CHAPTER 15

Classification Systems





The lemur is a primate that lives only on Madagascar, an island off the coast of Africa. The iguana, a reptile, lives on one of the Galapagos Islands off the coast of South America. Both of these animals—so different in appearance—are part of the great diversity of life on planet Earth.

From the numerous observations you make in your daily life, you are probably aware that a great many different kinds of organisms share planet Earth. In the last two chapters of this textbook, you glimpsed but a small part of this great diversity of life. The next twenty chapters will provide you with a broad overview of the many kinds of life that share your planet. But these chapters will touch on only a small fraction of Earth's species. Only a small fraction in twenty chapters might make you wonder how many species there are all together and how scientists can possibly keep them organized. The explanation of just how scientists do this is what this chapter is all about.

CHAPTER OUTLINE

15–1 Why Classify?

15–2 Biological Classification
- The Naming System of Carolus Linnaeus
- The Classification System of Linnaeus

15–3 Taxonomy Today
- Taxonomy and Evolutionary Relationships
- Biochemical Taxonomy

15–4 The Five-Kingdom System
- Monera
- Protista
- Fungi
- Plantae
- Animalia

15–1 Why Classify?

Section Objectives

- Discuss the usefulness of classification systems.
- List the characteristics of a good biological classification system.

Scientists have identified more than 2 1/2 million species of organisms on Earth so far, and their job is not even close to completion! Some biologists estimate that there may be another million species living in tropical rain forests and an unspecified number living in the depths of Earth's as yet unexplored waters.

No one, not even the world's greatest experts, can think about 2 1/2 million species at one time. The only way we can possibly study and understand this great diversity of living organisms is to divide them up into small, manageable groups. But what kinds of groups should we divide Earth's life into? **To help us work with the diversity of life we need a system of biological classification that names and orders living organisms in a logical manner.**

All accepted biological classification systems have two important characteristics. First, they assign a single universally accepted name to each organism. In this way, an American scientist, for example, can write to colleagues in Egypt, India, or Peru and be certain that everyone knows exactly what organism is being discussed. Second, good biological classification systems place organisms into groups that have real biological



Figure 15–1 *There are so many different species of organisms in the tropical rain forests that these areas have been called the "nurseries of the globe." Because many rain forest organisms have never been collected, studied, and classified, scientists view with alarm the destruction of these areas.*







Figure 15–2 *These three organisms are worms. Although they share certain characteristics, they differ from one another in major ways. Classifying and naming these organisms permit scientists all over the world to know which particular worm is being discussed in any type of scientific communication.*

meaning. Thus researchers can expect members of a group to share important characteristics. Any useful classification system requires a set of universally accepted rules for grouping organisms.

15–1 SECTION REVIEW

1. Why are classification systems useful?
2. What are two characteristics of a good classification system?
3. What advantage is there for two scientists on opposite sides of the world to use a single name for a particular organism?
4. Give an example of a system you use to classify objects or people around you.

Section Objectives

- Describe the importance of the classification system developed by Carolus Linnaeus.
- Identify the different taxa that make up the classification system developed by Linnaeus.

15–2 Biological Classification

By the eighteenth century, European scientists, responding to the need for a universally recognized naming system, no longer used common names in local languages to describe organisms. Instead, they used names based on Latin or ancient Greek words because these languages were understood by scientists everywhere.

These early scientific names described the physical characteristics of a species in great detail and were often twenty words long! For example, the English translation of the name of a particular tree might have been "Oak with deeply divided leaves that have no hairs on their undersides and no teeth around their edges."

This cumbersome system of naming organisms had another major drawback. It was difficult to standardize names of organisms because different scientists sometimes chose to describe different characteristics of the same species. Thus the same organism might have had different names.

The Naming System of Carolus Linnaeus

Some order was made out of all this confusion by the work of Carolus Linnaeus. Linnaeus, a Swedish botanist, developed a system for naming plants and animals that is still in use today. This system is known as **binomial nomenclature** (bigh-NOH-mee-uhl NOH-muhn-klay-cher).

In his system of binomial nomenclature, Linnaeus gave each organism a two-part scientific name. For example, the tree we call the red maple is called *Acer rubrum.* The first part of the name, *Acer,* is the genus name (JEE-nuhs; plural: genera, JEHN-er-uh). A genus name refers to the relatively small group of organisms to which a particular type of organism belongs. All maple trees carry the genus name *Acer,* the Latin word for maple. The second part of the name, *rubrum,* is the species name. The species name is usually a Latin description of some important characteristic of the organism. Red maples are called *Acer rubrum* because *rubrum* is the Latin word for red. Another kind of maple, which has no English common name, has a leaf that resembles a human hand. That maple is called *Acer palmatum. Palmatum* comes from the Latin word for hand.

