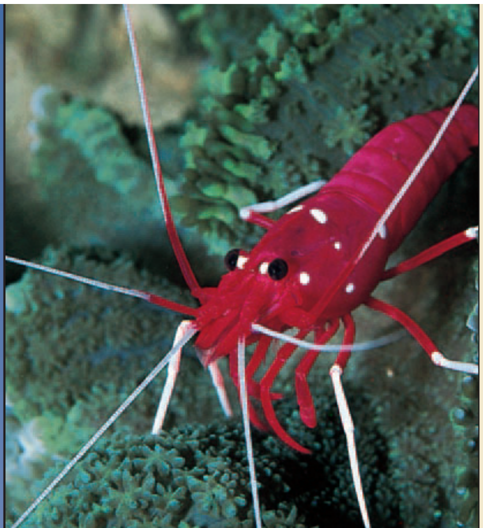


CHAPTER 23

The Classification and Evolution of Organisms

Chapter Outline

Key Concepts	Applications
Understand why and how scientists categorize organisms.	• Know why scientists use Latin names for organisms. • Identify the major categories of living things. • List the domains of organisms.
Know the criteria used to classify organisms into different kingdoms.	• Understand what makes mushrooms, bacteria, and seaweed different from plants.
Understand the relationship between geology, paleontology, and evolution.	• Understand what can be learned about extinct species from fossils. • Know how the age of a fossil is determined.

23.1 The Classification of Organisms

Every day you see a great variety of living things. Just think of how many different species of plants and animals you have observed. Biologists at the Smithsonian Institution estimated that there are over 30 million species in the world; over 1.5 million of these have been named. What names do you assign to each? Is the name you use the same as that used in other sections of the country or regions of the world? In much of the United States and Canada, the fish pictured in figure 23.1*a* is known as a largemouth black bass, but in sections of the southern United States it is called a trout. This use of local names can lead to confusion. If a student in Mississippi writes to a friend in Wisconsin about catching a 6-pound trout, the person in Wisconsin thinks that the friend caught the kind of fish pictured in figure 23.1*b*. In the scientific community, accuracy is essential; local names cannot be used. When a biologist is writing about a species, all biologists in the world who read that article must know exactly what that species is.

Taxonomy is the science of naming organisms and grouping them into logical categories. Various approaches have been used to classify organisms. The Greek philosopher Aristotle (384-322 B.C.) had an interest in nature and was the first person to attempt a logical classification system. The root word for *taxonomy* is the Greek word *taxis*, which means *arrangement*. Aristotle used the size of plants to divide them into the categories of trees, shrubs, and herbs.

During the Middle Ages, Latin was widely used as the scientific language. As new species were identified, they were given Latin names, often using as many as 15 words. Although using Latin meant that most biologists, regardless of their native language, could understand a species name, it did not completely do away with duplicate names. Because many of the organisms could be found over wide geographic areas and communication was slow, there could be two or more Latin names for a species. To make the situation even more confusing, ordinary people still called organisms by their common local names.

The modern system of classification began in 1758 when Carolus Linnaeus (1707–1778), a Swedish doctor and botanist, published his tenth edition of *Systema Naturae* (figure 23.2). (Linnaeus's original name was Carl von Linné, which he "latinized" to Carolus Linnaeus.) In the previous editions, Linnaeus had used a polynomial (many-name) Latin system. However, in the tenth edition he introduced the **binomial** (two-name) **system of nomenclature.** This system used two Latin names, genus and specific epithet (*epithet* = descriptive word), for each species of organism.

Recall that a species is a population of organisms capable of interbreeding and producing fertile offspring. Individual organisms are members of a species. A **genus** (plural, *genera*) is a group of closely related organisms; the **specific**

(a)

(b)

Figure 23.1

Fish Identification
Using the scientific name *Micropterus salmoides* for largemouth black bass (*a*) and *Salmo trutta* for brown trout (*b*) correctly indicates which of these two species of fish a biologist is talking about. Both fish are called trout in some parts of the world.

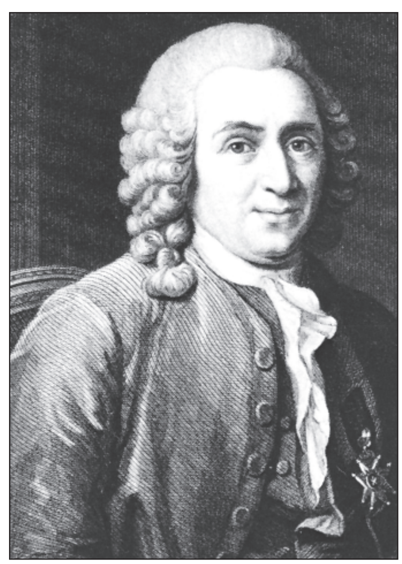


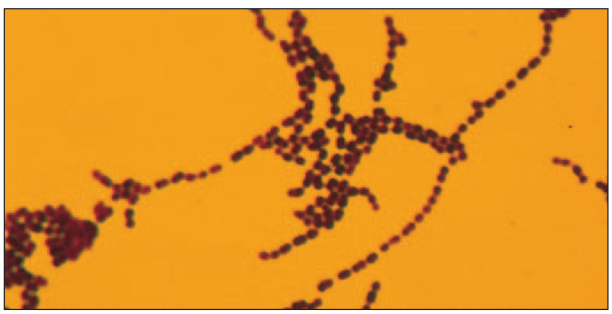
Figure 23.2

Carolus Linnaeus (1707–1778)
Linnaeus, a Swedish doctor and botanist, originated the modern system of taxonomy.

epithet is a word added to the genus name to identify which one of several species within the genus we are discussing. It is similar to the naming system we use with people. When you look in the phone book you look for the last name (surname), which gets you in the correct general category. Then you look for the first name (given name) to identify the individual you wish to call. The unique name given to a particular type of organism is called its species name or scientific name. In order to clearly identify the scientific name, binomial names are either *italicized* or underlined. The first letter of the genus name is capitalized. The specific epithet is always written in lowercase. *Micropterus salmoides* is the binomial name for the largemouth black bass.

When biologists adopted Linnaeus's binomial method, they eliminated the confusion that was the result of using common local names. For example, with the binomial system the white water lily is known as *Nymphaea odorata*. Regardless of which of the 245 common names is used in a botanist's local area, when botanists read *Nymphaea odorata*, they know exactly which plant is being referred to. The binomial name cannot be changed unless there is compelling evidence to justify doing so. The rules that govern the worldwide classification and naming of species are expressed in the International Rules for Botanical Nomenclature, the International Rules for Zoological Nomenclature, and the International Bacteriological Code of Nomenclature.

In addition to assigning a specific name to each species, Linnaeus recognized a need for placing organisms into groups. This system divides all forms of life into **kingdoms**, the largest grouping used in the classification of organisms. Originally there were two kingdoms, Plantae and Animalia. Today biologists recognize three *domains:*



(a)

(b)

(c)

(d)

(e)

Figure 23.3

Representatives of the Domains of Life

(*a*) The Domain Eubacteria is represented by the bacterium *Streptococcus pyogenes* (the cause of strep throat); The Domain Eucarya is represented by: (*b*) *Morchella esculenta,* kingdom Fungi; (*c*) *Amoeba proteus,* kingdom Protista; (*d*) *Homo sapiens,* kingdom Animalia; and (*e*) *Acer saccharum,* the kingdom Plantae.

Eubacteria, Archaea, and Eucarya. Each domain is subdivided into kingdoms. There are four kingdoms of life in the Domain Eucarya: Plantae, Animalia, Fungi, and Protista (protozoa and algae) (figure 23.3). Each of these kingdoms is divided into smaller units and given specific names. The taxonomic subdivision under each kingdom is usually called a **phylum,** although microbiologists and botanists replace this term with the word *division.* All kingdoms have more than one phylum. For example, the kingdom Plantae contains several phyla, including flowering plants, conifer trees, mosses, ferns, and several other groups. Organisms are placed in phyla based on careful investigation of the specific nature of their structure, metabolism, and biochemistry. An attempt is made to identify natural groups rather than artificial or haphazard arrangements. For example, although nearly all plants are green and carry on photosynthesis, only flowering plants have flowers and produce seeds; conifers lack flowers but have seeds in cones; ferns lack flowers, cones, and seeds; and mosses lack tissues for transporting water.

