, animal, or fungi can be called a *protist*. Protists did not descend from a single common ancestor.

For many years , biolgists recognized four major groups of protists: flagellates, amoebas, algae, and parasitic protists. More recently, biologists have proposed to replace Protista with several new kingdoms. These kingdoms would classify protists that seem to be unrelated to any other groups. However, some protists are being reclassified into other kingdoms. For example, algae that have chloroplasts are thought to be most closely related to plants, as shown in **Figure 11.** Biologists have not yet agreed how to resolve all of these issues.

Reading Check *Which kingdoms contain only heterotrophs?*

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Keyword: HX8CLSF11

Section 3 Review

KEY IDEAS

1. **Outline** how biologists have changed the major levels of the Linnaean system over time.
2. **List** the three domains, identify the kingdoms that align with each domain, and list the major characteristics of each kingdom.

CRITICAL THINKING

3. **Finding Evidence** The *theory of endosymbiosis* proposes that eukaryotes descended from a primitive combination of both archaea and bacteria. What evidence supports this theory?
4. **Science and Society** Microscopes led scientists to recognize new kingdoms. What other technology has impacted classification?

ALTERNATIVE ASSESSMENT

5. **Tree of Life Poster** Make a poster of the tree of life. At appropriate places on the tree, add images of representative organisms, along with labels. Include all domains and kingdoms as well as at least three major taxa within each kingdom.

go.hrw.com
interact online

Students can interact with the "Tree of Life" by going to go.hrw.com and typing in the keyword HX8CLSF11.

Close

Formative Assessment

Which of the following are distinguishing characteristics of fungi?

A. unicellular, heterotrophic (Incorrect. Most fungi are not unicellular.)
B. multicellular, heterotrophic, cell walls containing chitin (Correct! The characteristic of cell walls distinguishes fungi from animals, which are also multicellular heterotrophs.)
C. unicellular or multicellular, some species with cell walls (Incorrect. These are characteristics of Protista.)
D. multicellular, autotrophic, cell walls (Incorrect. Fungi are not autotrophic.)

Answers to Section Review

1. Answers should show a progression from Linnaeus' two-kingdom system of plants and animals through the later addition of protists, monerans, and fungi. Monerans were eventually split into two kingdoms that became domains Archaea and Bacteria. The remaining kingdoms make up the third domain, Eukarya.
2. **Archaea** Archaebacteria: unicellular, prokaryotic, unique genetic systems, cell walls with unique lipids

   Bacteria Eubacteria: unicellular, prokaryotic, unique genetic systems, cell walls with peptidoglycan

   Eukarya Animalia: multicellular, eukaryotic, heterotrophic; no cell walls

   Plantae: mostly multicellular, eukaryotic, autotrophic; cell walls with cellulose

   Fungi: mostly multicellular, eukaryotic, heterotrophic; cell walls with chitin

   Protista: unicellular or colonial, eukaryotic, autotrophic or heterotrophic, some with cell walls
3. The cell membrane lipid of bacteria and eukaryotes is similar, whereas the genetic systems of archaea and eukaryotes are similar.
4. Genetic analysis has led to understanding fundamental differences among cells, such as those between archaea and bacteria.
5. Student posters should be similar to Figure 10, but should include novel images with labels of organisms representing each group.

Lab

Time Required

One 45-minuted class period

Safety Caution

Review with students the safety cautions represented by the safety symbols before beginning the lab.

Tips and Tricks

Have students design a key for a random collection of objects from the classroom or school. An alternative collection of items could include small pieces of hardware or dry food items, such as noodles, beans, whole grains of wheat, rice, and other seeds.

Emphasize that a dichotomous key includes pairs of descriptions that lead to the identification of an object. Lead students through a discussion of using the process of elimination when working with a dichotomous key.

If students are unsure how to begin, tell them to start with the simplest way to split their collection into two groupings, or to find the "odd one out." Remind them that the groups do not have to be equal in size, just clearly differentiated. Then they simply repeat the splitting process for each remaining subgroup of items, until they have sorted through every item in their collection.

Skills Practice

Chapter 18 Lab

Objectives

- Identify objects by using a dichotomous key.
- Design a dichotomous key for a group of objects.

