CHAPTER PREVIEW

Main Ideas

In this chapter, you will learn about the need for a biological classification system. You will get an overview of Linnaeus's system for naming and classifying organisms, and you will explore the connection between evolutionary theory and taxonomy. You will also study the characteristics that make up the six-kingdom system of classification.

Reading Strategy

Outlining Information As you read this chapter, outline the classification system of Linnaeus, from the largest group (kingdom) to the smallest group (species). Then make an outline of the characteristics of each of the six kingdoms. Compare the two outlines.

Journal Activity

Biology and Your World Look around your home, school, or neighborhood. Are there any examples of a classification system in use? If so, write the examples in your journal. If there are no examples, can you suggest some?

15–1 Why Classify?

Guide For Reading

- Why are classification systems useful?
- What are some characteristics of a good classification system?

Scientists have identified more than 2.5 million kinds of organisms. Given that feat, you may be surprised to learn that this catalog of life isn't even close to being complete! Some biologists estimate that there may be another 20 million or so unknown species still out there. These species include insects living in tropical rain forests, odd creatures living in the unexplored depths of the sea, and microorganisms living all around us.

No one can think about that many organisms at once, and certainly no one can keep track of them by their names alone. The only way to study this great diversity of organisms is to divide living things into manageable groups. But what kinds of groups? **To work with the diversity of life, we need a system of biological classification that names and orders organisms in a logical manner.**

Biological classification systems have two important features. First, they assign a universally accepted name to each organism. In this way, an American scientist, for example, can talk to colleagues in Germany or India and be sure that everyone is discussing the same organism. Second, biological classification systems place organisms into groups that have real biological meaning. When we mentioned insects a moment ago, we gave you a rough idea about the type of animals we were discussing. When biologists place organisms into useful groups such as insects (or fishes, etc.), they can expect members of each group to

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

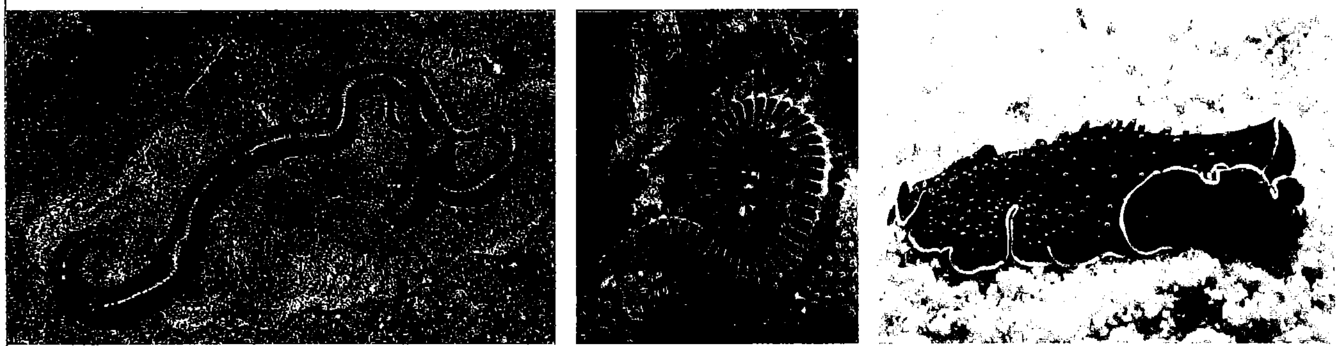


Figure 15–2 *These three organisms are all commonly referred to as worms because they share certain basic features. Yet one of the three animals differs from the others in several important ways. For this reason, the worms in the photographs at the left and center are classified together in one very large group whereas the worm in the photograph at the right is placed in another group.*

share important traits. Of course to be really useful, scientific groupings must be more precise than just "insects" (or "fishes"). The trick is to create a useful classification system based on a universally accepted set of rules for organizing the groups.