Notice that when we use the Latin name for an organism, we always capitalize the genus name but not the species name. We also print the entire name in italics. This rule helps us recognize scientific names as we read.

Today this system of two Latin names is used by scientists everywhere. Even in a scientific book written in Chinese, you will see the names of any organisms described in the text given in this form. An international committee makes certain that once a scientific name has been chosen, it is used consistently. That committee, as well as other scientists, also makes sure that there is a carefully selected specimen of each species on file for reference. By maintaining a library of organisms in zoology and botany museums, scientists can compare the specimen they are examining with a named preserved specimen. If the specimens match, the scientist knows that the species being examined has already been described and named. If the specimen does not match anything on file, the scientist may have found a new species—in which case he or she has the privilege of naming it.

The Classification System of Linnaeus

After naming organisms, Linnaeus grouped them together according to the body structures they shared. He did this by examining the structural characteristics of organisms and deciding which structures were the most important for classifying the organisms. Organisms that shared important characteristics were classified in the same group. The groups to which Linnaeus assigned organisms are called taxa (singular: taxon), and the science of naming organisms and assigning them to these groups is called **taxonomy.**



Figure 15–3 *Using a classification system based on physical descriptions would have mistakenly suggested that these three oak leaves—the red oak (top and bottom) and the white oak (center)— represented three species.*

Figure 15–4 *This herbarium sheet will become part of a major botanical garden's collection. The collection is used by scientists to compare unfamiliar plants with known plants in order to identify them.*





Figure 15–5 *This illustration shows the classification groups that contain a grizzly bear. As you can see, the species name of this bear provides a pretty accurate description of its personality.*

The smallest **taxon** is the **species**, which we have previously defined as a population of organisms that share similar characteristics and that can breed with one another. If two species share many features but are clearly separate biological units, they are classified as different species within the same **genus**. Genus is the next largest taxon within the Linnaean system of classification. All the various species included in the same genus have many common characteristics. The common house cat, for example, is named *Felis domesticus*. The genus *Felis* to which the house cat belongs contains other species, such as the familiar mountain lion, *Felis concolor*. All members of the genus *Felis* share many characteristics. For example, they all have similar teeth, feet, and claws.

There are other catlike animals, however, that differ enough from those in genus *Felis* that they are placed in different genera. Lions *(Panthera leo)* and tigers *(Panthera tigris)* belong to the genus *Panthera*. And cheetahs *(Acinonyx jubatus)*, although similar to lions and tigers, belong to a different genus —the genus *Acinonyx*. Groups of genera such as these, which share many common characteristics, are gathered into larger units called **families**. A family is a larger taxon than a genus. All genera of catlike animals belong in the family Felidae.

Several families of similar organisms make up the next largest taxon—an **order**. Cats (family Felidae) are placed in the same order as dogs (family Canidae). The order to which these two families, as well as several others, belong is called Carnivora. All members of the order Carnivora are carnivores, or meat-eaters.

Orders are grouped into **classes**. All members of the order Carnivora are warmblooded, have body hair, and produce milk for their young. For these reasons, they are placed together with humans (order Primates) and other similar animals in the class Mammalia.

In turn, several classes are placed in a **phylum** (FIGH-luhm), which includes a large number of very different organisms. These organisms, nevertheless, share some important basic characteristics. For example, mammals are placed in the phylum Chordata along with birds, fishes, and reptiles because all of them share certain similar characteristics.

In the classification system that was designed by Linnaeus, all phyla belonged in one of two giant taxa called **kingdoms**. Animals formed the kingdom Animalia, and plants formed the kingdom Plantae. The system developed by Linnaeus looks like this:

Kingdom
Phylum
Class
Order
Family
Genus
Species

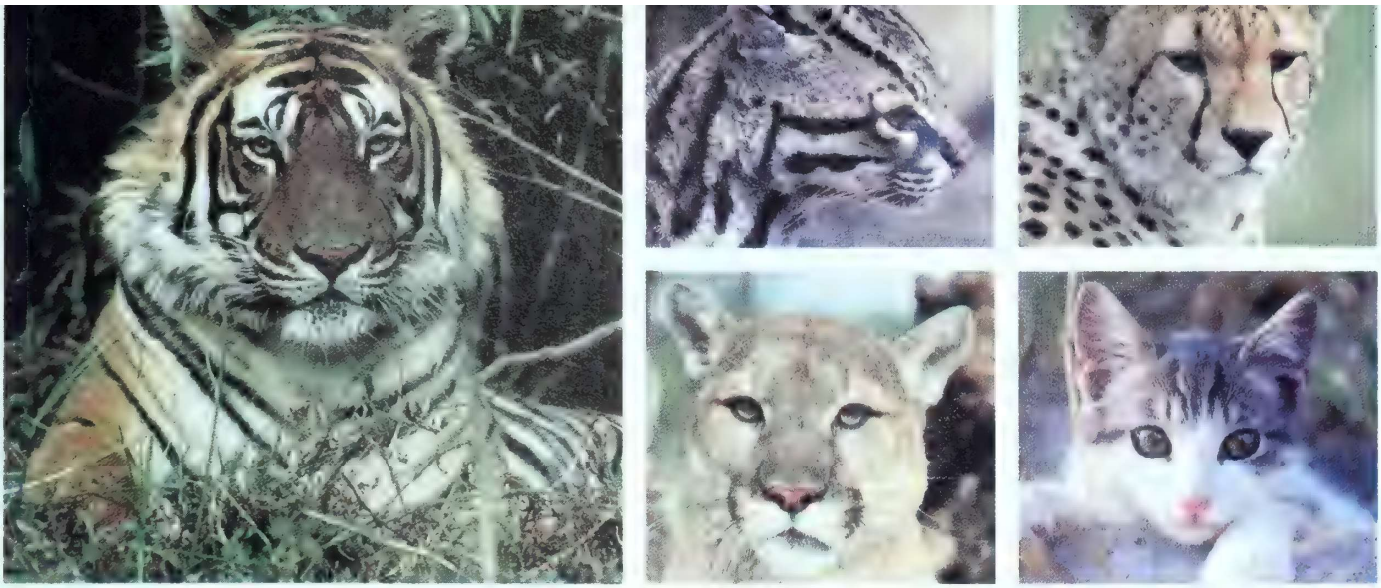


Figure 15–6 *These animals are all cats—some cute and cuddly, others not. Scientists group cats that roar in the genus* Panthera *and cats that purr in the genus* Felis. *The cheetah is a special case, however. It belongs to the separate genus* Acinonyx, *because unlike other cats, it cannot retract its claws.*

15-2 SECTION REVIEW

1. Why is the system of binomial nomenclature a good way to name organisms?
2. What is the smallest taxon? What is the largest taxon? Which of these taxons is the most specific?
3. Two groups of organisms are in different genera but they are included in the same family. What does this information tell you about the two groups?

15–3 Taxonomy Today

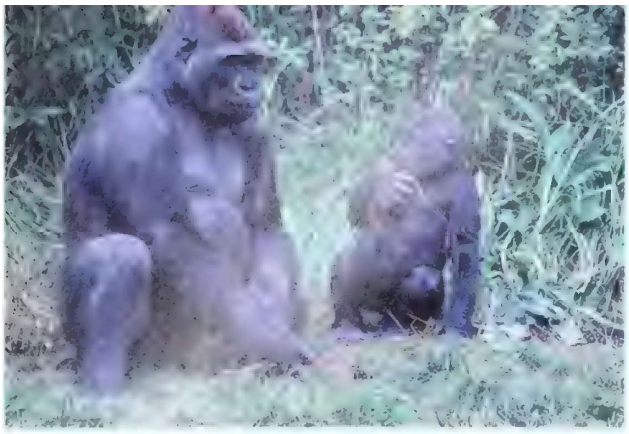
Section Objectives

- Discuss how taxa show evolutionary relationships between different organisms.
- Explain how modern scientific techniques contribute to the classification of organisms.

Taxonomy, particularly the grouping of organisms into higher taxa, is not as simple as it might seem. Ideas about the arrangement of organisms into families, orders, phyla, and kingdoms have changed dramatically since the time of Linnaeus. How and why has taxonomy changed so much?

Remember that despite the importance of taxonomy to biologists, the only taxon that has a clear biological identity is the species. Members of a species share a common gene pool because they breed with one another. So members of a species form a very real biological unit. We might even say that organisms themselves determine which individuals belong to their species and which do not.

The taxa above the level of species, however, do not have a clear biological identity. This is because taxonomists, or scientists who classify organisms, draw the lines between one genus and another and between one family and another. Of course, taxonomists try to create taxa that group organisms according to biologically important characteristics. But different scientists have different ideas about which characteristics are biologically most important. As a result, organisms have sometimes been "moved" from one taxon to another.