A **class** is a subdivision within a phylum. For example, within the phylum Chordata there are seven classes: mammals, birds, reptiles, amphibians, and three classes of fishes. An **order** is a category within a class. Carnivora is an order of meat-eating animals within the class Mammalia. There are several other orders of mammals including horses and their relatives, cattle and their relatives, rodents, rabbits, bats, seals, whales, and many others. A **family** subdivision of an order consists of a group of closely related genera, which in turn are composed of groups of closely related species. The cat family, Felidae, is a subgrouping of the order Carnivora and includes many species in several genera, including the Canada lynx and bobcat (genus *Lynx*), the cougar (genus *Puma*) the leopard, tiger, jaguar, and lion (genus *Panthera*), the house cat (genus *Felis*), and several other genera. Thus, in the present-day science of taxonomy, each organism that has been classified has its own unique binomial name. In turn, it is assigned to larger groupings that are thought to have a common evolutionary history. Table 23.1 uses the classification of humans to show how the various categories are used.

Phylogeny is the science that explores the evolutionary relationships among organisms and seeks to reconstruct evolutionary history. Taxonomists and phylogenists work together so that the products of their work are compatible. A taxonomic ranking should reflect the evolutionary relationships among the organisms being classified. Although taxonomy and phylogeny are sciences, there is no complete agreement as to how organisms are classified or how they are related. Just as there was dissension 200 years ago when biologists disagreed on the theories of spontaneous generation and biogenesis, there are still differences in opinion about the evolutionary relationships of organisms. People arrive at different conclusions because they use different kinds of evidence or interpret this evidence differently. Phylogenists use several lines of evidence to develop evolutionary histories: fossils, comparative anatomy, life cycle information, and biochemical/molecular evidence.

Fossils are physical evidence of previously existing life and are found in several different forms. Some fossils may be preserved whole and relatively undamaged. For example, mammoths and humans have been found frozen in glaciers, and bacteria and insects have been preserved after becoming embedded in plant resins. Other fossils are only parts of once-living organisms. The outlines or shapes of extinct plant leaves are often found in coal deposits, and individual animal bones that have been chemically altered over time are often dug up (figure 23.4). Animal tracks have also been discovered in the dried mud of ancient riverbeds. It is important to understand that some organisms are more easily fossilized than others. Those that have hard parts like cell walls, skeletons, and shells are more likely to be preserved than are tiny, soft-bodied organisms. Aquatic organisms are much more likely to be buried in the sediments at the bottom of the oceans or lakes than are their terrestrial counterparts. Later, when these sediments are pushed up by geologic forces, aquatic fossils are found in their layers of sediments on dry land.

Evidence obtained from the discovery and study of fossils allows biologists to place organisms in a time sequence. This can be accomplished by comparing one type of fossil with another. As geologic time passes and new layers of sediment are laid down, the older organisms should be in deeper layers, providing the sequence of layers has not been

(a) (b)

Figure 23.4

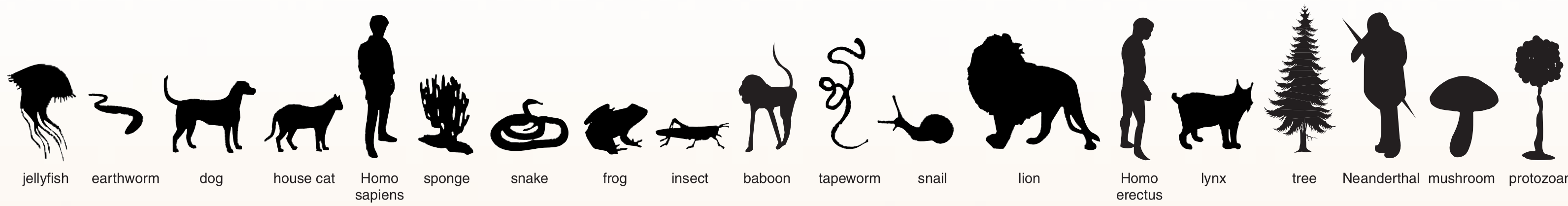
Fossil Evidence

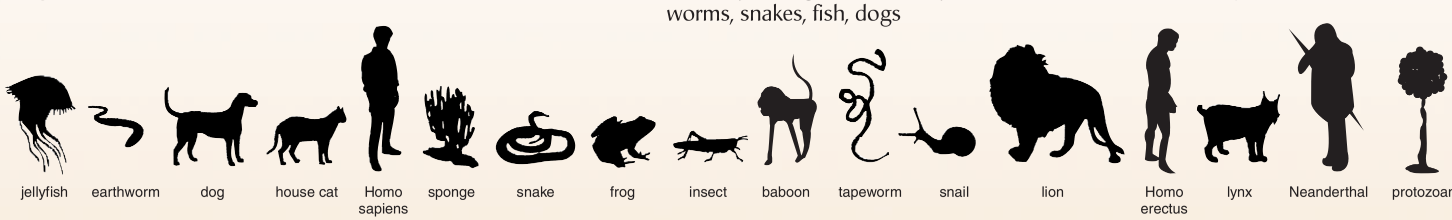
Fossils are either the remains of prehistoric organisms or evidence of their existence. (*a*) The remains of an ancient fly preserved in amber. (*b*) A bony fish specimen. The skeletons of fish make good fossils.

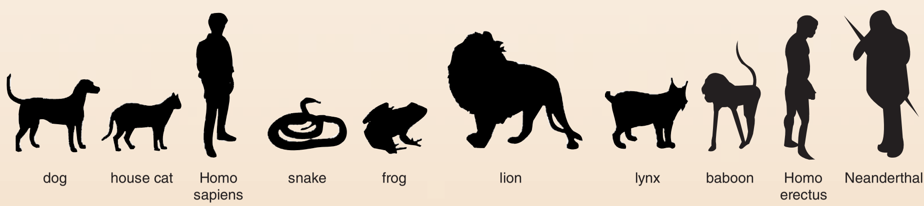
Table 23.1

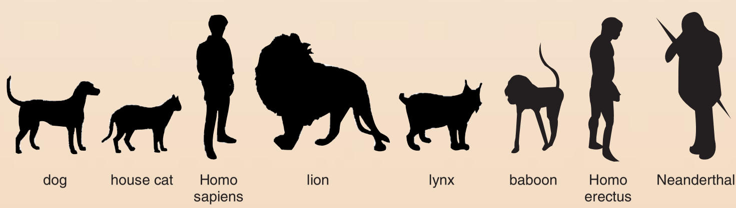
CLASSIFICATION OF HUMANS

Taxonomic Category	Human Classification	Other Representative Organisms in the Same Category
Domain	*Eucarya*	Plants, animals, fungi, protozoans, and algae
Kingdom	*Animalia*	Heterotrophic organisms with specialized tissues that are usually mobile: insects, snails, starfish, worms, snakes, fish, dogs
Phylum	*Chordata*	Animals with stiffening rod in the back: reptiles, amphibians, birds, fish
Class	*Mammalia*	Animals with hair and mammary glands: dogs, whales, mice









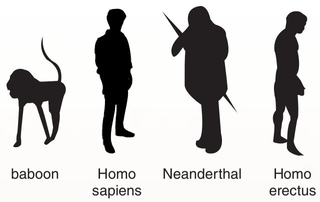
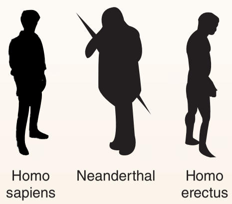
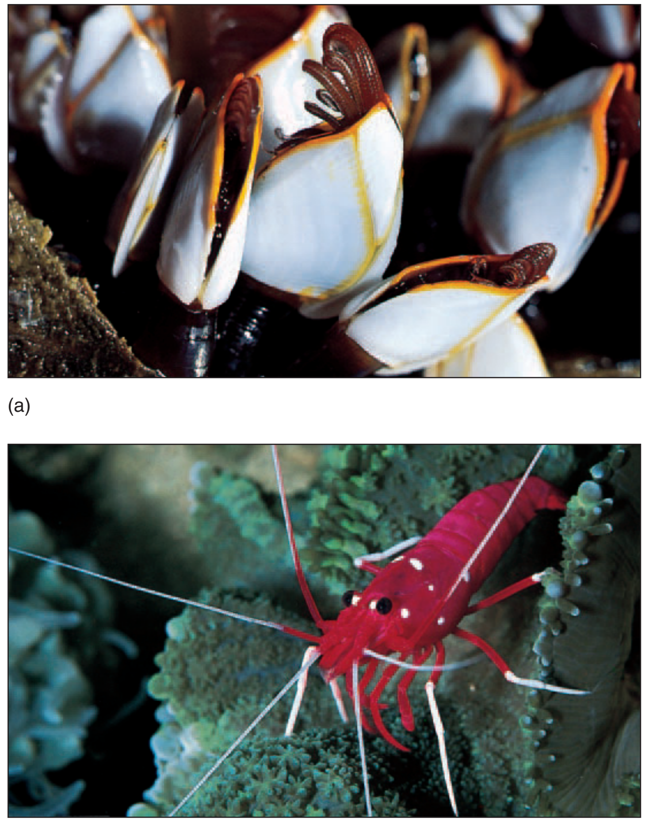
Order	*Primates*	Animals with large brains and opposable thumbs: apes, squirrel monkeys, chimpanzees, baboons
		
Family	*Hominidae*	Individuals that lack a tail and have upright posture: humans and extinct relatives (Neanderthal)
		
Genus	*Homo*	Humans are the only surviving member of the genus, although other members of this genus existed in the past (*H. erectus*)
		
Species	*Homo sapiens*	Humans
		

Figure 23.5

Determining the Age of Fossils
Because new layers of sedimentary rock are formed on top of older layers of sedimentary rock, it is possible to determine the relative ages of fossils found in various layers. The layers of rock shown here represent on the order of hundreds of millions of years of formation. The fossils of the lower layers are millions of years older than the fossils in the upper layers.



