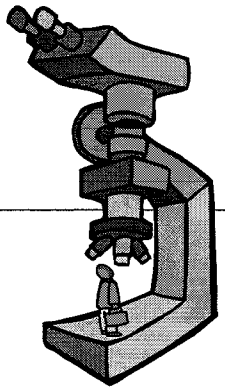
Kingdom Classifications

Section 15.1
The Six Kingdom System



Pre-View 15.1

- **Six Kingdom System** – classification system that includes Animalia, Plantae, Fungi, Protista, Eubacteria, and Archaebacteria
- **Archaebacteria** – newest kingdom that includes organisms that look like bacteria but have different characteristics than "normal" bacteria
- **Eubacteria** – typical bacteria that were classified as Monera in the five kingdom system
- **Prokaryotic** – describes single-celled organisms that do not have a true nucleus
- **Eukaryotic** – describes cells that have a nucleus and other membrane-bound organelles
- **Autotrophic** – describes organisms that make their own food
- **Heterotrophic** – describes organisms that cannot make their own food

The History of Kingdom Systems

When Aristotle first began to classify organisms, he divided them into two main kingdoms, plants and animals. You are probably most familiar with these two kingdoms. As scientists began using microscopes, they discovered microscopic organisms. They also discovered differences in cell structure between different organisms. They discovered that some organisms have characteristics that make it difficult to classify them as either plant or animal. Two kingdoms no longer worked, and eventually they decided on a **five kingdom system**: Animalia, Plantae, Fungi, Protista, and Monera.

The Six Kingdom System

These five kingdoms were used for a while, and many people still think in terms of these five kingdoms. However, more recently, something else interesting happened. With the new technology that became available, scientists discovered that some bacteria have different gene sequences than any other organism living on earth. This discovery led to the formation of a new kingdom called the **archaebacteria**, or "ancient bacteria." In addition to having different gene sequences, these bacteria also have chemical specializations in their cell walls, and they live in the most extreme conditions. All other bacteria were placed in the kingdom **Eubacteria**. Today most scientists use a **six kingdom system** for classification: Animalia, Plantae, Fungi, Protista, Eubacteria, and Archaebacteria. (Not to confuse the point, but some scientists classify the six kingdoms into three main "domains," with a domain being a taxon above kingdom. As we continue to learn more and more, these classification systems may change again!)

The Six Kingdoms

- **Archaebacteria** (newest kingdom) – organisms that resemble bacteria but live in extreme conditions
- **Eubacteria** (known as the **Monera** kingdom in the five kingdom system) – typical bacteria
- **Protista** – examples are algae, protozoa, slime molds
- **Fungi** – examples are molds, mushrooms, yeasts
- **Plantae** – examples are mosses, ferns, grasses, vegetable plants, trees
- **Animalia** – examples are sponges, jellyfish, worms, snails, insects, fish, frogs, lizards, birds, kangaroos

Section 15.1, continued
The Six Kingdom System

Remember that a kingdom is the largest classification group. Organisms in each kingdom share many cellular characteristics. For example, are the organisms unicellular or multicellular? Are the organisms' cells **prokaryotic** (no membrane bound organelles) or **eukaryotic** (have membrane-bound organelles)? Do the cells have a cell wall? If so, what is it made of? Does the organism make its own food (**autotrophic**), or must it obtain food (**heterotrophic**)? Note that organisms that make their own food usually have chloroplasts in their cells, which enable them to carry out photosynthesis. Only a few types of organisms can make their own food without chloroplasts, and those are the ones that undergo chemosynthesis instead of photosynthesis. The chart below shows these main cellular characteristics for organisms in the six kingdoms.

Kingdom	Type of cells	Nucleus?	Cell Wall?	Makes Its Own Food?	Main Types of Reproduction
Archaebacteria (or Archae)	Unicellular	No	Yes, but not made of peptidoglycan	Some do, mostly by chemosynthesis	binary fission, conjugation
Eubacteria (Monera)	Unicellular	No	Most do, usually made of peptidoglycan	Some do, mostly by photosynthesis	binary fission, conjugation
Protista	Unicellular or Multicellular	Yes	Some do, mostly made of cellulose	Some do by photosynthesis	binary fission, conjugation, mitosis, meiosis
Fungi	Unicellular or Multicellular	Yes	Yes, made of chitin and cellulose	No	fission, fragmentation, budding, spores (sexual and asexual)
Plantae	Multicellular	Yes	Yes, made of cellulose	Yes, by photosynthesis	vegetative propagation, sexual spores, pollination
Animalia	Multicellular	Yes	No	No	internal or external fertilization

