Unit 5

Small Plants and Little Animals

When the telescope was invented, it permitted people to see many stars that before could never have been seen. Likewise, the invention of the microscope opened a new world to man. Our study has shown that the size of these organisms is by no means a measure of their importance, for they make up by their vast numbers what they lack in diameter. Furthermore, some of these one-celled creatures are veritable chemical laboratories, synthesizing such important substances as vinegar and alcohol; even secreting toxins able to kill people. Yet much of the animal world is dependent upon these small plants and little animals for food. Important things often come in small packages.

Not your average puffball

While most puffballs are only a few inches across, the boy in this photograph was included to illustrate just how large the *giant puffball* can grow.

Kingdom Fungi: Non-green Plants

CLASSIFICATION OF FUNGI

10-1 Plants Without Chlorophyll

Fungi (fŭn´jī; *sing.* fungus, fŭng´gəs) are "plants" without chlorophyll (klôr´ə•fĭl). Chlorophyll is a complex chemical that in the presence of light breaks down water and carbon dioxide and recombines their atoms to produce carbohydrates (usually glucose). This process of **photosynthesis** (*photo* [light] + *synthesis* [to combine]) produces carbohydrates for all living things. Because fungi lack chlorophyll, they are unable to manufacture food; therefore, they must obtain it from other sources. Those that obtain food from living hosts are called **parasites**, or are said to be *parasitic*. Those obtaining food from nonliving organic matter are called **saprophytes** (săp´rə•fīts), or are said to be *saprophytic*.

10-2 Difficulty in Classification

In no section of biology is there more disagreement than over the classification of plants without chlorophyll. The major divisions, however, are evident. Bacteria are minute, one-celled microorganisms (fungus "plants"). Yet the slime molds, a group of fungus-like plants, have been the object of much controversy. During a part of its life cycle, a slime mold resembles a one-celled animal and might be considered an animal. But at another stage, it produces spores in structures, characteristic of molds, and is definitely plantlike. Generally, it is accepted that Kingdom Fungi includes fungus, molds, yeasts, rusts, and smuts (with the exception of **lichens** [lī´kəns], which are a fungus and an alga growing in *symbiotic* association; see "Lichens: Two Plants in One" in chapter 12). The members of the four phyla in the Fungi kingdom are separated by the type of reproduction used—*conjugation fungi*, *sac fungi*, *club fungi*, and the *imperfect fungi*, whose method of reproduction is unknown.

10-3 Slime Molds

These strange organisms grow on dead plant matter (occasionally on living plants) in moist woodlands. Sometimes they grow on the grass in a lawn. At one stage, they form a large mass of moving protoplasm, called a **plasmodium** (plăz•mō´dē•əm), with many nuclei and no cell wall. The often brightly colored plasmodium may extend over several square feet of area. The organism feeds on bits of decaying matter, bacteria, or protozoa. It is able to ingest solid particles, an animal characteristic. The protoplasm flows, alternating the direction of flow at regular intervals.

In a dry, adverse environment, the plasmodium may rapidly change into clusters of fruiting bodies called **sporangia** (spə•răn´jē•ə). These structures produce spores, the reproductive cells. If the spores germinate, they produce tiny cells that possess two flagella (microscopic, hairlike structures). The flagella propel the cells through

Figure 10-1 A slime mold growing on a decaying tree stump. The plasmodium is developing fruiting bodies (sporangia), which are brownish in this photo.

water. Amoeboid cells form a structure that eventually forms the plasmodium.

The slime molds are of little importance to man, being neither harmful nor helpful. They have been the objects of much study because of their strangeness and beauty, and because of the nature of their protoplasm.

Because of the plant-animal characteristics of slime molds as well as other organisms, taxonomists set up the three other kingdoms—**Protista** (or Protoctista), **Monera** (or Prokaryotae), and **Fungi**. Evolutionists consider such organisms as evidence that life started as cells that were neither plant nor animal and that the two other kingdoms branched from these original cells. Such "primitive" cells do not exist now, and there is no positive fossil evidence that they ever did. It is generally recognized that the slime molds are more complex than these so-called original primitive cells might have been. For these reasons, creationists believe that such groups have been distinct from the beginning.