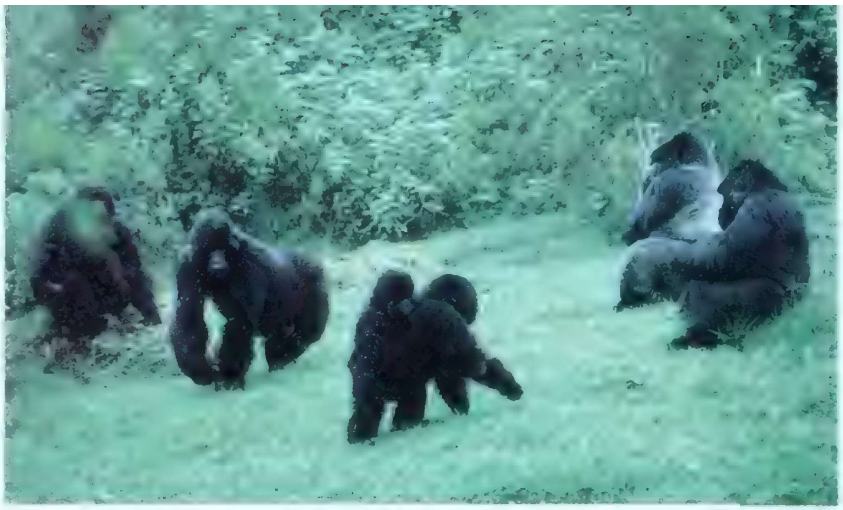


Figure 15–7 *The mountain gorilla (right) and the lowland gorilla (left) belong to different species. As their names indicate, they live in different areas. Although they are both gorillas, they represent two species because they do not breed with each other. They do not share a common gene pool.*

Taxonomy and Evolutionary Relationships

Today, evolutionary theory teaches that living species have evolved from earlier species. This unifying biological principle thus provides both a purpose and a guiding philosophy to modern classification systems. For this reason, taxonomists attempt to group organisms in ways that show their evolutionary relationships. Taxonomists do this by identifying and studying homologous structures in adult organisms, in developing embryos, and in well-preserved fossils. **Species shown to be closely related are classified together. Other species that may look alike but possess analogous structures only are classified in different groups.**

Deciding which structures are most important is not always easy though, and researchers often disagree on how to classify certain organisms. In writing this textbook, we have adopted one of the classification systems most widely accepted among biologists.

Figure 15–8 *Long thought to be extinct, the coelacanth was discovered in the Chalumna River in Africa. This photograph is one of the few taken of a living coelacanth. Coelacanths are believed to be relatives of the early fish that developed into four-legged land mammals.*



Biochemical Taxonomy

All organisms share many important organic molecules that are almost—but not exactly—identical from species to species. For example, mammals, birds, amphibians, reptiles, and fishes have hemoglobin in their blood, but each species has a slightly different variety of hemoglobin. All green plants have chlorophyll molecules, which are used in the process of photosynthesis. But some groups of green plants have chlorophyll molecules that differ in structure from other groups.

Biochemists can use similarities and differences among the compounds of life to classify organisms—just as anatomists use similarities and differences between homologous structures. The more similar the proteins of two species are, the more closely related these species are likely to be. Biochemists also study molecules of DNA and RNA, which vary in number, appearance, and amino acid sequence among different organisms.

Virtually every organism has its own form of cytochrome *c*, a complicated protein molecule found in the electron transport chain. Figure 15–9 illustrates differences among cytochrome *c*

of various organisms. These differences are the result of mutations that occurred after the ancestors of the various species split apart. If two species diverged millions of years ago, there has been lots of time for mutations to alter the structure of cytochrome *c* molecules in each species. Note, for example, the large difference between human cytochrome *c* and cytochrome *c* of *Neurospora*, a bread mold. This tells us that these two species are not closely related at all. The similarity between cytochrome *c* of chickens and that of penguins, on the other hand, shows that these two species are closely related.

The study of DNA sequences in mammals has yielded some surprising results. For example, scientists have found that humans and chimpanzees have DNA that differ in fewer than 1 percent of their nucleotide sequences.

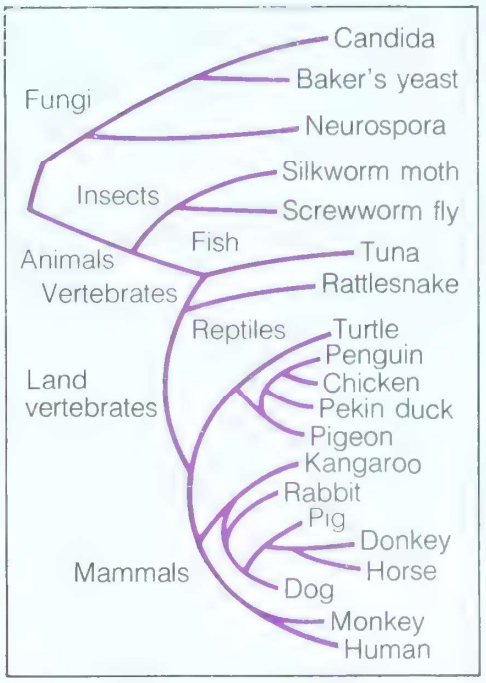


Figure 15–9 *Cytochrome c can be used to show relationships between organisms. Organisms on branches near one another are more closely related.*

15-3 SECTION REVIEW

1. Which taxon has a clear biological identity? Explain your answer.
2. Why did evolutionary theory prove important in taxonomy?
3. How can a study of biochemistry help taxonomists?