Kingdom Classifications

Section 15.2
Kingdoms of Archaebacteria and Eubacteria

Pre-View 15.2

- **Bacteria** – single-celled prokaryotic organisms
- **Prokaryote** – a single-celled organism that does not have a true nucleus
- **Archaebacteria** – a type of bacteria that lives in extreme environments
- **Eubacteria** – common bacteria; single-celled, prokaryotic organisms
- **Monerans** – a generic term for all bacteria
- **Archae** – another name for archaebacteria
- **Heterotroph** (or **consumer**) – an organism that cannot make its own food and must obtain food from another organism
- **Parasite** – an organism that gets food by feeding on another living organism
- **Autotroph** (or **producer**) – an organism that can make its own food
- **Saprotroph** (or **decomposer**) – an organism that feeds on dead or decaying organisms or organic wastes
- **Flagella** – a tail-like structure that is used by a cell for movement
- **Binary fission** – asexual reproduction used by bacteria
- **Conjugation** – a type of primitive sexual reproduction used by bacteria to exchange genetic information
- **Endospore** – a dormant stage formed by some bacteria to survive harsh environmental conditions

Bacteria

Organisms that are single-celled **prokaryotes** are called **bacteria**. Remember that prokaryotes do not have a true nucleus or any other membrane-bound organelles. Bacteria are the most widespread and most numerous organisms on the earth.

Bacteria are split into two kingdoms, **Kingdom Archaebacteria** and **Kingdom Eubacteria**. Before being split into two different kingdoms, all bacteria were called **monerans**, and they were classified into a Kingdom Monera. Both types of bacteria can be found growing in weird places, but *most* of the bacteria that grow in "extreme" environments are archaebacteria. (Some eubacteria are also found in extreme environments.)

How are archaebacteria and eubacteria different? Some argue that archaebacteria are so different from eubacteria that they shouldn't even be called bacteria. For that reason, they are sometimes referred to simply as **archae**. Both kingdoms of bacteria have a cell wall (at least most do), but the composition of their cell walls and plasma membranes are different. The genes found in archaebacteria are also very different from those found in eubacteria. The genes are actually more similar to eukaryotes (cells with a nucleus). Let's take a closer look at each of these kingdoms.

Kingdom Archaebacteria

Archaebacteria live in harsh environments and in some strange places — hot sulfur springs, volcanic deep-sea vents on the ocean floor, the Great Salt Lake, and even the intestines of mammals. Some love heat, some love extreme pH levels (acidic or basic), and some love salt. Even though they live in a wide variety of habitats, their relationship to each other is shown in their ribosomal RNA sequencing. (The gene sequences are a major difference between archaebacteria and eubacteria.)

One type of archaebacteria lives deep in the Pacific Ocean near cracks in the ocean floor. These are anaerobic **autotrophs** that are the first step in a very special food chain. (Autotrophs are also called **producers**; they make their own food, and they are food for other organisms.) Instead of using photosynthesis to make their own food, they use chemosynthesis. As you probably remember, **chemosynthesis** uses chemical energy instead of light energy to convert carbon dioxide to carbohydrates. All processes are anaerobic since there is very little oxygen available at those depths.

Many of the archaebacteria are autotrophic and use chemosynthesis to make their own food, but not all do. Some are autotrophic and use photosynthesis, and still others are heterotrophic and must obtain food instead of making it themselves.

Kingdom Eubacteria

The bacteria that you are more familiar with are the **eubacteria**, which are usually classified according to shape and their reaction to a process called Gram staining. A typical bacteria cell is shown in figure 15-1.

