

# 18-2 Modern Evolutionary Classification

In a sense, organisms determine who belongs to their species by choosing with whom they will mate! Taxonomic groups above the level of species are “invented” by researchers who decide how to distinguish between one genus, family, or phylum, and another. Linnaeus and other taxonomists have always tried to group organisms according to biologically important characteristics. Like any taxonomic system, however, Linnaeus’s system had limitations and problems.

## Which Similarities Are Most Important?

Linnaeus grouped species into larger taxa, such as genus and family, mainly according to visible similarities and differences. But which similarities and differences are most important? If you lived in Linnaeus’s time, for example, how would you have classified dolphins? Would you have called them fishes because they live in water and have finlike limbs? Or would you call them mammals because they breathe air and feed their young with milk? How about the animals shown in **Figure 18-6**? Adult barnacles and limpets live attached to rocks and have similarly shaped shells with holes in the center. Crabs, on the other hand, have body shapes unlike those of barnacles or limpets. Based on these features, would you place limpets and barnacles together, and crabs in a different group?



**Figure 18-6** Classifying species based on easily observed adult traits can pose problems. Observe the crab (top left), barnacles (bottom left), and limpet (right). Which seem most alike? **Asking Questions** What additional information might you gather to help inform your decision?



## Guide for Reading

### Key Concepts

- How are evolutionary relationships important in classification?
- How can DNA and RNA help scientists determine evolutionary relationships?

### Vocabulary

phylogeny  
evolutionary classification  
derived character  
cladogram  
molecular clock

### Reading Strategy:

**Predicting** Before you read, preview **Figure 18-7**. Predict how the field of taxonomy has changed since Linnaeus’s time. As you read, note whether or not your prediction was correct.

## Section 18-2

### 1 FOCUS

#### Objectives

- 18.2.1 Explain** how evolutionary relationships are important in classification.
- 18.2.2 Identify** the principle behind cladistic analysis.
- 18.2.3 Explain** how we can compare very dissimilar organisms.

## Guide for Reading

### Vocabulary Preview

Explain how some of the Vocabulary terms are related. Point out that the term *cladogram* refers to a type of evolutionary classification. Ask: **What do you think the term evolutionary classification refers to?** (A type of classification based on the evolutionary history of organisms)

### Reading Strategy

In comparing the traditional classification and the cladogram in **Figure 18-7**, students might point out that the cladogram includes references to different stages of an organism’s life.

### 2 INSTRUCT

## Which Similarities Are Most Important?

### Demonstration

Show students pictures of a variety of plants and animals. In each case, ask them to identify the kingdom to which the organism belongs. Point out that plants and animals are the only two kingdoms in Linnaeus’s system. Then, show students pictures of unicellular protists, such as paramecia, and challenge them to identify the kingdom to which they belong. (Students may or may not be able to identify the kingdom of paramecia as Protista.) **L1 L2**

### Answer to . . .

**Figure 18-6** You might gather information on embryology or on environmental adaptations in the three species to see if any of them are more similar in these ways.



## SECTION RESOURCES

### Print:

- **Teaching Resources**, Lesson Plan 18-2, Adapted Section Summary 18-2, Adapted Worksheets 18-2, Section Summary 18-2, Worksheets 18-2, Section Review 18-2
- **Reading and Study Workbook A**, Section 18-2
- **Adapted Reading and Study Workbook B**, Section 18-2

### Technology:

- **iText**, Section 18-2
- **Transparencies Plus**, Section 18-2

## Evolutionary Classification

### Build Science Skills

**Using Models** Tell students that some scientists used to think that monkeys of the New and Old Worlds had diverged from a monkeylike common ancestor fairly recently. Other scientists think that New and Old World monkeys diverged from a more generalized common ancestor much longer ago and later evolved similar characteristics because of similar environments. Challenge students to represent each of these theories with an evolutionary family tree, or phylogenetic tree. (A phylogenetic tree for the first theory would show a recent branching. A tree for the second theory would show a much less recent branching, followed by parallel evolution in the two groups.) **L2 L3**