15–4 The Five-Kingdom System

Section Objectives

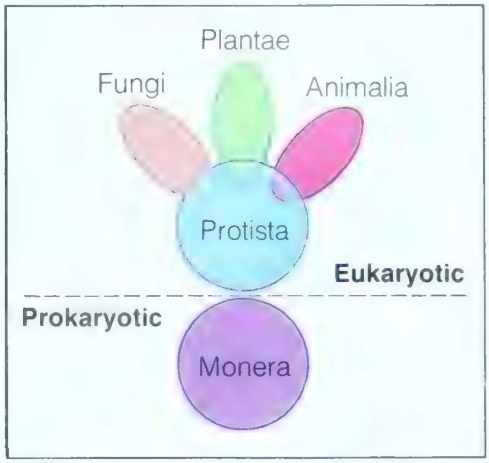
- Explain why the five-kingdom system more accurately represents evolutionary trends.
- Discuss characteristics of organisms placed in each of the five kingdoms.

Linnaeus created his taxa in the eighteenth century, basing his system on the knowledge available at that time. As biologists gathered more and more information over the years, it became clear that Linnaeus's two kingdoms were not sufficient to logically include all organisms.

For example, microorganisms, which were discovered only after the development of microscopes, look and act significantly different from plants and animals. Some of these microorganisms lack nuclei, mitochondria, and chloroplasts. As you may remember, organisms that lack a nucleus are known as prokaryotes. Scientists now consider these prokaryotes to be fundamentally different from other living things, so they have placed them in a separate kingdom: Monera. Most scientists also feel that many single-celled eukaryotes are different enough from multicelled eukaryotes that they belong in yet another kingdom: Protista. Finally, molds and yeasts, once included in the plant kingdom, are now considered different enough from green plants to be in their own kingdom: Fungi.

As a result of discoveries of new life forms and changing ideas about those characteristics of greatest importance in classifying organisms, the most generally accepted classification system now contains five kingdoms. **The five kingdoms are Monera, Protista, Fungi, Plantae, and Animalia.**

Figure 15–10 *These five kingdoms have been used as a basis for classification in this textbook.*



So Little Time, So Many Names

Will we have time to identify and classify all of the organisms with whom we share this planet? Probably not. For even with the modern methods used to classify organisms, time is running out. Throughout the world, species are becoming extinct. It has been estimated that 15 to 20 percent of the species on Earth will become extinct in the next 30 to 40 years. In one part of the world—the tropical rain forests—the rate of extinction has become critical. Scientists are concerned that organisms there are being destroyed faster than they can be classified. Tropical rain forests are home to more species than all other parts of the world combined. But only about 15 percent of these species have been identified.

Increasing economic pressures are threatening huge areas of tropical rain forests, and with these areas the future of life on Earth. In many parts of the world tropical rain forests are being destroyed so that farm crops can be grown and farm animals can be raised. Areas of tropical rain forests are usually cleared by burning the vegetation to the ground. Many other species—such as insects, birds, and small mammals—are destroyed as the flames level the plant life. If the rate of destruction of tropical rain forests continues, many species of organisms will become extinct before their value can be calculated and appreciated.

There is one especially sad footnote to the destruction of tropical rain forests. The soil there is very poor and can support farming for only a few years. When the soil, depleted of nutrients, can no longer support the growth of farm crops, it is abandoned. New areas must then be burned. Thus more and more land, and the life on it, is destroyed for very limited benefits.

The destruction of rain forests is a serious issue. Biologists argue that we must do everything possible to save the organisms that live in these rain forests, many of which exist nowhere else on Earth. But people who live in these areas argue that they cannot preserve the rain forest without sacrificing their own survival. As in most issues, both sides have a valid point.



In many areas, a shortage of space to grow crops forces people to cut down and burn rain forests. The soil in these areas contains few nutrients, and so more areas must be cut down and burned to continue the production of food crops.

You should keep in mind that not all scientists agree on this grouping. More research may someday show that other classification systems make more sense. But right now most scientists view this five-kingdom classification system as a useful tool for studying organisms, which is what taxonomy is all about. In order to understand why the five kingdoms are arranged as they are, it helps to think of them as representing a simple evolutionary tree. Following are brief descriptions of the five classification kingdoms.

Monera

All prokaryotes are placed in the kingdom **Monera.** You will learn in the next chapter about the strong biochemical and fossil evidence that indicates that prokaryotes were the earliest life forms on Earth. Like prokaryotes alive today, the ancient prokaryotes lacked nuclei, mitochondria, and chloroplasts, and reproduced by splitting apart in a process called binary fission.

Monerans are therefore placed at the base of our evolutionary tree. This does not mean that other organisms evolved from living prokaryotes. Rather, it means that other organisms probably evolved from extinct organisms that were very similar to modern prokaryotes.