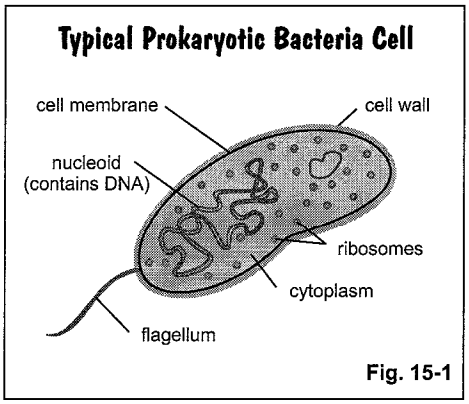


Fig. 15-1

Eubacteria are very diverse. They can be **heterotrophs** (consumers) that must eat other organisms as a food source. Some are **parasites** that get the nutrients they need by feeding on other living organisms. Others are **autotrophs**, which produce their own food. Some autotrophic eubacteria contain chloroplasts and use photosynthesis; others use chemosynthesis. (The archaebacteria are not the only bacteria that use chemosynthesis.) And finally, some are **saprotrophs** and get nutrients by decomposing dead organisms or organic wastes. That's a lot of variety!

Many bacteria have one or more **flagella** that are used for locomotion. The bacterial flagellum works like a propeller on a motorboat. It rotates to propel the bacterium cell forward. About half of the known bacteria use flagella to move around. The other half are unable to propel themselves.

Bacteria Shapes

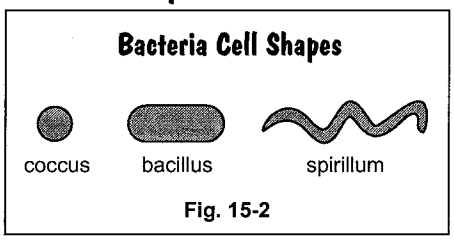


Fig. 15-2

Bacteria cells generally have one of three shapes: coccus, bacillus, or spirillum (figure 15-2). The prokaryotic cell shown in figure 15-1 is bacillus, or rod-shaped. Regardless of the shape, bacteria cells have the same prokaryotic characteristics. Bacteria are named depending on their shape and cell arrangement. For example, *Streptococcus pneumoniae*, the bacteria that causes pneumonia, has a coccus shape, and the cells arrange themselves in a straight line.

Bacteria Reproduction

Both archaebacteria and eubacteria have DNA in their cytoplasm, which may be a single loop. To reproduce, the bacteria cell will replicate its strand of DNA, double its cell size, and then divide in half. As you may remember, this type of asexual reproduction is called **binary fission**. Binary fission produces two genetically identical bacteria cells. Using this method of reproduction, bacteria can reproduce very quickly.

To increase genetic diversity, one bacterium can also exchange genetic material with another bacterium using a primitive form of sexual reproduction called **conjugation**. During conjugation, two bacteria create a hollow bridge between them. Genes can then move across the bridge from one bacterium to the other.

Some types of bacteria, when exposed to extreme conditions, will form **endospores**. Endospores are a dormant stage that can survive harsh conditions, such as high temperatures, toxic chemicals, and drought. When conditions become favorable, the bacterium will again emerge from the endospore.

Bacteria Pros and Cons

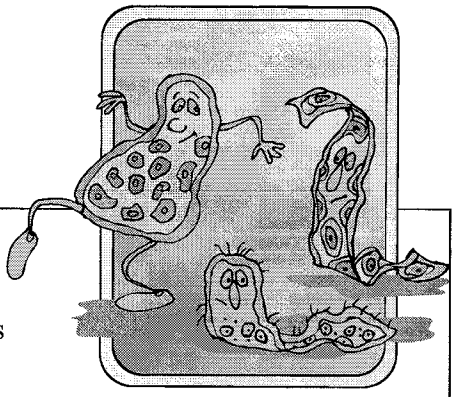
When most people think about bacteria, they think about "germs" that cause disease and infection, but most bacteria are important and beneficial:

- **Nitrogen-fixing bacteria** are an important part of the nitrogen cycle. They live in the roots of certain plants, and they are an example of eubacteria that undergo chemosynthesis. These and other chemosynthetic autotrophs not only make organic molecules for food, but they also do so by breaking down inorganic compounds that contain nitrogen and sulfur.
- Some bacteria live in the soil and help to break down and recycle organic and inorganic materials. These important bacteria are called saprotrophs, or decomposers.
- **Cyanobacteria** are photosynthetic bacteria that live in the water. They produce a great deal of the oxygen that is released into the atmosphere.
- Many foods, such as pickles, yogurt, sauerkraut, and Swiss cheese, depend on bacteria for their distinctive odors and flavors.
- Certain kinds of bacteria are used to make **antibiotics**, such as neomycin and erythromycin, which are used to destroy other bacteria.
- Bacteria called **probiotics** are important for human health. They live in the intestines and produce certain vitamins, enhance the absorption of nutrients, and strengthen the immune system.