Materials

- objects, common (6 to 10)
- labels, adhesive
- pencil

Safety

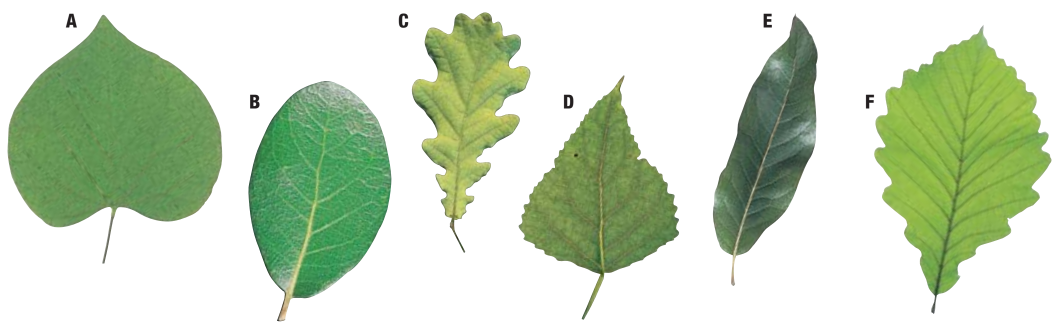
Dichotomous Keys

One way to identify an unknown organism is to use an identification key, which contains the major characteristics of groups of organisms. A dichotomous key is an identification key that contains pairs of contrasting descriptions. After each description, a key either directs the user to another pair of descriptions or identifies an object. In this lab, you will design and use a dichotomous key. A dichotomous key can be written for any group of objects.

Procedure

Use a Dichotomous Key

1. Work with a small group. Use the dichotomous key to identify the tree that produced each of the leaves shown here. Identify one leaf at a time. Always start with the first pair of statements (1a and 1b). Follow the direction beside the statement that describes the leaf.
2. Proceed through the key until you get to the name of a tree. Record your answer for each leaf shown.



Key to Forest Trees

1a	Leaf edge is smooth or barely curved.	go to 2
1b	Leaf edge has teeth, waves, or lobes.	go to 3
2a	Leaf has a sharp bristle at its tip.	shingle oak
2b	Leaf has no bristle at its tip.	go to 4
3a	Leaf edge has small, shallow teeth.	Lombardy poplar
3b	Leaf edge has deep waves or lobes.	go to 5
4a	Leaf is heart shaped.	eastern redbud
4b	Leaf is not heart shaped.	live oak
5a	Leaf edge has less than 20 large lobes.	English oak
5b	Leaf edge has more than 20 waves.	chestnut oak

45 min

Design a Dichotomous Key

3. Put on safety goggles, gloves, and a lab apron.Choose 6 to 10 objects from around the classroom or from a collection supplied by your teacher. Before you go to the next step, have your teacher approve the objects your group has chosen.
4. Study the structure and organization of the dichotomous key, which includes pairs of contrasting descriptions that form a "tree" of possibilities. Use this key as a model for the next step.
5. Work with the members of your group to design a new dichotomous key for the objects that your group selected. Be sure that each part of the key leads to either a definite identification of an object or another set of possibilities. Be sure that every object is included.
6. Test your key by using each one of the objects in your collection.

Exchange and Test Keys

7. After each group has completed the steps above, exchange your key and your collection of objects with another group. Use the key you receive to identify each of the new objects. If the new key does not work, return it to the group so that corrections can be made.

Cleanup

8. Clean up your work area and return or dispose of materials as directed by your teacher. Wash your hands thoroughly before you leave the lab and after you finish all of your work.

SCILINKS.
www.scilinks.org
Topic: Classification
Code: HX80295

Analyze and Conclude

1. **Summarizing Data** List the identity of the tree for each of the leaves that you analyzed in step 2.
2. SCIENTIFIC METHODS **Critiquing Procedures** What other characteristics might be used to identify leaves by using a dichotomous key?
3. **Analyzing Results** What challenges did your group face while making your dichotomous key?
4. **Evaluating Results** Were you able to use another group's key to identify the group's collection of objects? Describe your experience.
5. SCIENTIFIC METHODS **Analyzing Methods** Does a dichotomous key begin with general descriptions and then proceed to more specific descriptions, or vice versa? Explain your answer by using examples.
6. SCIENTIFIC METHODS **Evaluating Methods** Is a dichotomous key the same as the Linnaean classification system? Explain your answer.

Extension

7. **Research** Do research in the library or media center to find out what types of methods, other than dichotomous keys, are used to identify organisms.