(a)

(b)

Figure 23.6

Developmental Biology
The adult barnacle (*a*) and shrimp (*b*) are very different from each other, but the early larval stages look very much alike.

disturbed (figure 23.5). In addition, it is possible to age-date rocks by comparing the amounts of certain radioactive isotopes they contain. The older sediment layers have less of these specific radioactive isotopes than do younger layers. A comparison of the layers gives an indication of the relative age of the fossils found in the rocks. Therefore, fossils found in the same layer must have been alive during the same geologic period.

It is also possible to compare subtle changes in particular kinds of fossils over time. For example, the size of the leaf of a specific fossil plant has been found to change extensively through long geologic periods. A comparison of the extremes, the oldest with the newest, would lead to their classification into different categories. However, the fossil links between the extremes clearly show that the younger plant is a descendant of the older.

The comparative anatomy of fossil or currently living organisms can be very useful in developing a phylogeny. Because the structures of an organism are determined by its genes and developmental processes, those organisms having similar structures are thought to be related. Plants can be divided into several categories: all plants that have flowers are thought to be more closely related to one another than to plants like ferns, which do not have flowers. In the animal kingdom, all organisms that nurse their young from mammary glands are grouped together, and all animals in the bird category have feathers and beaks and lay eggs with shells. Reptiles also have shelled eggs but differ from birds in that reptiles lack feathers and have scales covering their bodies. The fact that these two groups share this fundamental eggshell characteristic implies that they are more closely related to each other than they are to other groups.

Another line of evidence useful to phylogenists and taxonomists comes from the field of developmental biology. Many organisms have complex life cycles that include many completely different stages. After fertilization, some organisms

HOW SCIENCE WORKS 23.1

New Discoveries Lead to Changes in the Classification System

Classification or *taxonomy* is one part of the much larger field of phylogenetic systematics. *Phylogeny* or *systematics* is an effort to understand the evolutionary relationships of living things, trying to interpret the way in which life has diversified and changed over billions of years of biological history. It attempts to understand how organisms have changed over time. Classification involves the creation of names for groups of organisms.

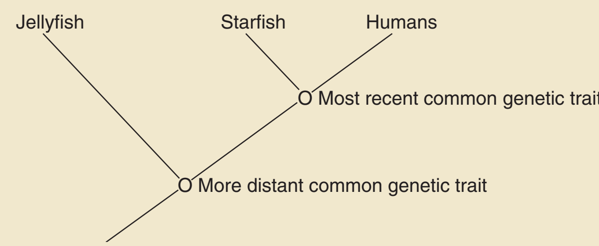
Cladistics (*klados* = branch) is a method biologists use to present their knowledge of the genetically derived traits of groups of organisms. The basic assumptions behind cladistics are that:

1. Groups of organisms are related by descent from a common ancestor.
2. There is a branching pattern over time that reveals that new evolutionary groups stem from a common ancestor.
3. Change in characteristics occurs in the related organisms over time.

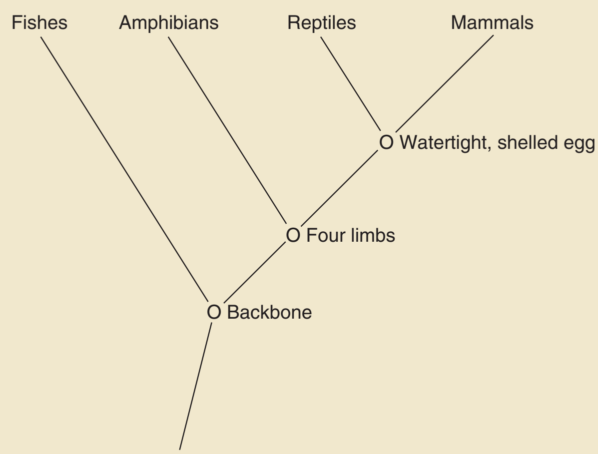
To be considered "close relatives," it is not enough for groups of organisms to just "share characteristics" or "appear to be alike." Two organisms may share many characteristics and still not be members of the same evolutionary group. For example, consider a jellyfish, starfish, and a human. Which two groups are most closely related? The jellyfish and starfish share the characteristics of living in water, having radial symmetry, and being invertebrates. So you might guess that they are the most closely related. However, this assumption does not reflect their *genetic* relatedness. Taking genetically based evolutionary relatedness into account, the starfish and human are actually more closely related. It is not just appearances that are important, but the presence of shared *genetically derived* characteristics. In the example above, all three characteristics are believed to have been present in the *common ancestor of all these animals,* and so are not as important, since all three organisms in question belong to the kingdom Animalia. While humans are different from the other two organisms, they differ only in genetic characteristics that arose newly in an ancestor that is not shared with the other two.

Source: World Health Organization of the United Nations.

A *cladogram* is a chart designed to show how closely groups of organisms are genetically related. A cladogram for the above example would be:



A cladogram for fishes, amphibians, mammals, and reptiles would appear as:



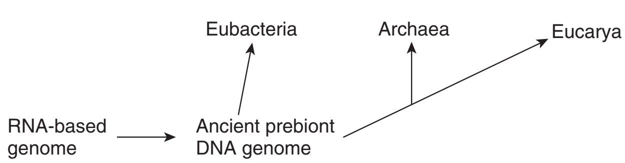
grow into free-living developmental stages that do not resemble the adults of their species. These are called *larvae* (singular, *larva*). Larval stages often provide clues to the relatedness of organisms. For example, adult barnacles live attached to rocks and other solid marine objects and look like small, hard cones. Their outward appearance does not suggest that they are related to shrimp; however, the larval stages of barnacles and shrimp are very similar. Detailed anatomical studies of barnacles confirm that they share many structures with shrimp; their outward appearance tends to be misleading (figure 23.6). This same kind of evidence is available in the plant kingdom. Many kinds of plants, such as peas, peanuts, and lima beans, produce large, two-parted seeds in pods (you can easily split the seeds into two parts). Even though peas grow as vines, lima beans grow as bushes, and peanuts have their seeds underground, all these plants are considered to be related.

Like all aspects of biology, the science of taxonomy is constantly changing as new techniques develop. Recent advances in DNA analysis are being used to determine genetic similarities among species (How Science Works 23.1). In the field of ornithology, which deals with the study of birds, there are those who believe that storks and flamingos are closely related; others believe that flamingos are more closely related to geese. An analysis of the DNA points to a higher degree of affinity between flamingos and storks than between flamingos and geese. This is interpreted to mean that the closest relationship is between flamingos and storks. Algae and plants have several different kinds of chlorophyll: chlorophyll *a*, *b*, *c*, *d*, and *e*. Most photosynthetic organisms contain a combination of two of these chlorophyll molecules. Members of the kingdom Plantae have chlorophyll *a* and *b*. The large seaweeds, like kelp, superficially resemble terrestrial plants like trees and shrubs. However, a comparison of the chlorophylls present shows that kelp has chlorophyll *a* and *d*. When another group of algae, called the *green algae,* are examined, they are found to have chlorophyll *a* and *b*. Along with other anatomical and developmental evidence, this biochemical information has helped establish an evolutionary link between the green algae and plants. All of these kinds of evidence (fossils, comparative anatomy, developmental stages, and biochemical evidence) have been used to develop the various taxonomic categories, including kingdoms.

Given all these sources of evidence, biologists have developed a hypothetical picture of how all organisms are related (figure 23.7). At the base of this evolutionary scheme is the biochemical evolution of cells first postulated by Oparin (see chapter 22). These first cells are thought to be the origin of the five kingdoms. Although protocells no longer exist, their descendants have diversified over millions of years. Of these groups, Eubacteria and Archaea have the simplest structure and are probably most similar to some of the first cellular organisms on Earth.