Of course, many bacteria do cause diseases. Some bacteria that form endospores can cause botulism or tetanus. Others cause Lyme disease, strep throat, and cavities in your teeth.

Kingdom Classifications

Section 15.3
Kingdom Protista



Pre-View 15.3

- **Protist** – eukaryotic organisms that don't fit into any of the other kingdoms; can be unicellular or multicellular, autotrophs or heterotrophs
- **Eukaryote** – an organism with cells that contain a nucleus or other membrane-enclosed organelles
- **Protozoa** – single-celled animal-like protists; examples: paramecium and amoeba
- **Algae** – a plantlike protist that contains chlorophyll and undergoes photosynthesis
- **Euglena** – a single-celled algae that lives in fresh water
- **Diatom** – a single-celled algae that has a glasslike outer shell

Kingdom Protista is sometimes called the "catch-all kingdom" because it contains so many organisms that don't fit into the other kingdoms. Protists are a very diverse group; there is no such thing as a typical protist! They can be unicellular or multicellular. They can be microscopic or large enough to be seen with the naked eye. Some are autotrophs, and some are heterotrophs. They are alike in that all of them are **eukaryotes**; they have cells that contain a nucleus and other membrane-bound organelles.

Animal-Like Protists

Many protists are somewhat animal-like. They are called **protozoans** and are single-celled. All animal-like protists are heterotrophs. They eat bacteria, algae, and smaller protists.

These animal-like protists are further classified according to how they move.

- The **ciliates** have hairlike projections called cilia that act like oars to help them move. The **paramecium** is a common ciliate that lives in freshwater ponds. See figure 15-3.
- **Flagellates** have one or more flagella to help them move. Several flagellates are parasites that cause disease in humans.
- **Amoebas** are irregularly shaped "blobs" that move by changing the shape of their cell to form **pseudopods**. Amoebas can be found living in fresh water, salt water, wet soil, and even in animals. See figure 15-4. Some also cause disease in humans.
- **Sporozoans** are parasitic protists that live in a host organism. Sporozoans cannot move on their own for most of their life cycle.

Some protozoans and other protists have an organelle called a **contractile vacuole** that pumps excess water out of the cell. This contractile vacuole is important because single-celled organisms, such as paramecia, live in fresh water, which is hypotonic to the cell. Water enters the cell by **osmosis**, and the contractile vacuole pumps the water back out so that the cell does not swell and burst. (Review Section 7.3 on osmosis if needed.)

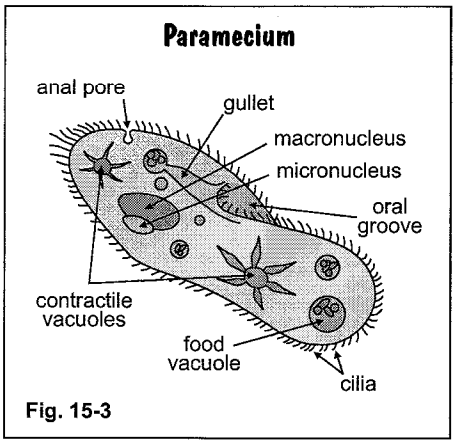


Fig. 15-3

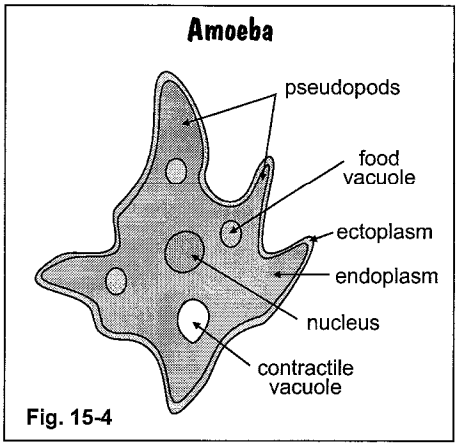


Fig. 15-4

Protozoans can reproduce in a variety of ways:

- Most reproduce asexually by binary fission. Amoebas and most flagellates, for example, reproduce by binary fission.
- Some protozoans can also divide into multiple, identical protozoan cells by a process sometimes called multiple fission.
- Ciliates, such as the paramecium, can often reproduce sexually by conjugation. The process of conjugation is a little more complex than conjugation in bacteria, but the result is the same — an exchange of genetic material between two organisms.
- Still other protozoans, especially parasitic sporozoans, reproduce both asexually and sexually during their lifetimes, and some have complex reproductive cycles. For example in one host, a sporozoan may reproduce asexually by binary fission, and in the next host, it may use the process of meiosis to produce gametes similar to egg and sperm. These gametes will fuse when the life cycle is repeated.