15–1 SECTION REVIEW

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

Guide For Reading

- Why was the classification system developed by Carolus Linnaeus important?
- What taxa made up the classification system developed by Linnaeus?

Quick Lab

To reinforce the **Main Idea** of classification systems, perform the Quick Lab activity called Creating a Classification System on p. 1089.

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.

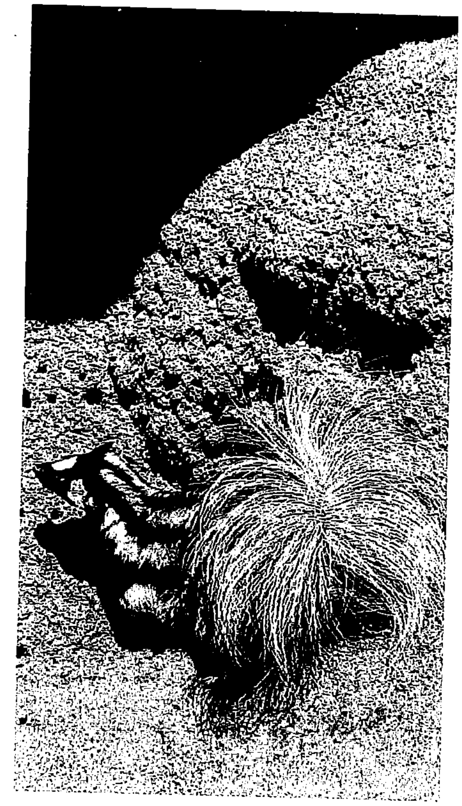
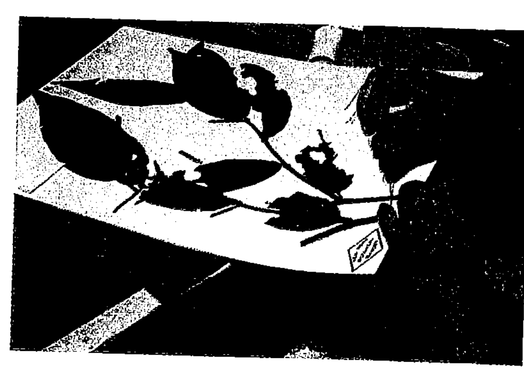


Figure 15–3 *The scientific name of an organism consists of two parts—the genus name and the species name. As is the case of the spotted skunk in the photograph, these names are often quite descriptive.* Spilogale putorius, *its scientific name, means smelly, spotted weasel—a fairly accurate description, indeed!*

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 15–4 *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.*