23.2 Domains Archaea and Eubacteria

Members of the Domains Archaea and Eubacteria are commonly known as bacteria. Some are disease-causing, such as *Streptococcus pneumoniae,* but most are not. In addition, many are able to photosynthesize. Members of these domains differ from one another in their cellular structures and position on the evolutionary tree. Evidence gained from studying DNA and RNA nucleotide sequences and a comparison of the amino acid sequences of proteins indicates that the first ancestral cells used DNA as their genetic material. They probably gave rise to today's Eubacteria followed by the Archaea and finally the Eucarya.



Archaea

The term archaea comes from the term *archaios* meaning "ancient." This group of prokaryotic cells is thought to have branched off in the neighborhood of 1.3 to 2.6 million years ago. Since the Eubacteria are actually older as a group than the Archaea, the naming of this group may seem confusing. However, the Archaea have many chemical similarities to the Eucarya. For example, the Archaea and Eucarya both lack peptidoglycan as their cell wall building material and they both have introns as components of their DNA. These bacteria have been found in many shapes including rods, spheres, spirals, filaments, and flat plates. Because they are found in many kinds of extreme environments, they have become known as extremophiles. Based on this fact, the Archaea are divided into three groups. *Methanogens* are methane-producing bacteria that are anaerobic. They can be found in the intestinal tracts of humans, sewage, and swamps. *Halobacteria* (*halo* = salt) are found growing in very salty environments such as the Great Salt Lake (Utah), salt ponds, and brine solutions. Some contain a special kind of chlorophyll and are therefore capable of generating their ATP by photosynthesis. The *thermophilic* Archaea live in environments that normally have very high temperatures and high concentrations of sulfur (e.g., hot sulfur springs or around deep-sea hydrothermal vents). Over 500 species of thermophiles have been identified at the openings of hydrothermal vents in the open oceans. One such thermophile, *Pyrolobus fumarii,* grows in a hot spring in Yellowstone National Park. Its maximum growth temperature is 113°C, its optimum is 106°C, and its minimum is 90°C.

Eubacteria

The "true bacteria" (*eu* = true) are small, single-celled organisms ranging from 1 to 10 micrometers (µm). Their cell walls typically contain complex organic molecules, such as peptidoglycan, polymers of unique sugars, and unusual amino acids not found in other kinds of organisms.

Eubacteria have no nucleus, and the genetic material is a single loop of DNA. Some have as few as 5,000 genes. The cells reproduce by binary fission. This is a type of asexual cell division that does not involve the more complex structures used by eukaryotes in mitosis or meiosis. As a result, the daughter cells produced have a single copy of the parental DNA loop (figure 23.8). Some cells move by secreting a slime that glides over the cell's surface, causing it to move through the environment. Others move by means of a kind of flagellum. The structure of the flagellum is different from the flagellum found in eukaryotic organisms.

Because the early atmosphere is thought to have been a reducing atmosphere, the first Eubacteria were probably anaerobic organisms. Today there are both anaerobic and aerobic Eubacteria.

Some prokaryotic heterotrophs are **saprophytes,** organisms that obtain energy by the decomposition of dead organic material; others are parasites that obtain energy and nutrients from living hosts and cause disease; still others are mutualistic and have a mutually beneficial relationship with their host; finally, some are commensalistic and derive benefit from a host without harming it. Several kinds of Eubacteria are autotrophic. Many are called cyanobacteria because they contain a blue-green pigment, which allows them to capture sunlight and carry on photosynthesis. They can become extremely numerous in some polluted waters where nutrients are abundant. Others use inorganic chemical reactions for their energy sources and are called chemosynthetic.

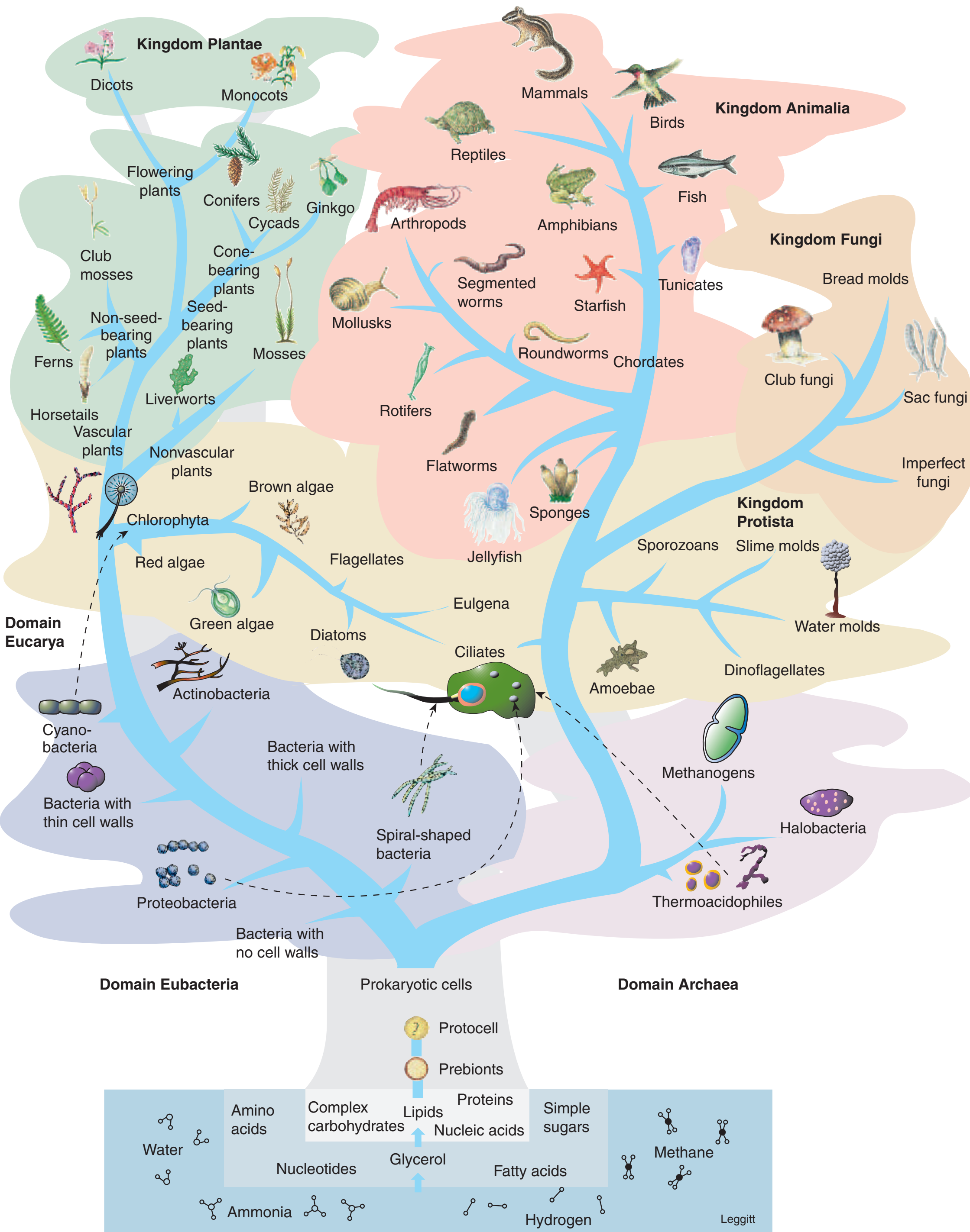
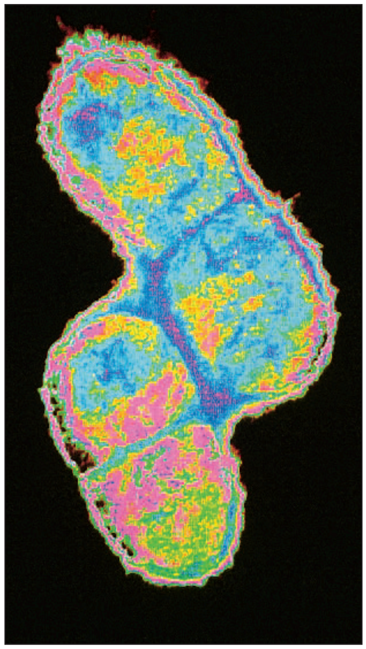


Figure 23.7

Molecules to Organisms

The theory of chemical evolution proposes that the molecules in the early atmosphere and early oceans accumulated to form prebionts—nonliving structures composed of carbohydrates, proteins, lipids, and nucleic acids. The prebionts are believed to have been the forerunners of the protocells—the first living cells. These protocells probably evolved into prokaryotic cells, on which the Domains Archaea and Eubacteria are based. Some prokaryotic cells probably gave rise to eukaryotic cells. The organisms formed from these early eukaryotic cells were probably similar to members of the kingdom Protista. Members of this kingdom are thought to have given rise to the kingdoms Animalia, Plantae, and Fungi. Thus, all present-day organisms evolved from the protocells.