Plantlike Protists

Other protists are much more plantlike. They are autotrophs and contain chlorophyll, so they can carry out photosynthesis. These protists are called **algae** (singular is alga). Algae do not have roots, stems, leaves, or flowers like plants. Because many types of algae contain pigments other than chlorophyll, they may appear red, brown, or even a golden color. Algae are classified according to their color and structure. They range in size from microscopic, single-celled organisms to multicellular organisms measuring meters long. Types of algae include euglenoids, golden algae, green algae, brown algae, and red algae.

- **Euglena** are unicellular algae that live in fresh water and can move around by using a single flagellum. Euglena contain chloroplasts. If light is present, they make their own food by photosynthesis. If they do not have light, they will eat bacteria and smaller protists. Figure 15-5 shows a diagram of a euglena with its organelles labeled.
- **Diatoms** are unicellular algae that have glasslike outer shells. When the diatom dies, the glasslike material collects at the bottom of the ocean and is called **diatomaceous earth**.

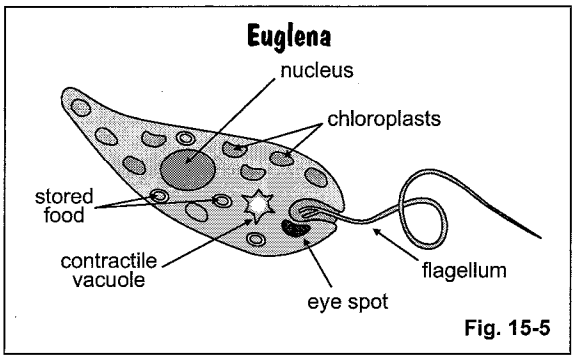


Fig. 15-5

Unicellular plantlike protists usually reproduce by binary fission. Some also reproduce asexually by forming spores that move using a flagellum. These spores are called zoospores. One exception are the diatoms. Diatoms reproduce asexually for several generations, but then they undergo a sexual stage in which they form gametes by meiosis. The gametes fuse to form a zygote, and the life cycle begins again.

Multicellular plantlike protists, such as several types of brown, green, and red algae, often reproduce both asexually and sexually. Many have life cycles that use alternation of generations. One stage of life will reproduce asexually, and the next stage will reproduce sexually.

Funguslike Protists

The remaining group of protists are similar to fungi. The funguslike protists decompose dead organisms. They are able to move from place to place for at least part of their life cycle. These protists include the slime molds, downy mildews, and water molds. Many are very colorful. Funguslike protists reproduce in complex life cycles that often include both asexual and sexual stages.

Don't confuse funguslike protists with the next kingdom we will review, Kingdom Fungi, which contains bread molds, yeasts, and mushrooms, which are immobile.

Pros and Cons of Protists

As with most organisms, some protists are beneficial and others are harmful. The plantlike protists tend to be beneficial.

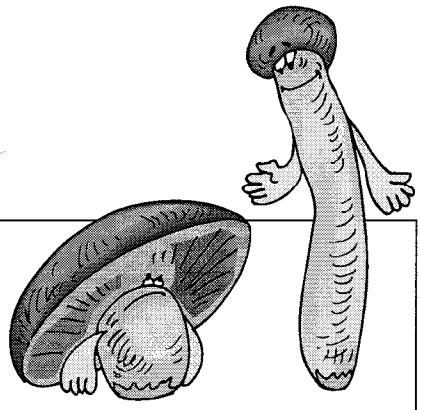
- Algae, the plantlike protists, are important food sources for many types of animals. They are also important in producing much of the world's atmospheric oxygen.
- Algae or substances that are made from algae are found all around the home. Items, such as brownie and cake mix, ice cream, pudding, mayonnaise, toothpaste, salad dressing, cosmetics, vitamins, and paint, may contain algae ingredients.
- Diatomaceous earth, which is left behind by a type of algae, is used as an abrasive in toothpaste and cleaners and also as a filtering agent for liquids. It is even used as a non-toxic insecticide.