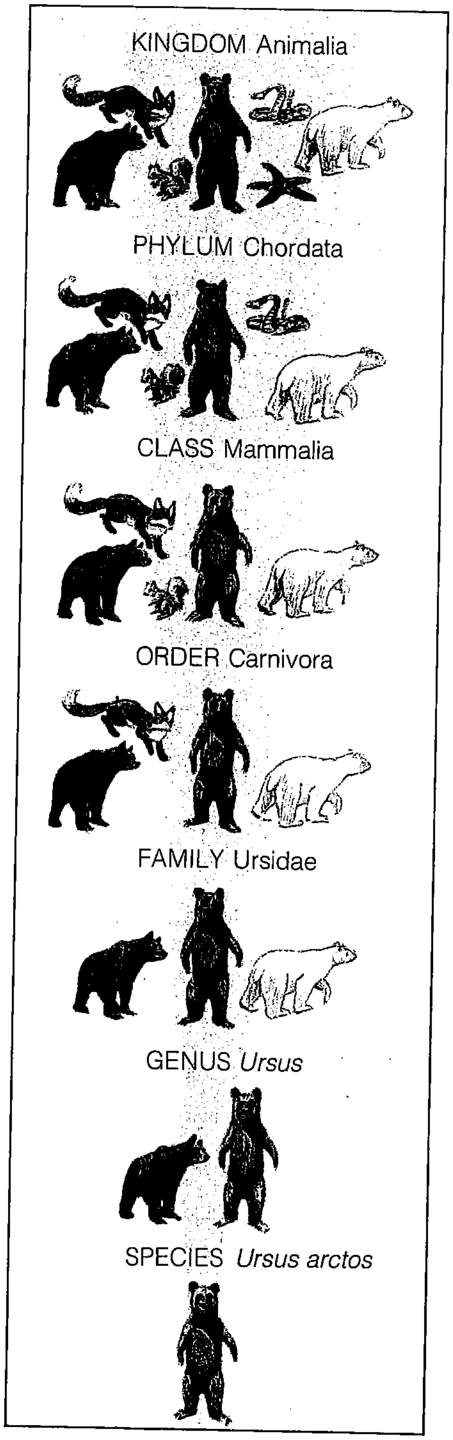


Figure 15–5 *This illustration shows the classification groups that contain a grizzly bear.*

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 **Although these animals are all members of the cat family** (Felidae), *scientists group them into different genera. The tiger (left) is placed in the genus* Panthera, *whereas the ocelot (top center), the puma (bottom center), and the house cat (bottom right) are placed in the genus* Felis. *The cheetah (top right) belongs to a third genus,* Acinonyx.

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 taxa is the most specific?
3. **Critical Thinking—Applying Concepts** 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

Guide For Reading

- How do taxa show evolutionary relationships among different organisms?
- How do 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.

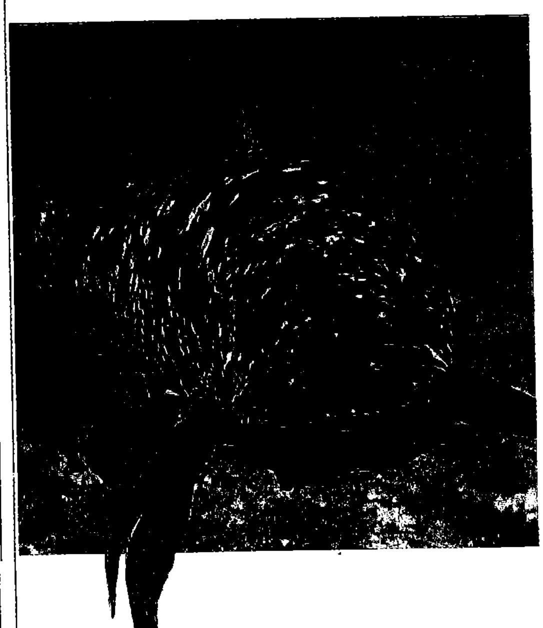
Figure 15–7 *The pygmy chimpanzee (left) and the common chimpanzee (right) belong to different species. They do not breed with each other and do not share a gene pool.*

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 *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 forms of life share organic molecules that are almost—but not exactly—identical from species to species. Taxonomists use these molecular similarities and differences to classify organisms in much the same way as anatomists use comparisons among visible body structures.

What sorts of biochemical similarities exist? As you probably already know, all forms of life (except some viruses) carry genetic information in the form of DNA. Because all DNA is descended from the DNA carried by the earliest life forms, the DNA of all organisms shares a common genetic code. And because the genes of living organisms descended from the genes of common ancestors, many genes in many different organisms strongly resemble one another. These similar genes direct the synthesis of similar proteins.

One such protein is cytochrome *c*. Virtually every organism uses cytochrome *c* in its electron transport chain. However, each species' cytochrome *c* differs slightly from the cytochrome *c* of other species. The differences among cytochrome *c* were produced by mutations that occurred after the ancestors of living species diverged. If two species diverged hundreds of millions of years ago, there has been lots of time for mutations to alter the structure of their cytochrome *c* genes. But if two species shared common ancestors until fairly recently, their genes and proteins are likely to be more similar.

To help classify organisms into groups, therefore, we can compare either the nucleotide sequences of their DNA and RNA or the amino acid sequences of their proteins. Figure 15–9 shows a wide range of organisms grouped according to the similarities and differences among their cytochrome *c* molecules.