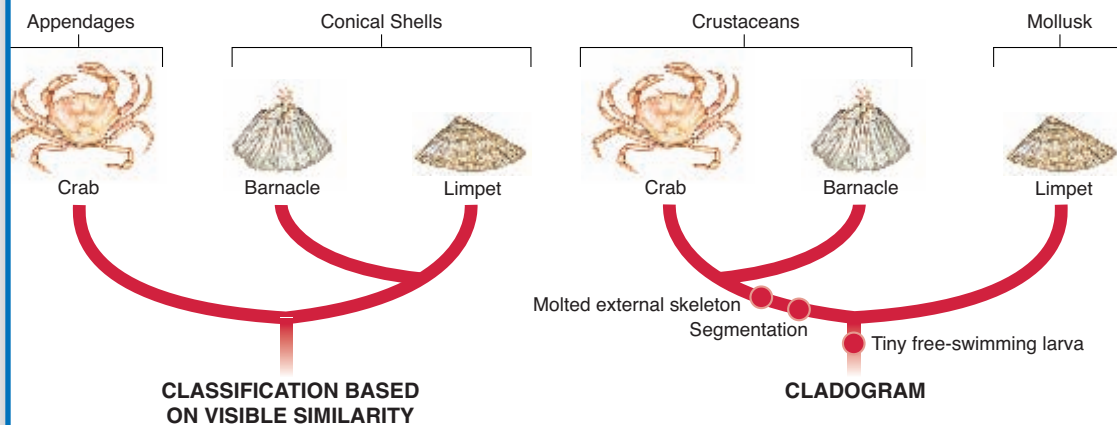
### Use Visuals

**Figure 18-7** Call students' attention to the figure. Ask: **In the early classification on the left, which traits are used to classify barnacles and limpets together?** (A conical shell and absence of appendages) **In the cladogram on the right, which traits are used to classify crabs and barnacles together?** (A segmented body and an external skeleton that is shed during growth) Call on students to explain why different traits are used in the two systems of evolutionary classification. Correct any misconceptions. **L2**

### Go online active art

For: Cladogram activity  
Visit: PHSchool.com  
Web Code: cbe-5189

Students get additional practice with cladograms.



**Figure 18-7** Early systems of classification grouped organisms together based on visible similarities. That approach might result in classifying limpets and barnacles together (left). **Biologists now group organisms into categories that represent lines of evolutionary descent, or phylogeny, not just physical similarities.** Crabs and barnacles are now grouped together (right) because they share several characteristics that indicate that they are more closely related to each other than either is to limpets. These characteristics include segmented bodies, jointed limbs, and an external skeleton that is shed during growth.

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Web Code: cbp-5182

## Evolutionary Classification

Darwin's ideas about descent with modification have given rise to the study of **phylogeny**, or evolutionary relationships among organisms. **Biologists now group organisms into categories that represent lines of evolutionary descent, or phylogeny, not just physical similarities.** The strategy of grouping organisms together based on their evolutionary history is called **evolutionary classification**.

Species within a genus are more closely related to one another than to species in another genus. According to evolutionary classification, that is because all members of a genus share a recent common ancestor. Similarly, all genera in a family share a common ancestor. This ancestor is further in the past than the ancestor of any genus in the family but more recent than the ancestor of the entire order. The higher the level of the taxon, the further back in time is the common ancestor of all the organisms in the taxon.

Organisms that appear very similar may not share a recent common ancestor. Natural selection, operating on species in similar ecological environments, has often caused convergent evolution. For example, superficial similarities once led barnacles and limpets to be grouped together, as shown on the left in **Figure 18-7**.

However, barnacles and limpets are different in important ways. For example, their free-swimming larvae, or immature forms, are unlike one another. Certain adult characteristics are different too. Adult barnacles have jointed limbs and a body divided into segments. Barnacles periodically shed, or molt, their external skeleton. These characteristics make barnacles more similar to crabs than to limpets. Limpets, in turn, have an internal anatomy that is closer to that of snails, which are mollusks. And like mollusks, limpets do not shed their shells. Because of such characteristics, taxonomists infer that barnacles are more closely related to crabs than to mollusks. In other words, barnacles and crabs share an evolutionary ancestor that is more recent than the ancestor that barnacles share with limpets. Thus, both barnacles and crabs are classified as crustaceans, and limpets are mollusks.