Several animal-like protists cause disease.

- The protist *Giardia* is an animal-like flagellate that causes intestinal illness in humans.
- Sporozoans are parasites. The sporozoan *Plasmodium vivax* causes malaria and is transmitted by the female mosquito of a certain species.

Kingdom Classifications

Section 15.4
Kingdom Fungi



Pre-View 15.4

- **Fungus** – a eukaryotic organism that has a cell wall usually made of chitin, is usually multicellular, and is always a consumer (heterotroph) or a decomposer (saprotroph)
- **Consumer** – an organism that must obtain food from another organism; a heterotroph
- **Chitin** – a complex carbohydrate that makes up the cell walls of most fungi cells
- **Hyphae** – threadlike structures used by fungi to break down and absorb food
- **Basidiospores** – mushroom spores formed by meoisis
- **Sporangium** – a specialized type of hypha used by certain molds that produce spores asexually
- **Zygospore** – a spore formed by sexual reproduction in certain molds
- **Saprotroph** – an organism that feeds on dead or decaying organisms; a decomposer
- **Lichen** – an "organism" made up of a fungus and an alga living together in a mutualistic relationship
- **Rusts** and **smuts** – types of fungi that cause plant diseases

If you look hard enough, you can find fungi just about everywhere. Fungi like to grow anywhere that has moisture — on the walls of basements and bathrooms, in yards and gardens, and even on people's feet. Most fungi are multicellular although there are a few single-celled fungi, such as yeasts.

The Roles of Fungi

Fungi used to be classified as plants, but they do not contain chlorophyll, and therefore, they can't undergo photosynthesis. Plants are called **producers** (autotrophs) because they make their own food and provide food for other organisms. Fungi, on the other hand, are either **consumers** (heterotrophs) or decomposers (saprotrophs). Either way, they obtain their food from another organism. A fungus gets nutrients by something called *extracellular digestion*. They are heterotrophs that send out threadlike structures called **hyphae** into their source of food. The hyphae release enzymes that break down the large food molecules into molecules small enough to diffuse directly into the hyphae. Unlike plants, which have cell walls made of cellulose, most fungi have cell walls made out of a complex carbohydrate called **chitin.**

Fungi Reproduction

Some fungi reproduce sexually, some asexually, and some both sexually and asexually. Examples of fungi reproduction are given below:

- Yeasts reproduce asexually by budding or by fission. In **budding**, a new yeast organism grows from a parent organism and eventually breaks off to form a new yeast cell. In **fission**, the yeast splits in half to form two yeast cells.

- Most mushrooms reproduce sexually by forming spores called **basidiospores**. These spores are produced in the cap of the mushroom. The spores, produced by meiosis, are haploid, and two compatible spores must germinate and fuse in order to produce a new mushroom.

- Bread molds and many other fungi can produce sexually or asexually. Bread molds can produce asexual spores in a specialized hypha called a **sporangium**. The sporangium releases the spores, and the spores can germinate and grow hyphae and additional sporangia. Bread molds can also reproduce sexually when environmental conditions become unfavorable. Two compatible mating strains of hyphae fuse together to form a **zygospore**. The zygospore has a thick wall and can remain dormant until conditions are favorable for germination.

Pros and Cons of Fungi

Many fungi are beneficial.

- Some fungi, such as mushrooms, are **saprotrophs**, which means they feed on dead organic matter. In the environment, fungi play an important role as **decomposers**, organisms that break down dead organisms and waste material.
- Many people like to eat mushrooms (although some mushrooms are poisonous).
- Yeast cells are added to bread dough to make it rise.
- A certain species of the *Penicillium* mold is used to make the antibiotic penicillin.
- Still other molds are used in making cheeses.
- The **lichens** that you see growing on rocks and trees are actually two organisms made up of a fungus and usually a green alga that have formed a mutualistic relationship so that both organisms benefit by living closely together. Lichens are important to the environment because they break down rocks into soil so that plants can grow. They also enrich the soil with nutrients when they themselves die and decompose.

Other fungi are harmful.

- Fungi that cause plant diseases are called **rusts** and **smuts**. They destroy large amounts of timber and crops each year.
- Some fungi produce spores that can be fatal if inhaled by humans.
- Others fungi, like the ones that cause ringworm and athlete's foot in humans, are parasites and absorb nutrients directly from the cells of the host organism on which they live.