Answers to Analysis and Conclusions

1. A: eastern redbud; B: live oak; C: English oak; D: Lombardy poplar; E: shingle oak; F: chestnut oak
2. Other leaf characteristics might include whether the leaf is compound or simple, whether it is needlelike, the arrangement of leaves on the branches, and the leaf's vein pattern.
3. Answers will vary. Accept all reasonable responses.
4. Students might have found that some of the pairs of statements were not contrasting enough, that some of the items were not correctly described, or that the key did not include a sufficient number of descriptions to distinguish all the items from one another.
5. Dichotomous keys proceed from general characteristics to specific characteristics. Examples from keys will vary but should reflect this gradation.
6. No, because a dichotomous key is used primarily to identify individual things, where the Linnaean classification system is used to group things.

Answers to Extension

7. Answers will vary. Some keys, such as field guides, use descriptive paragraphs, diagrams, and/or photos for comparison to identify organisms.

Key Resources

- Holt Lab Generator
- Lab Datasheet (Levels A, B, C)
- Holt Science Biology Video Labs
- Virtual Investigations

Chapter 18

SUPER SUMMARY

Have students connect the major concepts in this chapter through an interactive Super Summary. Visit **go.hrw.com** and type in the key word **HX8CLSS** to access the Super Summary for this chapter.

Reteaching Key Ideas

Scientific Names Have students determine what is incorrect about each of the following "scientific" names: spotted leopard (common name), *Tabanus b.* (species name missing), *Acer Rubrum* (species name is capitalized). **LS Logical**

Cladograms Have students work with a partner to devise a table and cladogram for the following animals: eagle, frog, goldfish, dog, and mouse. They should compare at lease five different traits. **LS Logical**

Classification Systems Have students prepare a graphic organizer to show the relationships of the following shapes: triangle, hexagon, trapezoid, parallelogram, square, pentagon, rectangle, quadrilateral, and polygon. Ask students to justify the rationale for their graphic organizer. **LS Logical**

Chapter 18 Summary

go.hrw.com
SUPER SUMMARY
Keyword: HX8CLSS

Key Ideas	Key Terms

1 The Importance of Classification

- Biologists use taxonomic systems to organize their knowledge of organisms. These systems attempt to provide consistent ways to name and categorize organisms.
- All scientific names for species are made up of two Latin or Latin-like terms.
- In the Linnaean system of classification, organisms are grouped at successive levels of a hierarchy based on similarities in their form and structure. The eight levels of modern classification are domain, kingdom, phylum, class, order, family, genus, and species.

Key Terms: **taxonomy** (423), **genus** (424), **binomial nomenclature** (424)

2 Modern Systematics

- Scientists traditionally have used similarities in appearance and structure to group organisms. However, this approach has proven problematic.
- Grouping organisms by similarity is often assumed to reflect phylogeny, but inferring phylogeny is complex in practice.
- Cladistic analysis is used to select the most likely phylogeny among a given set of organisms.
- Biologists compare many kinds of evidence and apply logic carefully in order to infer phylogenies.

Key Terms: **phylogeny** (428), **cladistics** (429)

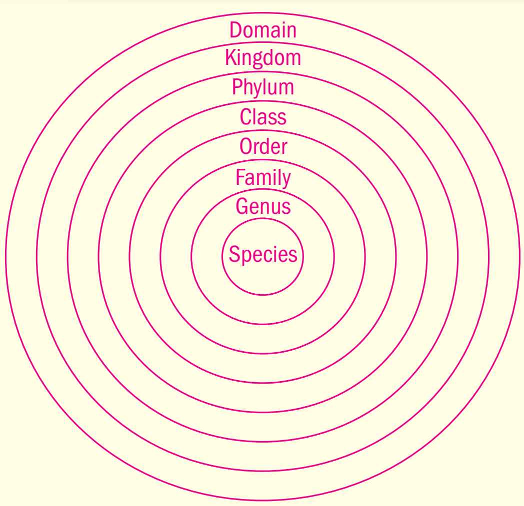
3 Kingdoms and Domains

- Biologists have added complexity and detail to classification systems as they have learned more.
- Today, most biologists tentatively recognize three domains and six kingdoms. Domain Bacteria is equivalent to Kingdom Eubacteria. Domain Archaea is equivalent to Kingdom Archaebacteria. Domain Eukarya is made up of Kingdoms Protista, Fungi, Plantae, and Animalia.

Key Terms: **bacteria** (434), **archaea** (435), **eukaryote** (435)

Answer to Concept Map

The following is one possible answer to Chapter Review question 2.



Chapter 18 Review

READING TOOLBOX

1. **Word Parts** Use the table of word parts at the beginning of this chapter to analyze the word *phylogeny*.
2. **Concept Map** Make a Venn diagram that shows the relationships between all major levels of the modern Linnaean classification system.