Figure 15–11 *These rod-shaped bacteria, photographed on the head of a pin, are placed in the kingdom Monera. The bacteria have been magnified more than 4000 times to make them visible.*

Protista

Unlike prokaryotes (Monerans), all eukaryotes possess membrane-enclosed organelles. All eukaryotes have a nucleus and mitochondria; some eukaryotes have chloroplasts. In the five-kingdom classification system, all single-celled eukaryotic organisms are placed in the kingdom **Protista**.

The kingdom Protista is further divided into three groups: animallike protists, plantlike protists, and funguslike protists. Ancestors of animallike protists may have evolved into animals. Ancestors of plantlike protists may have evolved into land plants. And ancestors of funguslike protists may have evolved into the living fungi.

Recall, however, that taxonomic groups are set up by biologists, not by the organisms that make up the groups. In the next several chapters you will see that the division between the protists and the three multicellular kingdoms is not clear-cut at all. Many species straddle the line between single-celled and multicellular plants, animals, and fungi. These organisms are important examples of in-between steps in evolution that link the modern groups of organisms together.

Figure 15–12 *The fragile appearance of this paramecium belies its strong constitution. Parameciums, which are placed in the kingdom Protista, are widely distributed in many bodies of water throughout the world. Can you see why the paramecium is called the "slipper organism"? Its shape looks much like the impression made by a slipper on wet sand.*



Fungi

Members of the kingdom **Fungi** build cell walls that do not contain cellulose. Fungi are heterotrophic. Heterotrophs do not carry on photosynthesis. And although fungi have many nuclei,





Figure 15–13 *The fly agaric (left), a beautiful and colorful member of the kingdom Fungi, is poisonous. The small maple tree in the foreground and the moss plants growing on the tree (right) are both members of the kingdom Plantae.*

they do not always have separate cells divided by complete cell walls. For these reasons, the fungi are not included with the plants and are placed in their own kingdom.

Plantae

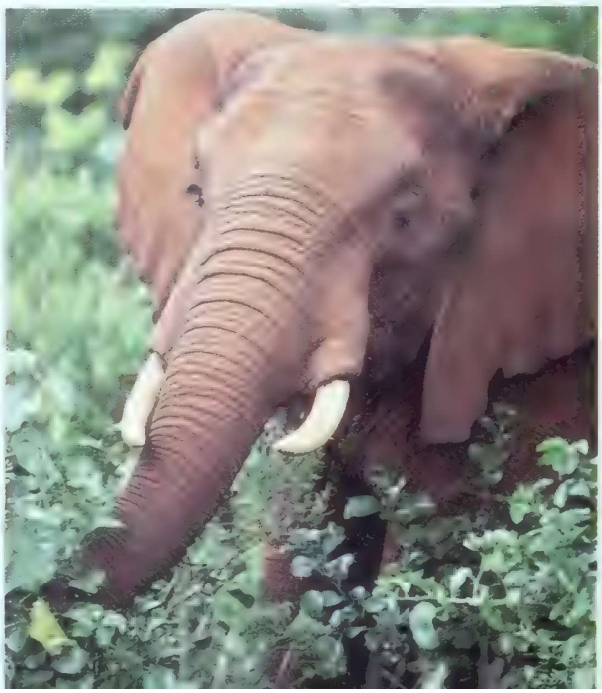
Members of the kingdom **Plantae** are multicellular, have cell walls that contain cellulose, and are autotrophic. Autotrophic plants are able to carry on photosynthesis using chlorophyll. The plant kingdom includes all the plants you have come to know by now, such as the flowering plants, mosses, and ferns. In our classification system, the plant kingdom also includes multicellular algae.

Animalia

Members of the kingdom **Animalia** are multicellular, heterotrophic, and have cell membranes without cell walls. As you will see in later chapters, there is incredible diversity within the animal kingdom.

Figure 15–14 *Both of these organisms are placed in the kingdom Animalia. The orange sponge (left) grows attached to the ocean bottom, unable to move from place to place. Unlike the sponge, the huge elephant (right) is able to move about.*





PROBLEMS IN BIOLOGY

CLASSIFYING COMMON OBJECTS

Imagine that you are setting up a hardware store and have just received an assortment of items used to fasten things together. To help your customers find the items they need, you must devise a sensible way to group and arrange these objects on your shelves. In grouping the fasteners, you will proceed in much the same way that scientists do in classifying organisms.

In order to make sensible groupings, you should first examine the similarities among these objects as well as the differences. You must determine how these similarities and differences relate to the objects' functions. Finally, you must decide which functions are most important to your customers.

Even a quick glance reveals several possible ways to group your hardware. You may feel that the most important feature of these objects is the tool used to drive them. Some of the fasteners can be driven with a screwdriver; others with a hammer. The shape of the fasteners' head will indicate how they are driven. Thus you could group the fasteners by the shape of their head.