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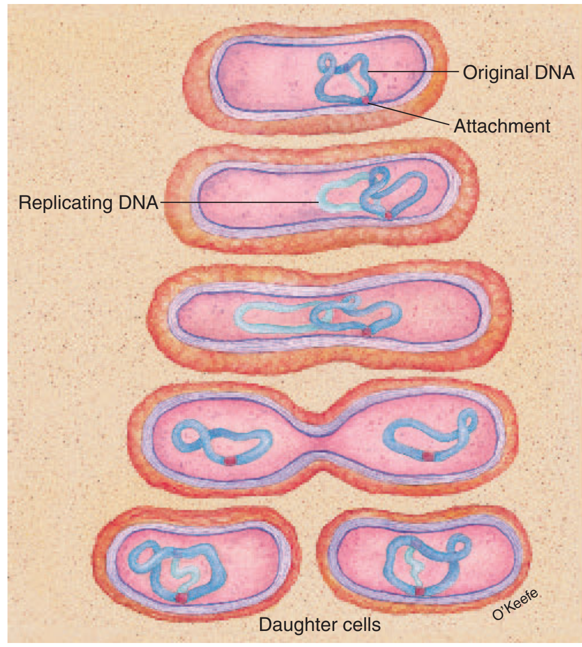


(b)

Figure 23.8

Binary Fission
Two cells of the bacterium *Bacillus megaterium* formed by binary fission (*a*). (*b*) Binary fission consists of DNA replication and cytoplasmic division.

Some biologists hypothesize that eukaryotic cells evolved from prokaryotic cells by a process of endosymbiosis. This hypothesis proposes that structures like mitochondria, chloroplasts, and other membranous organelles originated from separate cells that were ingested by larger, more primitive cells. Once inside, these structures and their functions became integrated with the host cell and ultimately became essential to its survival. This new type of cell was the forerunner of present-day eukaryotic cells. (See "The Origin of Eukaryotic Cells," pages 416–418 and figure 22.10.) Single-celled eukaryotic organisms are members of the kingdom Protista (figure 23.7).

23.3 Domain Eucarya

Kingdom Protista

The changes in cell structure that led to eukaryotic organisms most probably gave rise to single-celled organisms similar to those currently grouped in the kingdom Protista. Most members of this kingdom are one-celled organisms, although there are some colonial forms. Eukaryotic cells are usually much larger than the prokaryotes, typically having more than a thousand times the volume of prokaryotic cells. Their larger size was made possible by the presence of specialized membranous organelles, such as mitochondria, the endoplasmic reticulum, chloroplasts, and nuclei.

There is a great deal of diversity within the 60,000 known species of Protista. Many species live in freshwater; others are found in marine or terrestrial habitats, and some are parasitic, commensalistic, or mutualistic. All species can undergo mitosis, resulting in asexual reproduction. Some species can also undergo meiosis and reproduce sexually. Many contain chlorophyll in chloroplasts and are autotrophic; others require organic molecules as sources of energy and are heterotrophic. Both autotrophs and heterotrophs have mitochondria and respire aerobically.

Because members of this kingdom are so diverse with respect to form, metabolism, and reproductive methods, most biologists do not think that the Protista form a valid phylogenetic unit. However, it is still a convenient taxonomic grouping. By placing these organisms together in this group it is possible to gain a useful perspective on how they relate to other kinds of organisms. After the origin of eukaryotic organisms, evolution proceeded along several different pathways. Three major lines of evolution can be seen today in the plantlike autotrophs (algae), animal-like heterotrophs (protozoa), and the funguslike heterotrophs (slime molds). *Amoeba* and *Paramecium* are commonly encountered examples of protozoa. Many seaweeds and pond scums are collections of large numbers of algal cells. Slime molds are less frequently seen because they live in and on the soil in moist habitats; they are most often encountered as slimy masses on decaying logs.

Through the process of evolution, the plantlike autotrophs probably gave rise to the kingdom Plantae, the animal-like heterotrophs probably gave rise to the kingdom Animalia, and the funguslike heterotrophs were probably the forerunners of the kingdom Fungi (figure 23.7).

Kingdom Fungi

Fungus is the common name for members of the kingdom Fungi. The majority of fungi are nonmotile. They have a rigid, thin cell wall, which in most species is composed of chitin, a complex carbohydrate containing nitrogen. Members of the kingdom Fungi are nonphotosynthetic, eukaryotic organisms. The majority (mushrooms and molds) are multicellular, but a few, like yeasts, are single-celled. In the multicellular fungi the basic structural unit is a network of multicellular filaments. Because all of these organisms are heterotrophs, they must obtain nutrients from organic sources. Most are saprophytes and secrete enzymes that digest large molecules into smaller units that are absorbed. They are very important as decomposers in all ecosystems. They feed on a variety of nutrients ranging from dead organisms to such products as shoes, food-stuffs, and clothing. Most synthetic organic molecules are not attacked as readily by fungi; this is why plastic bags, foam cups, and organic pesticides are slow to decompose.

Some fungi are parasitic, whereas others are mutualistic. Many of the parasitic fungi are important plant pests. Some attack and kill plants (chestnut blight, Dutch elm disease); others injure the fruit, leaves, roots, or stems and reduce yields. The fungi that are human parasites are responsible for athlete's foot, vaginal yeast infections, valley fever, "ringworm," and other diseases. Mutualistic fungi are important in lichens and in combination with the roots of certain kinds of plants.

Kingdom Plantae

Another major group with roots in the kingdom Protista are the green, photosynthetic plants. The ancestors of plants were most likely specific kinds of algae commonly called *green algae*. Members of the kingdom Plantae are nonmotile, terrestrial, multicellular organisms that contain chlorophyll and produce their own organic compounds. All plant cells have a cellulose cell wall. Over 300,000 species of plants have been classified; about 85% are flowering plants, 14% are mosses and ferns, and the remaining 1% are cone-bearers and several other small groups within the kingdom.

A wide variety of plants exist on Earth today. Members of the kingdom Plantae range from simple mosses to vascular plants with stems, roots, leaves, and flowers. Most biologists believe that the evolution of this kingdom began about 400 million years ago when the green algae of the kingdom Protista gave rise to two lines: The nonvascular plants like the mosses evolved as one type of plant and the vascular plants like the ferns evolved as a second type (figure 23.9). Some of the vascular plants evolved into seed-producing plants, which today are the cone-bearing and flowering plants, whereas the ferns lack seeds. The development of vascular plants was a major step in the evolution of plants from an aquatic to a terrestrial environment.

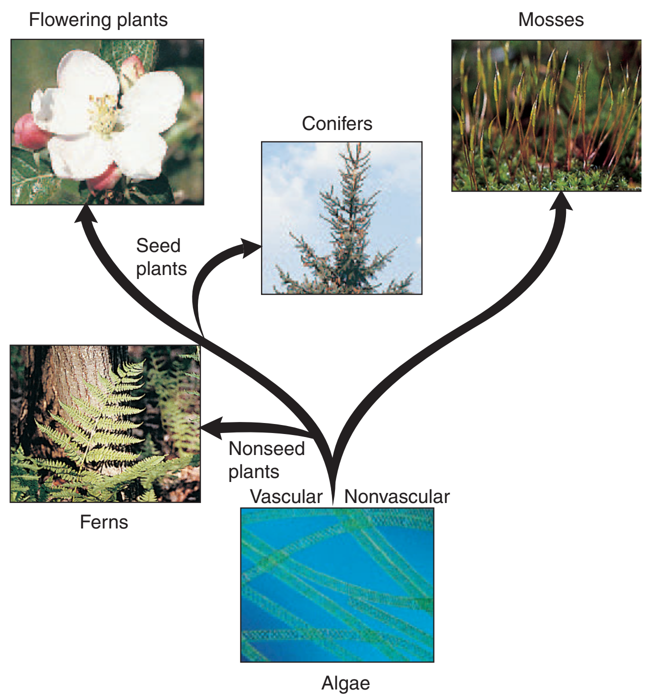


Figure 23.9

Plant Evolution
Two lines of plants are thought to have evolved from the plantlike Protista, the algae. The nonvascular mosses evolved as one type of plant. The second type, the vascular plants, evolved into the seed and nonseed plants.

Plants have a unique life cycle. There is a haploid **gametophyte stage** that produces a haploid sex cell by mitosis. There is also a diploid **sporophyte stage** that produces haploid spores by meiosis. This **alternation of generations,** which is a unifying theme that ties together all members of this kingdom, is fully explained in chapter 25. In addition to sexual reproduction, plants are able to reproduce asexually.