Using Key Terms

For each pair of terms, explain how the meanings of the terms differ.

3. *genus* and *species*
4. *bacteria* and *archaea*

Complete each of the following sentences by choosing the correct term from the word bank.

cladistics *taxonomy*
phylogeny *binomial nomenclature*

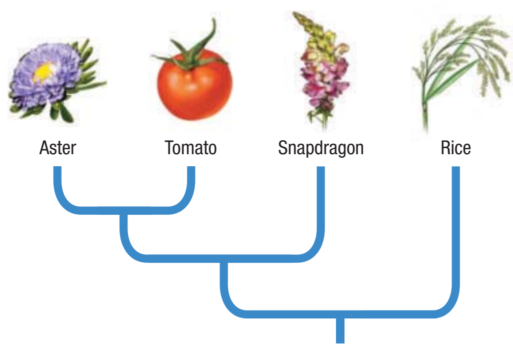
5. Scientists use ___ to name and classify organisms.
6. All modern scientific names are based on Linnaeus's original system of ___.
7. Today, biologists use ___ to analyze evolutionary relationships between groups of organisms.
8. Looking at obvious similarities is not always enough to infer ___.

Understanding Key Ideas

9. Which language is used for each scientific name?
   - **a.** Greek
   - **b.** Latin
   - **c.** English
   - **d.** French
10. Which classification level contains subgroups within orders?
    - **a.** family
    - **b.** class
    - **c.** phylum
    - **d.** domain
11. Which of the following pairs of characters are analogous but not homologous?
    - **a.** eggs of a lizard and eggs of a snake
    - **b.** feet of a dinosaur and feet of a bird
    - **c.** wings of a butterfly and wings of a bat
    - **d.** beak of a bluebird and beak of a blue jay
12. When constructing a cladogram, systematists use the principle of parsimony. This principle leads to cladograms that contain
    - **a.** very few branch points.
    - **b.** a few large branches, each with many smaller branches.
    - **c.** the greatest number of character changes between branch points.
    - **d.** the fewest number of character changes between branch points.
13. How do scientists use DNA sequences to infer which organisms share the most recent ancestry?
    - **a.** They re-create fossil DNA to model ancient organisms.
    - **b.** They compare all of the genes of every organism that exists.
    - **c.** They look for organisms that share the most similar DNA sequences.
    - **d.** They look for any organisms that have differences in DNA sequences.

Explaining Key Ideas

14. **Justify** the need for scientific nomenclature.
15. **Explain** why analogous characters, such as wings, should not be used to classify organisms.
16. **Differentiate** between the major characteristics of organisms in the domains Bacteria and Eukarya.
17. **Describe** this diagram. What does it represent? What does it tell us about an aster plant and a tomato plant as compared with a snapdragon?



Assignment Guide	
Section	**Questions**
1	2, 3, 5, 6, 9, 10, 14, 21, 26, 28
2	1, 7, 11, 12, 13, 15, 17, 18, 19, 20, 22, 23, 29
3	4, 8, 16, 19, 21, 24, 25, 27, 28

Review

Reading Toolbox

1. *Phylogeny* means "the origin of new clans or lineages."
2. See previous page for answer to concept map.

Using Key Terms

3. A *species* is a unique group of organisms that interbreed or form a distinct lineage. A *genus* is a group of several closely related species.
4. *Bacteria* and *archaea* are both prokaryotes, but they differ in cellular chemistry and genetic systems.
5. taxonomy
6. binomial nomenclature
7. cladistics
8. phylogeny

Understanding Key Ideas

9. b 10. a 11. c 12. d
13. c

Explaining Key Ideas

14. The scientific name allows scientists to know that they are talking about the same organism. It provides a common way of communicating for scientists around the world.
15. Analogous characters may arise in unrelated organisms in response to similar environmental conditions. Therefore, analogous characters cannot be used as evidence for evolutionary relationships.
16. Bacteria are unicellular organisms composed of prokaryotic cells that have cell walls. Eukaryotes are unicellular or multicellular organisms composed of highly organized eukaryotic cells that may or may not have cell walls. Bacteria reproduce asexually; eukaryotes reproduce sexually.
17. The diagram is a cladogram or phylogenetic tree. It represents a hypothesis of the evolutionary relationships among several kinds of plants. It tells us that asters and tomatoes are more closely related to each other than they are to snapdragons or rice.