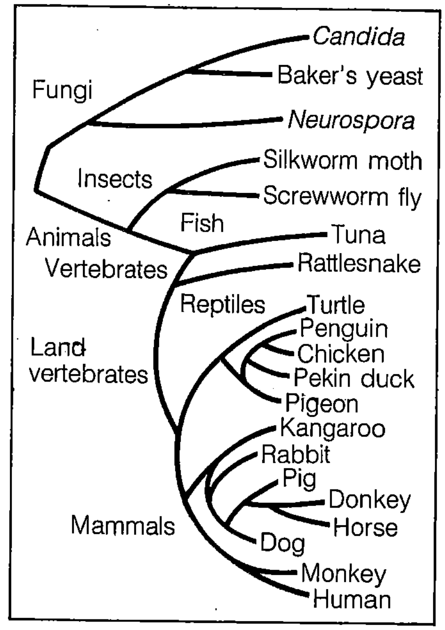


***Figure 15–9** This diagram groups organisms according to the similarities and differences in the versions of cytochrome* c *that they possess.*

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. **Critical Thinking—Relating Concepts** How can a study of biochemistry help taxonomists?

15–4 The Six-Kingdom System

Guide For Reading

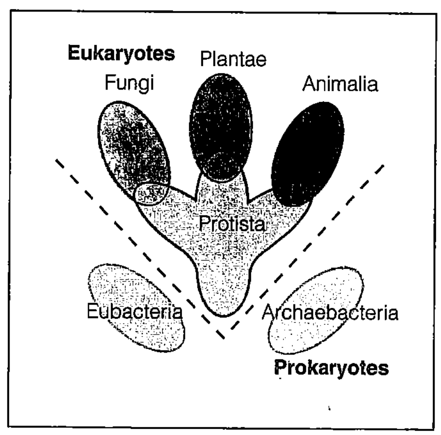
- Why does the six-kingdom system more accurately represent evolutionary trends?
- What are the characteristics of organisms that make up each of the six kingdoms?

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 called prokaryotes. Scientists now consider prokaryotes to be so different from other organisms that they place them into two kingdoms of their own: Eubacteria and Archaebacteria. 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 most important characteristics in classifying organisms, the most generally accepted classification system now contains six kingdoms. **The six kingdoms are Eubacteria, Archaebacteria, Protista, Fungi, Plantae, and Animalia.**

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



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 six-kingdom classification system as a useful tool for studying organisms, which is what taxonomy is all about. In order to understand why the six kingdoms are arranged as they are, it helps to think of them as representing a simple evolutionary tree. Following are brief descriptions of the six classification kingdoms.

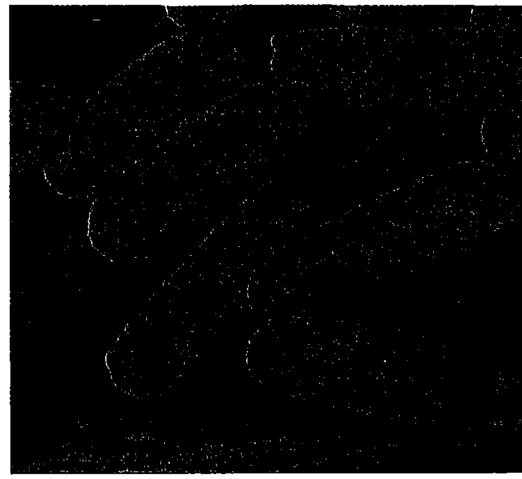


Figure 15–11 These rod-shaped bacteria, photographed on the head of a pin, are placed in the kingdom Eubacteria. The bacteria have been magnified more that 4000 times to make them visible.

The Prokaryotic Kingdoms

All prokaryotes are placed in one of two kingdoms: the **Eubacteria** or the **Archaebacteria.** In the next chapter, you will learn about the strong fossil and biochemical evidence that indicates that prokaryotes were the first life forms on Earth. Like today's living prokaryotes, the ancient prokaryotes lacked nuclei, mitochondria, and chloroplasts, and reproduced by splitting apart in a process called binary fission.