Kingdom Animalia

Like the fungi and plants, the animals are thought to have evolved from the Protista. Over a million species of animals have been classified. These range from microscopic types, like mites or aquatic larvae of marine animals, to huge animals like elephants or whales. Regardless of their types, all animals have some common traits. All are composed of eukaryotic cells and all species are heterotrophic and multicellular. All animals are motile, at least during some portion of their lives; some, like the sponges, barnacles, mussels, and corals, are sessile (nonmotile, i.e., not able to move) when they are most easily recognized—the adult portion of their lives. All animals are capable of sexual reproduction, but many of the less complex animals are also able to reproduce asexually.

It is thought that animals originated from certain kinds of Protista that had flagella (see figure 23.7). This idea proposes that colonies of flagellated Protista gave rise to simple multicellular forms of animals like the ancestors of present-day sponges. These first animals lacked specialized tissues and organs. As cells became more specialized, organisms developed special organs and systems of organs and the variety of kinds of animals increased.

Although taxonomists have grouped organisms into six kingdoms, some organisms do not easily fit into these categories. Viruses, which lack all cellular structures, still show some characteristics of life. In fact, some scientists consider them to be highly specialized parasites that have lost their complexity as they developed as parasites. Others consider them to be the simplest of living organisms. Some even consider them to be nonliving. For these reasons viruses are considered separate from the six kingdoms.

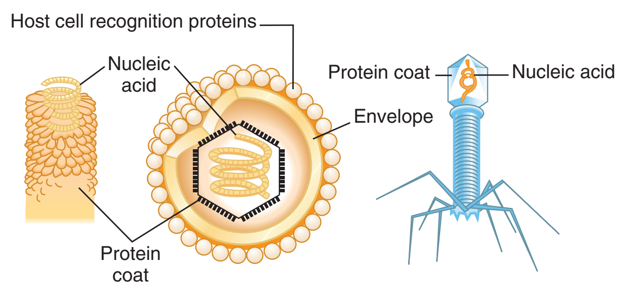


Figure 23.10

Typical Viruses
Viruses consist of a core of nucleic acid, either DNA or RNA, surrounded by a protein coat. Some have an additional layer called an envelope.

23.4 Acellular Infectious Particles

All of the groups discussed so far fall under the category of cellular forms of life. They all have at least the following features in common. They have (a) cell membranes, (b) nucleic acids as their genetic material, (c) cytoplasm, (d) enzymes and coenzymes, (e) ribosomes, and (f) use ATP as their source of chemical-bond energy. Since the three groups to follow lack this cellular organization, they are referred to as *acellular* (the prefix *a* = lacking) or are known as infectious particles. In order for these to make more of their own kind, they must make their way into true cells where they become parasites eventually causing harm or death to their host cells. The only infectious particles that are considered beneficial are a few that have been modified through bioengineering to help in the genetic transformation of cells. One example of an infectious agent that has been "domesticated" is HIV, human immunodeficiency virus. Many bioengineers use this "tame" form of the virus to carry laboratory-attached genes into host animal cells in an attempt to change their genetic makeup. Since evolutionary biologists can only speculate on the origin of acellular infectious particles, they are not classified using the same methods outlined above. Therefore, the names of *viruses, viroids,* and *prions* are varied and may not seem logical.

Viruses

A **virus** consists of a nucleic acid core surrounded by a coat of protein (figure 23.10). Viruses are **obligate intracellular parasites,** which means they are infectious particles that can function only when inside a living cell. Because of their unusual characteristics, viruses are not members of any of the three domains. Biologists do not consider them to be living because they are not capable of living and reproducing by themselves and show the characteristics of life only when inside living cells.

Soon after viruses were discovered in the late part of the nineteenth century, biologists began to speculate on how they originated. One early hypothesis was that they were either prebionts or parts of prebionts that did not evolve into cells. This idea was discarded as biologists learned more about the complex relationship between viruses and host cells. A second hypothesis was that viruses developed from intracellular parasites that became so specialized that they needed only the nucleic acid to continue their existence. Once inside a cell, this nucleic acid can take over and direct the host cell to provide for all of the virus's needs. A third hypothesis is that viruses are runaway genes that have escaped from cells and must return to a host cell to replicate. Regardless of how the viruses came into being, today they are important as parasites in all forms of life.

Viruses are typically host-specific, which means that they usually attack only one kind of cell. The **host** is a specific kind of cell that provides what the virus needs to function. Viruses can infect only those cells that have the proper receptor sites to which the virus can attach. This site is usually a glycoprotein molecule on the surface of the cell membrane. For example, the virus responsible for measles attaches to the membranes of skin cells, hepatitis viruses attach to liver cells, and mumps viruses attach to cells in the salivary glands. Host cells for the HIV virus include some types of human brain cells and several types belonging to the immune system (Outlooks 23.1).

Once it has attached to the host cell, the virus either enters the cell intact or it injects its nucleic acid into the cell. If it enters the cell, the virus loses its protein coat, releasing the nucleic acid. Once released into the cell, the nucleic acid of the virus may remain free in the cytoplasm or it may link with the host's genetic material. Some viruses contain as few as 3 genes, others contain as many as 500. A typical eukaryotic cell contains tens of thousands of genes. Most viruses need only a small number of genes because they rely on the host to perform most of the activities necessary for viral

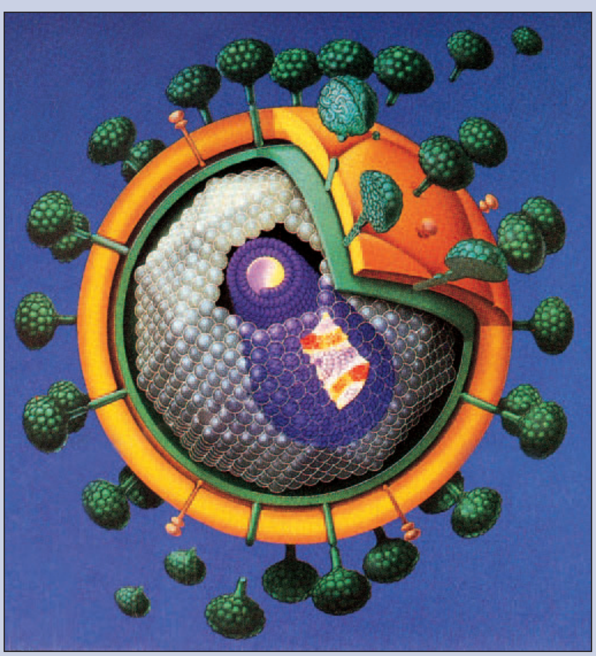
OUTLOOKS 23.1

The AIDS Pandemic

Epidemiology is the study of the transmission of diseases through a population. Diseases that occur throughout the world population at extremely high rates are called *pandemics.* Influenza, the first great pandemic of the first part of the twentieth century, killed hundreds of thousands of people. AIDS has become the greatest pandemic of the second half of the century. This viral disease has been reported in all countries around the world. UNAIDS (the United Nations Joint HIV/AIDS Program) reported in 2000 that 2.8 million adults died of AIDS and 5.6 million became HIV infected since the beginning of the pandemic. Of the 2.8 million deaths, 50% have been adult females and 50% have been adult males. There have been approximately 4.3 million deaths of children (ages less than 15).

AIDS is an acronym for *a*cquired *i*mmuno*d*eficiency *s*yndrome and is caused by human immunodeficiency viruses (HIV-1 and HIV-2), shown in the illustration. Evidence strongly supports the belief that this RNA-containing virus originated through many mutations of an African monkey virus sometime during the late 1950s or early 1960s. The virus probably moved from its original monkey host to humans as a result of an accidental scratch or bite. Not until the late 1970s was the virus identified in human populations. It has since spread to all corners of the globe. The first reported case of AIDS was diagnosed in the United States in 1981 at the UCLA Medical Center. Although it appears that the virus first entered the United States through the homosexual population, it is not a disease unique to that group; no virus known shows a sexual preference. Transmission of HIV can occur in homosexual and heterosexual individuals. Today in all parts of the world AIDS is being spread primarily through sexual contact and intravenous drug use. The World Health Organization estimates that 1.8 million people died of AIDS in 1997 and that about 12 million have died since the pandemic began.

The distribution of the virus is lowest in the economically developed countries and highest in the developing countries. Figure 23.A shows estimates by the World Health Organization of the numbers of HIV-infected people in various parts of the world. In the less-developed world there is little medical care to treat AIDS and a lack of resources to identify those who have HIV. Many people do not know they are infected and will continue to pass the disease to others. UNAIDS currently reports that an estimated 16,000 men, women, and children become newly infected each minute of each day. AIDS has become the fourth leading cause of death in the world. In some countries in southern Africa, AIDS is the leading cause of death resulting from disease. In its report, “Children on the Brink 2000,” the U.S. Agency for International Development estimates that there are 1.6 million African children who have lost at least one parent to AIDS. It also expects that number will reach 28 million in the next 10 years.