### UNIVERSAL ACCESS

#### Less Proficient Readers

Help students understand evolutionary classification systems by showing them a family tree with at least three generations. Point out that both the family tree and the phylogenetic trees in their text show relationships among descendants of a common ancestor. Say that species with a recent common ancestor are like siblings in a family, and species with a remote common ancestor are like distant cousins. **L1 L2**

#### Advanced Learners

Have interested students research similarities in the DNA of humans and a number of other different organisms. They should include organisms that are closely related to humans, such as other species of primates, as well as those that are only distantly related to humans, such as sharks or other species of fish. Suggest to students that they present their findings in a table and share it with the rest of the class. **L3**

## Classification Using Cladograms

To refine the process of evolutionary classification, many biologists now prefer a method called cladistic analysis. Cladistic analysis identifies and considers only those characteristics of organisms that are evolutionary innovations—new characteristics that arise as lineages evolve over time. Characteristics that appear in recent parts of a lineage but not in its older members are called **derived characters**.

Derived characters can be used to construct a **cladogram**, a diagram that shows the evolutionary relationships among a group of organisms. You can see an example of a cladogram on the right-hand side of **Figure 18–7**. Notice how derived characters, such as “free-swimming larva” and “segmentation,” appear at certain locations along the branches of the cladogram. These locations are the points at which these characteristics first arose. You can see that crabs and barnacles share some derived characters that barnacles and limpets do not. One such shared derived character is a segmented body. Another is a molted external skeleton. Thus, this cladogram groups crabs and barnacles together as crustaceans and separates them from limpets, which are classified as a type of mollusk.

Cladograms are useful tools that help scientists understand how one lineage branched from another in the course of evolution. Just as a family tree shows the relationships among different lineages within a family, a cladogram represents a type of evolutionary tree, showing evolutionary relationships among a group of organisms.

**CHECKPOINT** What is a cladogram?

## Classification Using Cladograms

### Quick Lab

**Objective** Students will be able to construct a cladogram to classify a group of animals. **L2 L3**

**Skills Focus** Using Tables and Graphs, Classifying, Drawing Conclusions, Inferring

**Time** 15 minutes

### Strategies

- Advise students to start with the organism that lacks at least one characteristic that all the other organisms share.
- Check that students have correctly identified the earthworm as the organism that lacks all three listed traits.
- Refer students to Figure 18–7 for ideas about how to construct a cladogram.

**Expected Outcome** Students should draw a cladogram that shows backbones evolved first, followed by legs, and then by hair.

### Analyze and Conclude

1. Lack of a backbone
2. Trout, lizard, and human
3. Yes; lizards and humans shared an ancestor that had legs and a backbone and that evolved after the earthworm’s lineage branched off on another evolutionary pathway.
4. A frog would occupy a branch between the trout and the lizard, because it has the derived character of legs. Another derived character, such as dry skin, would then have to be added for the lizard.

### Quick Lab

#### How is a cladogram constructed?

#### Procedure

1. Identify the organism in the table that is least closely related to the others.
2. Use the information in the table to construct a cladogram of these animals.

#### Analyze and Conclude

1. **Using Tables and Graphs** What trait separates the least closely related organism from the other animals?
2. **Classifying** List the animals in your cladogram in order of distance from the least closely related organism.

### Derived Characters in Organisms

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

3. **Drawing Conclusions** Does your cladogram indicate that lizards and humans share a more recent common ancestor than either does with an earthworm? Explain.
4. **Inferring** Where would you insert a frog if you added it to the cladogram? Explain your answer.



### FACTS AND FIGURES

#### Homologous vs. analogous

When classifying organisms, taxonomists are careful to distinguish between homologous structures and analogous structures. Homologous structures have a similar structure and development pattern. However, the function of homologous structures may be different. The wing of a bird and the

human arm are homologous structures due to their similar structure pattern of development. Analogous structures appear similar and perform similar functions; however, their structure and developmental patterns are quite different. The wing of a bird and the wing of a butterfly are analogous structures.