Using Science Graphics

18. b **19.** a **20.** a

Critical Thinking

21. Taxonomists may have found groups that don't fit perfectly into one of the existing taxa. Inventing "in-between" taxa enables them to keep classifying things within the Linnaean system even though it is becoming outdated.

22. Any characters that an outgroup organism has in common with ingroup organisms is ancestral because organisms in the outgroup are distantly related to the other organisms in the cladogram, but do not share the unique derived characteristics of the clade in question.

23. Embryonic development gives clues to phylogeny because it is also determined by genes. Scientists could infer that chickens evolved from an early ancestor that had more bones in its feet and had a long, bony tail.

24. Answers will vary. Accept all reasonable answers.

25. Similarities: multicellular, heterotrophic; difference: cell walls in fungi, organ systems in animals

Why It Matters

26. No, because new species are continuously discovered.

Writing for Science

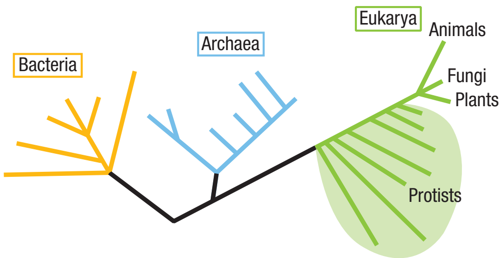
27. Student lyrics should reflect an understanding of the major characteristics or representative organisms of their chosen kingdom.

Alternative Assessment

28. Posters should show classification of an organism at all eight levels, as well as a general description of characteristics and a list of similar organisms in each taxon.

Using Science Graphics

This phylogenetic tree represents recent hypotheses about the major lineages of all life and relationships between each of these groups. In this diagram, the length of each branch represents the relative amount of divergence over time for each lineage. Use the diagram below to answer the following questions.



18. According to this model, which of the following two groups are most closely related?
a. bacteria and plants
b. animals and fungi
c. archaea and eukarya
d. fungi and protists

19. Which of the following statements is in agreement with this model?
a. Protists do not make up a clade.
b. Bacteria are descended from protists.
c. Fungi should be reclassified as plants.
d. Animals and protists form their own clade.

This table compares characters of several animals. Use the table to answer the following question.

Characters in Vertebrates

	Amniotic sac	Mammary glands	Placenta
Trout	no	no	no
Hummingbird	yes	no	no
Koala	yes	yes	no
Gray squirrel	yes	yes	yes

20. Which organism in the table would be used as the outgroup in a cladogram that unites the other three organisms?
a. trout
b. hummingbird
c. koala
d. gray squirrel

Critical Thinking

21. Using Logical Systems In practice, taxonomists have invented many "in-between" levels for the Linnaean system, such as "subclass" or "superorder." Why might they have done this?

22. Analyzing Concepts Explain why ancestral characters are associated with the outgroup in a cladogram.

23. Constructing Explanations How could the presence of extra bones and a tail on a chicken embryo help scientists understand the evolutionary history of chickens?

24. Justifying an Opinion Given the the current characteristics of each kingdom in the six-kingdom system, would you split any of the kingdoms into new kingdoms? Explain your reasoning.

25. Comparing Features What similarities and differences exist between animals and fungi?

Why It Matters

26. New Species Will scientists ever finish classifying all species? Explain your answer.

Writing for Science

27. Lyrics Choose one of the six kingdoms, and write a song or poem about it.

Alternative Assessment

28. Linnaean Album Use library or Internet resources to make a picture album representing the six kingdoms. Find a picture of one species from each kingdom, and mount a copy of the picture in your album. Add a listing of each species' classification, using as many taxonomic levels as possible.

Math Skills

29. Rates Suppose that the amino acid sequence for gene Z of plant A has 10 bases that differ from those in the sequence for the same gene in plant B. Assume that mutations in this kind of gene occur at a rate of 2 mutations every 10,000 years. Estimate how long ago these two plants diverged from a common ancestor.

Math Skills

29. $\frac{\text{10 changed bases}}{\text{2 changed bases/10,000 y}} = \text{50,000 years}$

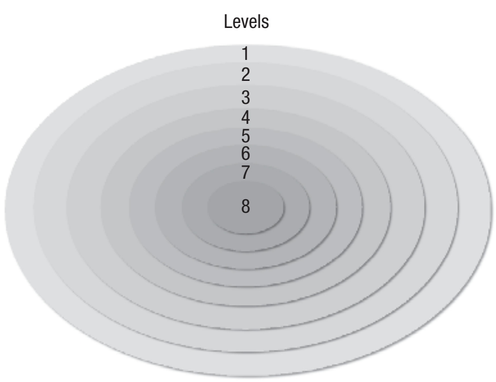
Chapter 18 Standardized Test Prep

TEST TIP After you finish writing your answer to a short-response item, proofread it for errors in spelling, grammar, and punctuation.