Prokaryotes 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.

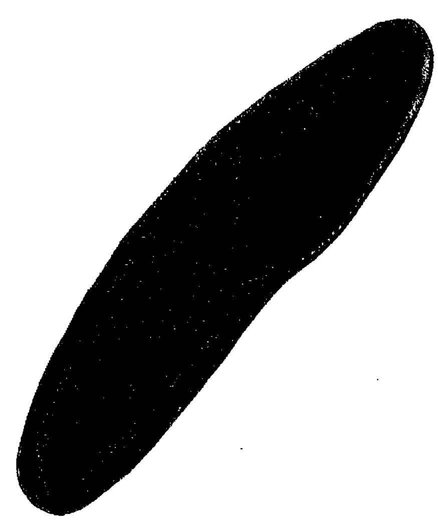
Protista

In the six-kingdom classification system, the kingdom **Protista** contains all the single-celled eukaryotic organisms. Eukaryotes, remember, differ from prokaryotes because they possess a nucleus and membrane-bound organelles. Some eukaryotes (including some protists) also have chloroplasts.

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 determined 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 at all clear-cut. 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,

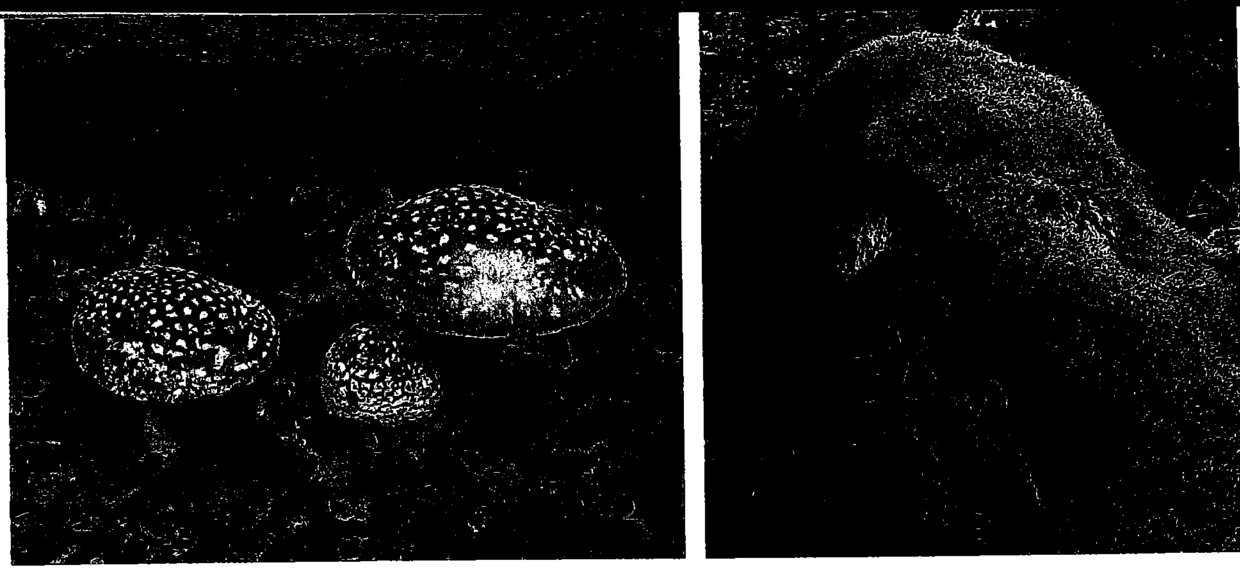


Figure 15–13 The fly agaric (left), a beautiful and colorful member of the kingdom Fungi, is poisonous. The small maple tree in the foreground and the moss plants growing on the tree (right) are both members of the kingdom Plantae.

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.