### Answer to . . .

**CHECKPOINT** A cladogram is a diagram that shows evolutionary relationships among organisms based on shared derived characters.

## 18-2 (continued)

### Similarities in RNA and DNA

#### Make Connections

**Chemistry** Explain that the most precise method of comparing the DNA of two species is DNA sequencing, in which the researcher first prepares comparable DNA segments from two species and then determines the extent to which nucleotide sequences are the same in the two segments. (See Chapter 13, Section 2.) Another method, called DNA–DNA hybridization, measures the extent of hydrogen bonding between single strands of DNA from different species. The more hydrogen bonding that occurs, the greater the similarity between the DNA strands of the two species. **L2 L3**

#### Demonstration

Obtain and display a copy of a cytochrome-c family tree, which is a phylogenetic tree based solely on mutations in the protein cytochrome-c. (Alternatively, you might want to ask students to research and locate a cytochrome-c tree.) Explain that cytochrome-c, a protein that plays a role in cellular respiration, was chosen for study because it is present in most organisms. Point out how closely the phylogenetic tree based on this single important protein resembles traditional phylogenetic trees based on other kinds of evidence. **L2**



▲ **Figure 18-8** 🌍 **Similarities at the DNA level in the genes of organisms can be used to help determine classification.** Traditionally, African vultures (top) and American vultures (center) were classified together in the falcon family. But DNA analysis has revealed that American vultures are actually more closely related to storks (bottom).

### Similarities in DNA and RNA

All of the classification methods discussed so far are based primarily on physical similarities and differences. But even organisms with very different anatomies have common traits. For example, all organisms use DNA and RNA to pass on information and to control growth and development. Hidden in the genetic code of all organisms are remarkably similar genes. Because DNA and RNA are so similar across all forms of life, these molecules provide an excellent way of comparing organisms at their most basic level—their genes.

🌍 **The genes of many organisms show important similarities at the molecular level. Similarities in DNA can be used to help determine classification and evolutionary relationships.** Now that scientists can sequence, or “read,” the information coded in DNA, they can compare the DNA of different organisms to trace the history of genes over millions of years.

**Similar Genes** Even the genes of diverse organisms such as humans and yeasts show many surprising similarities. For example, humans have a gene that codes for myosin, a protein found in our muscles. Researchers have found a gene in yeast that codes for a myosin protein. As it turns out, myosin in yeast helps enable internal cell parts to move. Myosin is just one example of similarities at the molecular level—an indicator that humans and yeasts share a common ancestry.

**DNA Evidence** DNA evidence can also help show the evolutionary relationships of species and how species have changed. The more similar the DNA sequences of two species, the more recently they shared a common ancestor, and the more closely they are related in evolutionary terms. And the more two species have diverged from each other, or changed in comparison to each other during evolution, the less similar their DNA will be.

Consider the birds in **Figure 18-8**. The bird in the top photograph looks a lot like the bird in the middle photograph. Both birds have traditionally been classified together as “vultures.” One group of birds inhabits Africa and Asia, and the other, the Americas. But American vultures have a peculiar behavior: When they get overheated, they urinate on their legs, and evaporative cooling removes some body heat. The only other birds known to behave this way are storks, which look quite different and have always been put in a separate family. Does this similarity in behavior indicate a close evolutionary relationship?

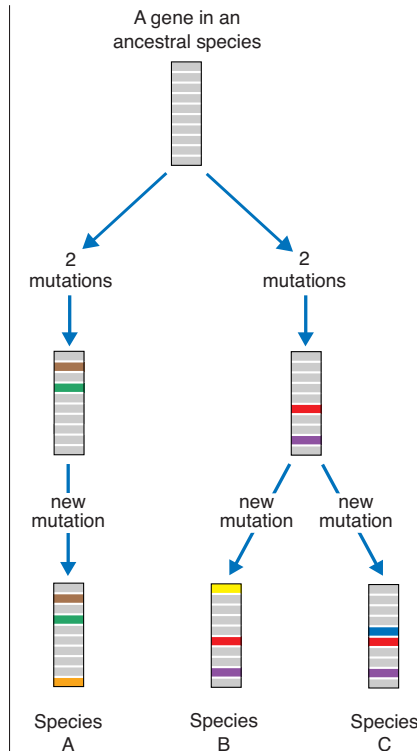
Scientists analyzed the DNA of these three birds. The analysis showed that the DNA sequences of the American vulture and the stork were more similar than those of the American vulture and the African vulture. This similarity in DNA sequences indicates that the American vulture and the stork share a more recent common ancestor than do the American vulture and the African vulture. Therefore, the American vulture is more closely related to storks than to other vultures.