HIV is a spherical virus containing an RNA genome, including a gene for an enzyme called *reverse transcriptase,* a protein shell, and a lipid-protein envelope. RNA viruses are called *retroviruses* because their genetic material is RNA, which must be reverse transcribed (*retro* = reverse) into DNA before they can reproduce. The virus gains entry into a suitable host cell through a very complex series of events involving the virus envelope and the host-cell membrane. Certain types of human cells can serve as hosts because they have a specific viral receptor site on their surface identified as CD4 (CD stands for “clusters of differentiation,” molecules on the surface of cells. CD4 refers to group 4). CD4-containing cells include some types of brain cells and several types of cells belonging to the immune system, namely, monocytes, macrophages, and T4-helper/inducer lymphocytes. Once inside the host cell, the RNA of the HIV virus is used to make a DNA copy with the help of reverse transcriptase. This is the reverse of the normal transcription process, in which a DNA template is used to manufacture an RNA molecule. When reverse transcriptase has completed its job, the DNA genome is spliced into the host cell’s DNA. In this integrated form, the virus is called a *provirus.* As a provirus, it may remain inside some host cells for an extended period without causing any harm. Some estimate that this dormant period can last more than 30 years. Eventually, the virus replicates, the host cell dies, and new viruses are released into surrounding body fluids where they can be transmitted to other cells in the body or to other individuals. AIDS patients, therefore, have a decrease in the number of CD4 cell types. A decrease in one type of CD4 cell—the T4 lymphocytes—is an important diagnostic indicator of HIV infection and an indicator of the onset of AIDS symptoms.

Another unique feature of HIV is its rapid mutation rate. Studies have indicated over 100 mutant strains of the virus developing from a single parental strain over the course of the infection in one individual. Such an astronomical mutation rate makes a vaccine against HIV very difficult to develop because the vaccine would have to stimulate an immune response that would protect against all possible mutant forms.

Because lymphocyte host cells are found in the blood and other body fluids, it is logical that these fluids serve as carriers for the transmission of HIV. The virus is transmitted through contact with contaminated blood, semen, mucus secretions, serum, breast milk or blood-contaminated hypodermic needles. If these body fluids contain the free viruses or infected cells (monocytes, macrophages, T4-helper/inducer lymphocytes) in sufficient quantity, they can be a source of infection. There is no evidence indicating transmission through the air; by toilet seats; by mosquitoes; by casual contact such as shaking hands, hugging, touching, or closed-mouth kissing; by utensils such as silverware or glasses; or by caring for AIDS patients. The virus is too fragile to survive transmission by these routes.

The immune system cells killed by the AIDS virus are responsible for several important defense mechanisms against disease.

1. They assist in the production of antibodies.
2. They encourage the killing of tumor cells, microorganisms, and cells infected by microorganisms.

OUTLOOKS 23.1 *(continued)*

3. They encourage disease-fighting cells to reproduce and increase their number.

When T4 lymphocytes are destroyed by HIV, all these defensive efforts of the immune system are depressed. This leaves the body vulnerable to invasion by many types of infecting microbes or to being overtaken by body cells that have changed into tumor cells. This means that the HIV virus normally does not directly cause the death of the infected individual. AIDS is a progressive disease that can occur over many years or even decades. It is a series of bodily changes that involves the destruction of brain cells and ends in death as a result of rare forms of cancer or infections caused by otherwise harmless organisms. Some of the more common microbial infections include:

1. A rare lung infection, *Pneumocystis carinii* pneumonia (PCP), caused by a fungus
2. Gastroenteritis (severe diarrhea) caused by the protozoan *Isospora*
3. Cytomegalovirus (CMV) infections of the retina of the eye

One of the most common forms of cancer found among AIDS patients is Kaposi's sarcoma, a form of skin cancer that shows up as purple-red bruises. The initial symptoms of the disease have been referred to as *ARC,* or *AIDS-related complex, or pre-AIDS.*

At the present time, the progress of the infection is slowed (but not cured) by using drugs that can kill infected cells, improve the body's immune system, or selectively interfere with the life cycle of the virus. The life cycle may be disrupted when the virus enters the cell and the reverse transcriptase converts the RNA to DNA. If this enzyme does not operate, the virus is unable to function. Several drugs have been developed that block this reverse transcriptase step necessary for the reproduction of the virus. In addition, protease inhibitors block the protease enzyme also needed by the virus. Usually two or more drugs are given simultaneously or in sequence. This reduces the chance that the virus will develop resistance to the drugs being used.

What about the development of a vaccine to prevent the virus from infecting the body? Experimental vaccines have been developed based on the body's ability to produce antibodies against the virus. Vaccines, however, have been shown to be effective only in monkeys. In addition, it will be necessary to deal with the problem of genetic differences among the many kinds of HIV viruses. The greater the variety of viruses, the greater the variety of vaccine types needed to prevent infection.

To control the spread of the virus, there must be wide public awareness of the nature of the disease and how it is transmitted. People must be able to recognize high-risk behavior and take action to change it. The most important risk factor is promiscuous sexual behavior (i.e., sex with many partners). This increases the probability that one of the partners may be a carrier. Other high-risk behaviors include intravenous drug use with shared needles, contact with blood-contaminated articles, and intercourse (vaginal, anal, oral) without the use of a condom. Babies born to women known to be HIV-positive are at high risk.

Blood tests (the ELISA and Western blot) can indicate exposure to the virus. The tests should be taken on a voluntary basis, absolutely anonymously, and with intensive counseling before and after. People who test positively (HIV^+) should not expose anyone else or place themselves in a situation where they might be reinfected. They should do everything they can to maintain good health—exercise regularly, eat a balanced diet, get plenty of rest, and reduce stress. We cannot stop this pandemic in its tracks, but it can be slowed.

Source: World Health Organization of the United Nations multiplication. Viruses do not "reproduce" as do true cells—that is, mitosis or meiosis. In those processes, the contents of the cell are doubled prior to splitting the cell into daughter cells. If automobiles "reproduced," you would find your car parts doubling as time went by (i.e., one steering wheel would become two, two seats would become four, etc.). Then one day you would discover that your "adult" car had reproduced forming two "baby" cars. Cars are not "reproduced" by manufacturers; they are "*replicated*" as are viruses. Virus particles are recreated using a set of instructions (genes) and new building materials.

Some viruses have DNA as their genetic material but many have RNA. The RNA must first be reverse transcribed to DNA before the virus can reproduce. Reverse transcriptase, the enzyme that accomplishes this has become very important in the new field of molecular genetics because its use allows scientists to make large numbers of copies of a specific molecule of DNA.

Viral genes are able to take command of the host's metabolic pathways and direct it to carry out the work of making new copies of the original virus. The virus makes use of the host's available enzymes and ATP for this purpose. When enough new viral nucleic acid and protein coat are produced, complete virus particles are assembled and released from the host (figure 23.11). The number of viruses released ranges from 10 to thousands. The virus that causes polio releases about 10,000 new virus particles from each human host cell. Some viruses remain in cells and are only occasionally triggered to reproduce, causing symptoms of disease. Herpes viruses, which cause cold sores, genital herpes, and shingles reside in nerve cells.

Viruses vary in size and shape, which helps in classifying them. Some are rod-shaped, others are round, and still others are in the shape of a coil or helix. Viruses are some of the smallest infecting agents known to humans. Only a few can be seen with a standard laboratory microscope; most require an electron microscope to make them visible. A great deal of work is necessary to isolate viruses from the environment and prepare them for observation with an electron microscope. For this reason, most viruses are more quickly identified by their activities in host cells. Almost all the species in the six kingdoms serve as hosts to some form of virus (table 23.2).

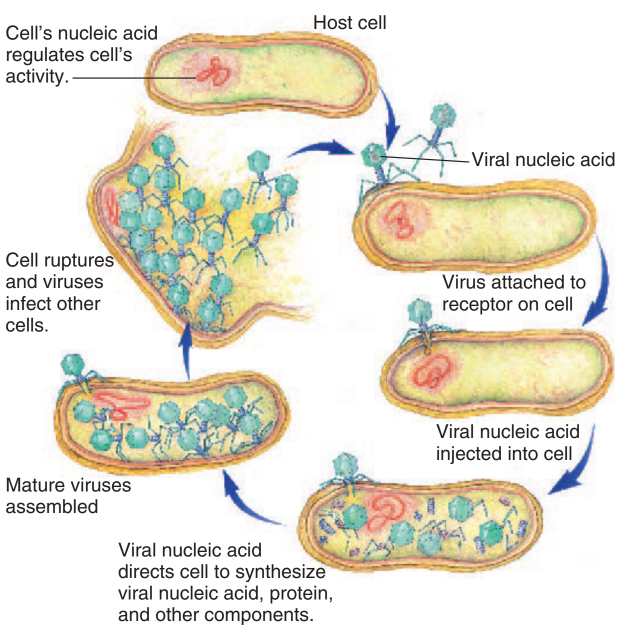


Figure 23.11

Viral Invasion of a Bacterial Cell

The viral nucleic acid takes control of the activities of the host cell. Because the virus has no functional organelles of its own, it can become metabolically active only while it is within a host cell.