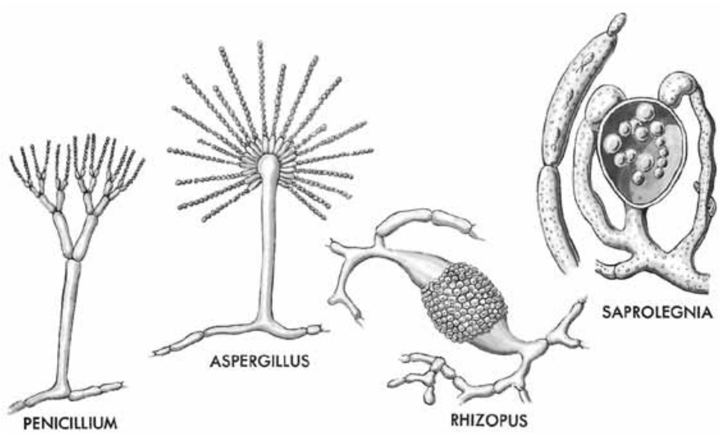

Figure 10-2 Various types of fungi

10-4 True Fungi

The main structure of a true fungus is a mass of threadlike strands of protoplasm, growing in various directions, resembling a spider web (Figure 10-2). A single strand is called a **hypha** (hī´fə); *pl.* hyphae [hī´fē]), and the whole network is a **mycelium** (mī•sē´lē•əm, *pl.* mycelia [mī•sē´lē•ə]). The structure can be seen in a young mold with the aid of a magnifying lens. With food and moisture, the hyphae grow rapidly. The reproductive bodies are spores, which are borne in such large numbers that their color—black, green, or brown—may give color to the whole fungus. A spore is a single cell that can grow into a mature plant. It is different from a seed in that it contains no embryo plant and very little stored food. Since it lacks these features, a spore cannot grow unless conditions are very favorable. In addition to this asexual method, some fungi reproduce sexually by the union of two cells, or gametes, to form a zygote.

Questions: Classification of Fungi

1. Why was it difficult to classify fungi? Give examples.
2. What are the differences between a seed and a spore?
3. What is the main difference among the phyla of this kingdom?

Taking it Further: Classification of Fungi

1. List several positive and negative effects of fungi.

Figure 10-3 Typical structure of classic mold spores on a branch
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THE MOLDS

10-5 Blue-green Molds

There are two common genera of these molds—*Penicillium* (pĕ•nə•sĭ´lē•əm; *pl.* penicillia [pĕ•nə•sĭ´lē•ə]) and *Aspergillus* (ăs´pər•jĭ´ləs; *pl.* aspergilli [ăs´pər•jĭ´lī]), which resemble each other in structure. The spores are formed in chains at the tips of stalks. *Aspergillus* produces more chains than *Penicillium*. *Penicillium* is nearly always blue or green in color. It is found on citrus fruits and is used commercially in the production of blue cheese. *Aspergillus* may be black, rust, or green. It is a common mold found on foods.

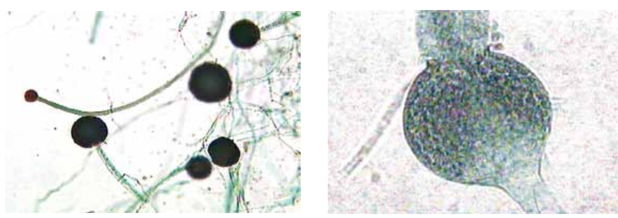

Figure 10-4 Common bread mold, *Rhizopus* with close-up of the sporangia bursting open, releasing the spores (right)

10-6 Bread Molds

One of the most common bread molds, having black spores, is called *Rhizopus* (rī´zə•pəs). In this mold, the sporangia are in the form of globular heads. This genus