## Molecular Clocks

Comparisons of DNA can also be used to mark the passage of evolutionary time. A model known as a **molecular clock** uses DNA comparisons to estimate the length of time that two species have been evolving independently. To understand molecular clocks, think about a pendulum clock. It marks time with a periodically swinging pendulum. A molecular clock also relies on a repeating process to mark time—mutation.

Simple mutations occur all the time, causing slight changes in the structure of DNA, as shown in **Figure 18–9**. Some mutations have a major positive or negative effect on an organism’s phenotype. These mutations are under powerful pressure from natural selection. Other mutations have no effects on phenotype. These neutral mutations accumulate in the DNA of different species at about the same rate. A comparison of such DNA sequences in two species can reveal how dissimilar the genes are. The degree of dissimilarity is, in turn, an indication of how long ago the two species shared a common ancestor.

The use of molecular clocks is not simple, however, because there is not just one molecular clock in a genome. Instead, there are many, each of which “ticks” at a different rate. This is because some genes accumulate mutations faster than others. These different clocks allow researchers to time different kinds of evolutionary events. Think of a conventional clock. If you want to time a brief event, you pay attention to the second hand. To time an event that lasts longer, you use the minute hand or the hour hand. In the same way, researchers would use a different molecular clock to compare modern bird species than they would to estimate the age of the common ancestor of yeasts and humans.



**▲ Figure 18–9** By comparing the DNA sequences of two or more species, biologists estimate how long the species have been separated. **Analyzing Data** What evidence indicates that species C is more closely related to species B than to species A?

## Molecular Clocks

### Use Visuals

**Figure 18–9** Have students examine the figure. Then, ask: **Why do biologists study mutations in genes that do not code for essential proteins?** (Those mutations occur in different species at about the same rate, and they can be used as a basis for comparison.) **L1 L2**

### 3 ASSESS

#### Evaluate Understanding

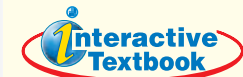
Have students make a Venn diagram to show similarities and differences between traditional classification diagrams and cladograms.

#### Reteach

Call on students to explain in their own words what molecular clocks are, how they are used, and why some molecular clocks “tick” at different rates. Correct any errors or misunderstandings.

#### Thinking Visually

Students should draw a cladogram based on several derived characteristics of a type of manufactured item. Instead of the automobile, they might choose the television, video game, or camera. Their diagrams should show the order in which innovations were developed in the item they chose. For example, a cladogram for the television might show that this item first acquired colored pictures, then solid-state circuitry, and then remote controls.



If your class subscribes to the iText, use it to review the Key Concepts in Section 18–2.

## 18–2 Section Assessment

- Key Concept** How is information about evolutionary, or phylogenetic, relationships useful in classification?
- Key Concept** How are genes used to help scientists classify organisms?
- What is the principle behind cladistic analysis?
- What gene indicates that yeasts and humans share a common ancestor?
- Describe the relationship between evolutionary time and the similarity of genes in two species.
- Critical Thinking Inferring** Would a barnacle’s DNA be more similar to the DNA of a crab or that of a limpet? Explain.

### Thinking Visually

#### Constructing a Chart

Draw a cladogram of a manufactured item, such as an automobile or a household item, that has changed over the years. Label derived characters that appeared as new models arose. For example, automobiles came to have electronic fuel injection and antilock brakes.