Viroids: Infectious RNA

The term **viroid** refers to infectious particles that are only like (*-oid* = similar to) viruses. Viroids are composed solely of a small, single strand of RNA. To date no viroids have been found to parasitize animals. The hosts in which they have been found are cultivated crop plants such as potatoes, tomatoes, and cucumbers. Viroid infections result in stunted or distorted growth and may sometimes cause the plant to die. Pollen, seeds, or farm machinery can transmit viroids from one plant to another. Some scientists believe that viroids may be parts of normal RNA that have gone wrong.

Table 23.2

VIRAL DISEASES

Type of Virus	Disease
Papovaviruses	Warts in humans
Paramyxoviruses	Mumps and measles in humans; distemper in dogs
Adenoviruses	Respiratory infections in most mammals
Poxviruses	Smallpox
Wound-tumor viruses	Diseases in corn and rice
Potexviruses	Potato diseases
Bacteriophage	Infections in many types of bacteria

Prions: Infectious Proteins

Several kinds of brain diseases appear to be caused by proteins that can be passed from one individual to another. These infectious agents are called **prions**. All the diseases of this type currently known cause changes in the brain that result in a spongy appearance to the brain called spongiform encephalopathies. The symptoms typically involve abnormal behavior and eventually death. In animals the most common examples are scrapie in sheep and goats and mad cow disease in cattle. Scrapie got its name because one of the symptoms of the disease is an itching of the skin associated with nerve damage that causes the animals to rub against objects and scrape their hair off.

The occurrence of mad cow disease (BSE-bovine spongiform encephalitis) in Great Britain was apparently caused by the spread of prions from sheep to cattle. This occurred because of the practice of processing unusable parts of sheep carcasses into a protein supplement that was fed to cattle. Other similar diseases are known from mink, cats, dogs, elk, and deer. It now appears that the original form of BSE has changed to a variety that is able to infect humans. This new form is called vCJD which makes scientists believe that BSE and CJD (Creutzfeldt-Jakob disease) are in fact the same prion.

In humans there are several similar diseases. Kuru is a disease known to have occurred in the Fore people of the highlands of Papua New Guinea. The disease was apparently spread because the people ate small amounts of brain tissue of dead relatives. (This ritual is performed as an act of love and respect for the relative.) When the Fore people were encouraged to discontinue this ritual, the incidence of the disease declined. Creutzfeldt-Jakob disease (CJD) is found throughout the world. Its spread is associated with medical treatment, i.e., tissue transplants. Contaminated surgical instruments and tissue transplants such as corneal transplants are the most likely causes of transfer from affected to uninfected persons.

It now appears to be well-established that these proteins can be spread from one animal to another and they do cause disease, but how are they formed and how do they multiply? The multiplication of the prion appears to result from the disease-causing prion protein coming in contact with a normal body protein and converting it into the disease-causing form, a process called *conversion*. Since this normal protein is produced as a result of translating a DNA message, scientists looked for the genes that make the protein and have found it in a wide variety of mammals. The normal allele produces a protein that does not cause disease, but is able to be changed by the invading prion protein into the prion form. Prions do not "reproduce" or "replicate" as do viruses or viroids. A prionecious protein (pathogen) presses up against a normal (not harmful) body protein and may cause it to change shape to that of the dangerous protein. When this conversion happens to a number of proteins, they stack up and interlock, as do the individual pieces of a Lego toy. When enough link together they have a damaging effect—they form plaques (patches) of protein on the surface of nerve cells that disrupt the flow of the nerve impulses and eventually cause nerve cell death. Brain tissues taken from animals that have died of such diseases appear to be full of holes, thus the name spongiform (spongelike in appearance) encephalitis (inflammation of the brain). Because infected organisms lose muscle mass and weight as a result of prion infection, these diseases are now called *chronic wasting diseases (CWDs)*. A person's susceptibility to acquiring a prion disease such as CJD depends on many factors, among them their genetic makeup. If the normal protein is of a significantly different amino acid sequence, the prion may not be able to convert it to its own dangerous form. These abnormal proteins are resistant to being destroyed by enzymes and most other agents used to control infectious diseases. Therefore individuals with the disease-causing form of the protein can serve as the source of the infectious prions.

There is still much to learn about the function of the prion protein and how the abnormal, infectious protein can cause copies of itself to be made. A better understanding of the alleles and the proteins they make will eventually lead to effective treatment and prevention of these serious diseases in humans and other animals.

SUMMARY

To facilitate accurate communication, biologists assign a specific name to each species that is cataloged. The various species are cataloged into larger groups on the basis of similar traits.

Taxonomy is the science of classifying and naming organisms. Phylogeny is the science of trying to figure out the evolutionary history of a particular organism. The taxonomic ranking of organisms reflects their evolutionary relationships. Fossil evidence, comparative anatomy, developmental stages, and biochemical evidence are employed in the sciences of taxonomy and phylogeny.

The first organisms thought to have evolved were single-celled organisms of the Domains Archaea and Eubacteria. From this simple beginning, more complex, many-celled organisms evolved, creating members of the kingdoms Protista, Fungi, Plantae, and Animalia.

Although viruses are not considered living organisms, they are able to display some of the characteristics of life when they invade cells. Because of their pathogenic effects, the viruses are an important factor in the world of living organisms.

THINKING CRITICALLY

A minimum estimate of the number of species of insects in the world is 750,000. Perhaps then it would not surprise you to see a fly with eyes on stalks as long as its wings, a dragonfly with a wingspread greater than 1 meter, an insect that can revive after being frozen at −35°C, and a wasp that can push its long, hairlike, egg-laying tool directly into a tree. Only the dragonfly is not presently living, but it once was!

What other curious features of this fascinating group can you discover? Have you looked at a common beetle under magnification? It will hold still if you chill it.

CONCEPT MAP TERMINOLGY

Construct a concept map to show relationships among the following concepts.

binomial system of nomenclature
class
family
genus
kingdom
order
phylogeny
phylum
species
specific epithet
taxonomy

KEY TERMS

alternation of generations
binomial system of nomenclature
class
family
fungus
gametophyte stage
genus
host
kingdom
obligate intracellular parasites
order
phylogeny
phylum
prion
saprophyte
specific epithet
sporophyte stage
taxonomy
viroid
virus

e—LEARNING CONNECTIONS *www.mhhe.com/enger10*

Topics	Questions	Media Resources
23.1 The Classification of Organisms	1. Why are Latin names used for genus and species? 2. Who designed the present-day system of classification? How does this system differ from previous systems? 3. What is the value of taxonomy? 4. An order is a collection of what similar groupings?	**Quick Overview** • Organizing and naming **Key Points** • The classification of organisms **Animations and Review** • Hierarchies • Kingdoms • Three domains • Phylogeny • Concept quiz **Interactive Concept Maps** • Text concept map **Experience This!** • Developing a classification key
23.2 Domains Archaea and Eubacteria		**Quick Overview** • Overview of bacteria **Key Points** • Domains Archaea and Eubacteria
23.3 Domain Eucarya		**Quick Overview** • Organisms with membrane-bound organelles **Key Points** • Domain Eucarya **Animations and Review** • Characteristics • Diversity • Concept quiz

(*continued*)

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Topics	Questions	Media Resources
Kingdom Protista		**Quick Overview** • Overview of Protista **Key Points** • Kingdom Protista **Animations and Review** • Characteristics • Protozoa • Photosynthetic • Concept quiz
Kingdom Fungi		**Quick Overview** • Overview of Fungi **Key Points** • Kingdom Fungi **Animations and Review** • Characteristics • Diversity • Concept quiz
Kingdom Plantae	5. What is the difference between a bacterium and a plant? 6. What characteristics are there in common between the members of the kingdoms Fungi and Plantae?	**Quick Overview** • Overview of Plantae **Key Points** • Kingdom Plantae
Kingdom Animalia	7. What are the six kingdoms of living things? 8. Eukaryotic cells are found in which kingdoms?	**Quick Overview** • Overview of Animalia **Key Points** • Kingdom Animalia **Labeling Exercises** • Kingdoms of life **Interactive Concept Maps** • The kingdoms
23.4 Acellular Infectious Particles	9. Why do viruses invade only specific types of cells? 10. How do viruses reproduce? 11. What are the components of a viral particle? 12. How are viruses thought to have originated?	**Quick Overview** • Viruses and. . . . **Key Points** • Acellular infectious particles **Animations and Review** • Characteristics • Life cycles • Concept quiz