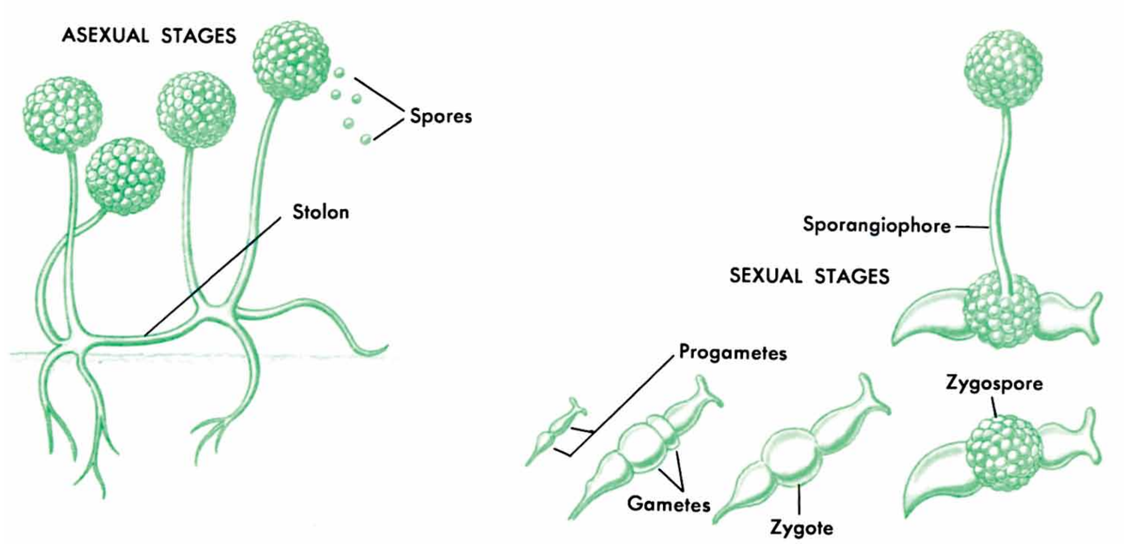

Figure 10-5 *Rhizopus* is a bread mold that reproduces both sexually (right) and asexually (left).

is interesting because the hyphae grow over the surface of the bread, starting other colonies. Such hyphae have no cross walls between the cells. This genus is an example of mold that can reproduce sexually by conjugation. Two hyphae join at the tips (Figure 10-5). The ends of the hyphae form gametes that unite to form zygotes, in this case known as **zygospores** (zī´gə•spôrs´). Eventually, the zygospores germinate and start another colony. The joining hyphae look alike but are different strains, designated plus (+) and minus (–). The majority of spores are formed asexually.

10-7 Water Molds

The *Saprolegnia* (să´prə•ləg´nē•ə), or water molds, are similar to *Rhizopus* in structure (Figure 10-2). Some are saprophytes and remove dead matter from water by eating and digesting it. Other forms are parasitic. They are sometimes a problem in aquariums, where they may attack fish. One may see this mold on a dead fly in water.

Questions: The Molds

1. To what phylum do the *conjugating* (or algal) *fungi* belong?
2. What other applications does *Penicillium* have besides making cheese?
3. What is the difference between a saprophyte and a parasite?

Taking It Further: The Molds

1. Find an example of a living mold and, by its color and location, try to determine its genus.

OTHER FUNGI

10-8 Harmful Fungi, Parasitic on Plants

There are two classes of mildews that attack plants. The least harmful are the **powdery mildews**, which form whitish or grayish patches on the leaves of many plants such as roses, lilacs, grapes, and apples. Mildew grows chiefly on the surface of the leaf. The **downy mildews** often extend deeper into the cells of the plants and are more deadly. One of these fungi caused the potato famine in Ireland, which lasted from 1845 to 1849. Probably a million people starved, while nearly the same number emigrated—mostly to North America, with some to Australia and Britain; thus, this particular mold helped change the course of history. These plants attack other farm and garden plants, as well.