## 18–2 Section Assessment

- Organisms are placed in various taxonomic groups based on evolutionary descent.
- Scientists compare the DNA of different organisms to establish similarities between them and reconstruct possible evolutionary relationships.
- Cladistic analysis traces the process of evolution in a group of organisms by focusing on unique features that appear in some organisms but not in others.
- A gene that codes for the protein myosin
- The longer it has been since two species descended from a common ancestor, the more different their genes are likely to be.
- It would be more similar to the DNA of a crab, because barnacles and crabs have a closer evolutionary relationship.

### Answer to . . .

**Figure 18–9** The DNA molecules in species B and C show two common mutations that do not appear in the DNA in species A.

After students have read this feature, you might want to discuss one or more of the following:

- The reasons that newly discovered species are likely to live in remote, hard-to-reach places
- Why tropical forests have so many different species compared with other types of ecosystems
- How advances in technology, such as portable computers, wireless communication devices, and the Internet, have made research in remote locations easier and more efficient
- The ways that technological advances, such as electron microscopy and DNA analysis, are used to determine whether a particular organism represents a newly discovered species

## Research and Decide

Students should describe and sketch ideas for inventions that would help them search for new species high up in the tree canopy of a forest or in some other hard-to-reach place, such as a sheer rock wall, a deep cave, or the ocean floor. For example, students might describe and sketch a system of harnesses and platforms, similar to those used by window washers, to search for new species on sheer rock walls, or they might describe a pressurized compartment, like a bathysphere, to search for new species on the ocean floor.

### Go Online

[PHSchool.com](http://PHSchool.com)

Students can research the search for new species on the site developed by authors Ken Miller and Joe Levine.

## The Search for New Species in Tropical Forests

So far, scientists have identified about 1.5 million species. Yet, millions more have never been discovered. Researchers continue to find new species—not just tiny organisms, but also fish, birds, and mammals. Because new species are likely to live in hard-to-reach places, scientists call on technology to help in the search, including scuba gear, helicopters, and ultralight airplanes. Remote cameras and e-mail let scientists follow the work of others continents away.

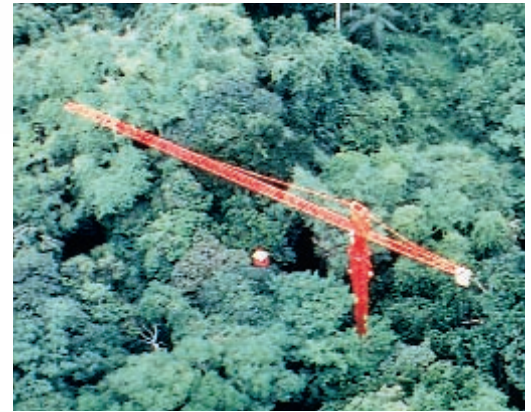
### Exploring the Forest Canopy

One place to search for new species is in tropical forests, which are teeming with life. Researchers especially want better ways to study the canopy—the upper layers of the forest. Scientists have used ropes to climb the tall trees, but it is hard to stay up long or collect specimens. Then, French researchers invented an unusual “raft” suspended from a hot-air balloon that floats over the tops of the trees. Scientists on the raft could work together for longer periods of time, collecting many more species.

One canopy explorer, biologist Margaret Lowman, worked with a structural engineer to design and build a canopy walkway as her “green laboratory.” The walkway looks like a huge tree-



house 75 feet above the forest floor, with platforms on which researchers can work. Another new and dramatic route into the canopy is a huge construction crane like those used in building skyscrapers. Scientists on the arm of the crane get a close-up look at trees. Today there is a worldwide network of forest sites.



### New Species or Not?

When researchers spot an unfamiliar organism, they may use simple observation to classify it. How many petals are on the flower? How many toes are on the animal? If the organism does not match known categories, the species may be new. Unusual antlers, for instance, were a major clue in identifying a new deer species in Vietnam.

External appearances can fool you, however. X-rays and electron microscopes may reveal differences that set one species apart from another. The most exciting advances have come with studies of DNA. By analyzing DNA, scientists can demonstrate how two organisms are—or are not—related.

### Research and Decide

Use library or Internet resources to learn more about the search for new species. Then, describe and sketch your own ideas for an invention that would help scientists search in a forest canopy or other location that is hard to reach.

### Go Online

[PHSchool.com](http://PHSchool.com)

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