You may feel, however, that a more important feature of the fasteners is whether they are meant to be used to fasten wood or metal. Or perhaps what the fasteners are made of is the most important feature to you. Or whether they have threads.

Notice that there is no single correct way to classify these fasteners. Each classification scheme serves a different purpose for you and your customers.

With this in mind, choose one approach to begin this exercise and create a classification system for these objects. Your smallest taxon should contain only items that are very similar to one another. Your largest taxon might include all the objects used as fasteners. If partway through this exercise you feel your system is not the best one, save your work and begin developing another strategy. Compare your results with those of your classmates, noting similarities and differences in the various schemes.

What information about the objects and about the classification process have you learned from this exercise? Do you now understand why taxonomists often disagree about the classification of organisms? Do you now have a greater appreciation for why classification is useful?

15–4 SECTION REVIEW

1. Why did the five-kingdom system of classification become widely used?
2. Why are the fungi placed in a separate kingdom?
3. A single-celled organism could be placed in the Monera or the Protista kingdom. What factor would be the most significant for determining into which kingdom this organism should be placed?

LABORATORY INVESTIGATION

PREPARING A COLLECTION OF ORGANISMS

PROBLEM

How do you prepare a collection of organisms that represents each of the five kingdoms?

MATERIALS *(per group)*

- microscope
- medicine dropper
- glass slides
- coverslips
- forceps
- baby food jars with lids
- 70% ethanol
- petri dishes and covers
- nutrient agar
- bread
- sour milk, sauerkraut, or yogurt
- pond water
- small plastic food bags
- transparent tape
- labels
- mosses and other plants
- worms and insects

PROCEDURE

1. List characteristics of organisms in each of the five kingdoms of the classification system used in this textbook. You may refer to material already presented in this chapter. After you examine each organism in this investigation, decide which kingdom it belongs to. Be prepared to defend your decisions.
2. Use a medicine dropper to put a drop of liquid from sauerkraut, yogurt, or sour milk on a glass slide. Cover the drop with a coverslip. Examine your specimen under the high-power objective of the microscope. Draw what you observe. Label the drawing with the kingdom of the organism.
3. Use a medicine dropper to place a drop of pond water on a glass slide. Place a coverslip over the drop. Use the microscope to examine the pond water. Draw the organisms you observe. Label the drawing with the kingdom of the organism.
4. Moisten a piece of bread and place it in an open petri dish. Leave the dish on a windowsill for several days. After that time, use a forceps to remove some of the "fuzzy" material that has grown on the bread. Place this material on a glass slide. Add a drop of tap water and cover the drop with a coverslip. Examine this slide with the low-power objective. Draw what you observe. Remove another sample from the bread and place this sample in a jar. Fill the jar with ethanol. Cover the jar tightly and label it with the name of the kingdom to which the organism belongs.
5. Examine several small plants, leaves, or flowers. Put each sample in a separate baby food jar. Fill the jar with ethanol. Cover tightly. Label each jar and display.
6. Look for worms, grubs, and pill bugs in the soil. Find some insects on plants in areas near your home or school. Place each specimen in a baby food jar. Fill the jar with ethanol and cover tightly. Label each jar and display.

OBSERVATIONS

1. For organisms in which kingdoms did you require a microscope for observation?
2. What similarities and differences do you observe among organisms from different kingdoms?
3. For which kingdom was it easiest to find a variety of organisms? Most difficult?

ANALYSIS AND CONCLUSIONS

1. Why are photographs or drawings necessary for making a display of protists and monerans?
2. What difficulties did you encounter in classifying organisms?

STUDENT STUDY GUIDE

SUMMARIZING THE CONCEPTS

The key concepts in each section of this chapter are listed below to help you review the chapter content. Make sure you understand each concept and its relationship to other concepts and to the theme of this chapter.

15–1 Why Classify?

- A classification system allows us to name and order living organisms in a logical manner.
- A good classification system provides a universally accepted name to each organism.

15–2 Biological Classification

- Because they assigned a long, complicated series of names to an organism, early classification systems were very difficult to learn and cumbersome to use.
- Carolus Linnaeus gave each organism he classified a simple two-part scientific name.

15–3 Taxonomy Today

- Taxonomy is the science that names organisms and assigns the organisms to groups known as taxa.
- Taxa show evolutionary relationships among organisms.
- Today, biochemists use similarities and differences among chemical compounds to classify organisms. Molecules of DNA and RNA are often used to demonstrate evolutionary relationships among different kinds of organisms.