Science Concepts

1. Why do biologists have taxonomic systems?
   - **A** to provide descriptive Latin names
   - **B** to maintain a small number of taxa
   - **C** to provide consistent ways to identify and classify organisms as they are being studied
   - **D** to construct a family tree that predicts how many species may be discovered in the future
2. Which taxonomic system was developed by Carl Linnaeus in the 1750s and is used today?
   - **F** cladistics
   - **G** taxonomic phylogeny
   - **H** the polynomial system
   - **J** binomial nomenclature

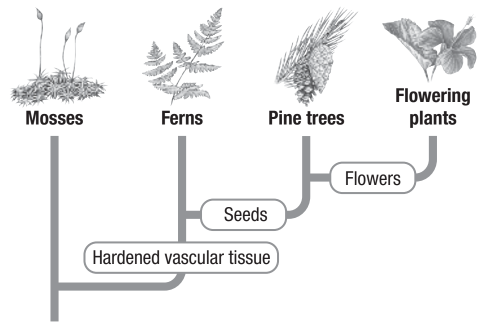
This diagram shows the major levels of taxonomy in the modern Linnaean system. Use the diagram to answer the following questions.



3. Which level represents the genus category?
   - **A** level 1
   - **B** level 2
   - **C** level 7
   - **D** level 8
4. Which level represents the kingdom category?
   - **F** level 1
   - **G** level 2
   - **H** level 7
   - **J** level 8

Using Science Graphics

This diagram shows the relationship between several types of plants. Use the diagram to answer the following questions.



5. Which derived character is shared by pine trees and flowering plants but not ferns?
   - **A** seeds
   - **B** flowers
   - **C** mosses
   - **D** vascular tissue
6. Which of the following pairs of plant groups form a clade that is exclusive of all other plants?
   - **F** mosses and ferns
   - **G** ferns and pine trees
   - **H** mosses and flowering plants
   - **J** pine trees and flowering plants
7. What is the name of the domain that contains all of the organisms shown in the diagram?
   - **A** Algae
   - **B** Plantae
   - **C** Eukarya
   - **D** Bacteria

Writing Skills

8. **Short Response** Describe the origins of the modern Linnaean system of taxonomy.
9. **Extended Response** Write an essay that summarizes the historical development of scientific naming and classification systems. Include the reasons why such systems were invented, and describe the ways that modern systematics differs from earlier systems.

Answers

1. C
2. J
3. C
4. G
5. A
6. J
7. C
8. Sample answer: The modern Linnaean system had its origin in the work of Carl Linnaeus in the 1700s. He tried to catalog many organisms, and proposed a consistent system for naming and grouping them. His system is still used, although the levels of grouping have been modified over time.
9. Essays should include how Linnaeus cataloged the known species and recognized a need for unique names to avoid confusion among scientists. As awareness of the diversity of life grew, Linnaeus' system had shortcomings. New technologies enable closer examination of organisms resulting in new hypotheses about their evolutionary relationships.

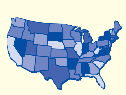
TEST DOCTOR

Question 2 **F** is incorrect, because cladistics is a recent system that infers phylogeny by careful comparison of shared characters. **G** is incorrect, because Linnaeus used taxonomic phylogeny, but he did not develop that concept. **H** is incorrect. Polynomials were used in the early days of European biology. **J** is correct. Linnaeus added binomial nomenclature to the polynomial system.

Question 5 **A** is correct. Seeds are a derived character of pine trees and flowering plants, and are not present in ferns or mosses. **B** is incorrect because flowers are only characteristic of flowering plants. **C** is incorrect because mosses make up a group that shares characters with all the other groups shown. **D** is incorrect because vascular tissue is present in ferns as well as pine trees and flowering plants.

Question 6 **F** is incorrect, because mosses and ferns have characteristics shared by pine trees and flowering plants. **G** is incorrect because ferns and pine trees have characteristics shared by flowering plants. **H** is incorrect, because mosses and flowering plants have characteristics shared by ferns and pine trees. **J** is correct. Pine trees and flowering plants have a characteristic that is not present in mosses and ferns.

State Resources



For specific resources for your state, visit go.hrw.com and type in the keyword **HSHSTR**.

Test Practice with Guided Reading Development