15–4 The Five-Kingdom System

- Because living things are so diverse and complex, Linnaeus's two-kingdom classification system is considered inadequate today in accurately representing relationships between all living things.
- A five-kingdom classification system has been developed and is widely used. This classification system shows relationships between different groups of organisms. This five-kingdom system more accurately groups organisms based on evolutionary trends.
- The Monera, Protista, Fungi, Plantae, and Animalia are five kingdoms that are used to group organisms.

REVIEWING KEY TERMS

Vocabulary terms are important to your understanding of biology. The key terms listed below are those you should be especially familiar with. Review these terms and their meanings. Then use each term in a complete sentence. If you are not sure of a term's meaning, return to the appropriate section and review its definition.

15–2 Biological Classification

binomial nomenclature
taxonomy
taxon
species
genus
family
order
class
phylum
kingdom

15–4 The Five-Kingdom System

Monera
Protista
Fungi
Plantae
Animalia

CHAPTER REVIEW

CONTENT REVIEW

Multiple Choice

Choose the letter of the answer that best completes each statement.

1. The largest taxon is a
   a. kingdom. c. family.
   b. species. d. phylum.
2. A good classification system does all of the following except
   a. show relationships.
   b. show evolutionary trends.
   c. create confusion.
   d. use one name for an organism.
3. The two-name system for classifying organisms was developed by
   a. Charles Darwin. c. a Swedish king.
   b. Thomas Edison. d. Carolus Linnaeus.
4. *Acer rubrum* and *Acer palmatum* are both names of different kinds of maple trees. What is the genus name for all maple trees?
   a. *Acer* d. Cannot be determined from the information given.
   b. *rubrum*
   c. *palmatum*
5. The science of naming organisms and placing them in groups is called
   a. biology. c. ornithology.
   b. taxonomy. d. ecology.
6. Each of the following is the name of a taxon except
   a. group. c. family.
   b. genus. d. kingdom.
7. The only taxon that has a clear biological identity is the
   a. kingdom. c. genus.
   b. phylum. d. species.
8. The kingdom that includes all prokaryotes is the
   a. Monera. c. Protista.
   b. Fungi. d. Plantae.

True or False

Determine whether each statement is true or false. If it is true, write "true." If it is false, change the underlined word or words to make the statement true.

1. All members of the kingdom Protista are prokaryotes.
2. Linnaeus developed the two-name system for naming organisms.
3. Fungi are photosynthetic, heterotrophic organisms.
4. All members of the plant kingdom are unicellular.
5. A good classification system uses standardized names.
6. *Acer rubrum* is the scientific name for the red maple. *Acer* is the species name for this organism.
7. The largest taxa is the species.
8. Several families of similar organisms make up an order.

Word Relationships

A. *In each of the following sets of terms, three of the terms are related. One term does not belong. Determine the characteristic common to three of the terms and then identify the term that does not belong.*

1. family, phylum, group, species
2. plants, animals, fungi, prokaryotes
3. biochemistry, cytochrome *c*, DNA and RNA, height
4. Monera, Protista, Fungi, Carnivora

B. *An analogy is a relationship between two pairs of words or phrases generally written in the following manner: a:b::c:d. The symbol : is read "is to," and the symbol :: is read "as." For example, cat:animal::rose:plant is read "cat is to animal as rose is to plant."*

In the analogies that follow, a word or phrase is missing. Complete each analogy by providing the missing word or phrase.

5. genus:species::family:_____
6. Darwin:evolution::Linnaeus:_____
7. orders:classes::phyla:_____
8. biochemistry:cytochrome *c*::homologous organ:_____

CONCEPT MASTERY

Use your understanding of the concepts developed in the chapter to answer each of the following in a brief paragraph.

1. Why were some of the early classification systems difficult to use?
2. What are three characteristics of a good classification system?
3. List the taxa in the classification system in current use from the smallest to the largest.
4. How does a workable classification system promote scientific understanding?
5. Suppose an organism had three common names in different parts of the United States. How might these names lead to confusion?

CRITICAL AND CREATIVE THINKING

Discuss each of the following in a brief paragraph.

1. **Making comparisons** In what ways was the classification system developed by Linnaeus an advantage over previous classification systems?
2. **Applying technology** How has the development of new technologies changed the ways we classify organisms?
3. **Applying concepts** Suppose you discovered a new single-celled organism. This organism had a nucleus, mitochondria, and a giant chloroplast. In what kingdom would you place this organism? What are your reasons?
4. **Making inferences** It has been said that organisms decide which individuals belong to their species and which do not. What does this statement mean?
5. **Assessing concepts** Libraries use the Dewey Decimal System to group books by similarities. How do the major groupings in this system help you locate research materials more quickly?
6. **Using the writing process** It has been estimated that there are more unknown organisms in the tropical rain forests than there are known organisms in the world. Scientists are concerned that these rain forests might be destroyed before the organisms in them can be classified. Write an editorial for a television news program protesting the destruction of rain forests. Offer reasons why rain forests should be protected.