Figure 10-6 Powdery mildew on the leaves of a lilac bush

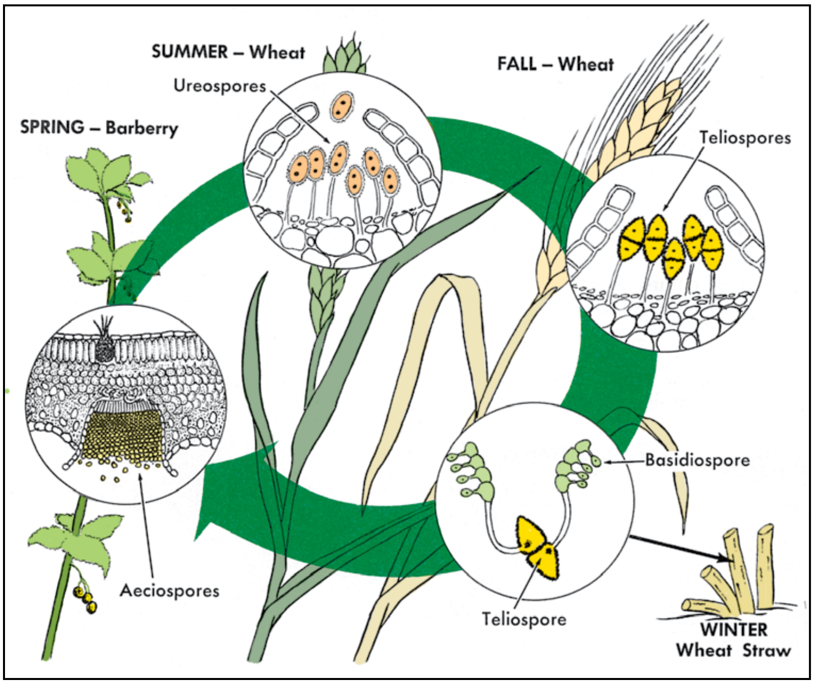

Figure 10-7 The wheat rust cycle

The **rusts** are a group of fungi that require two hosts (Figure 10-7). Some rusts cause serious damage to crops; the most important among these is wheat rust (Figure 10-8). This fungus attacks wheat (the first host) during the time it is producing seeds. At this stage, the rust is reddish in color from the red spores. Late in the summer, the fungus enters a second stage in which it forms black spores on the dry stalks left in the fields. These spores then are blown by the wind and fall on barberry bushes (the second host), where they attack the leaves in the spring. A third type of spore is formed on the barberry bushes, which is blown to the young wheat, and again the red stage is produced. (The Japanese barberry, the one most often planted, is not a host for this rust.)

Destroying barberry bushes is one method of controlling the fungus, but it is not effective because the spores can be blown many miles, and it is difficult to remove all the barberry bushes. A more effective control is the breeding of rust-resistant wheat, which has been one of the major accomplishments of the wheat geneticists.

Smuts are fungi producing black spores that attack cereals (plants of the grass family such as corn, barley, oats, and rye). Corn smut is especially conspicuous because it forms large, blister-like structures on the ears and stems of corn (Figure 10-9). Corn smut causes much economic loss. The disease is best controlled by plowing the stalks under or by burning infected stalks.

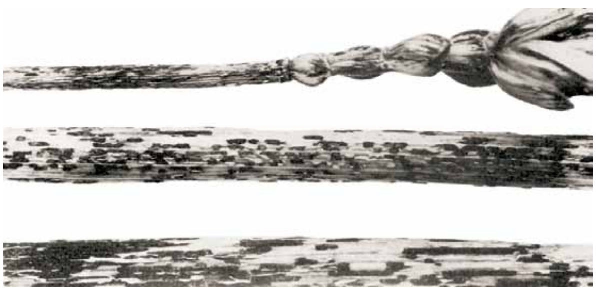

Figure 10-8 At the top are wheat stems blighted by rusts.

The middle two photos show normal, plump wheat kernels (left) and the same number of rust-blighted kernels (right).

The common barberry bush (bottom) is the second host for the rusts.

Rusts can also affect oats, barley, and rye in a similar manner.

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Figure 10-9 A large, ripe corn smut mass atop the stem has burst open, releasing great quantities of fungal spores.

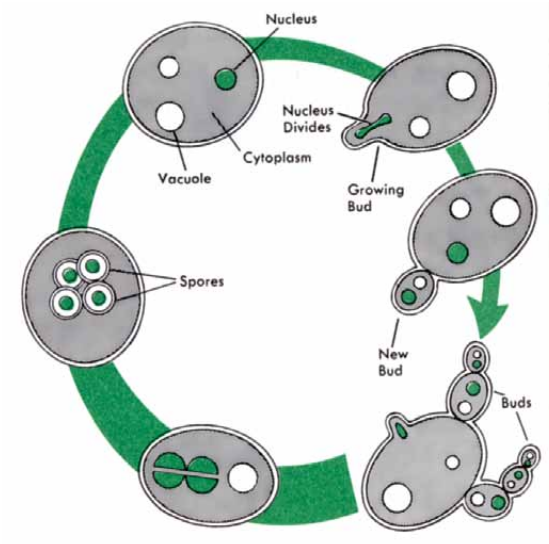

Figure 10-10 Yeast cells. Yeasts reproduce both by spore formation and by budding.

10-9 Yeasts

Yeasts (Figure 10-10) are one-celled fungus plants and members of the **sac fungi**. Structurally, they are different from the other fungi. No hyphae are formed. The plants reproduce by budding; that is, a small cell grows from the side of the mother cell. Sometimes chains are formed with each successive cell smaller than the preceding one. The plants also form spores that can remain inactive for a long time. The *dry yeast* used in baking is made of yeast at the spore stage. Like the slime molds, the yeasts create real problems in classification for the taxonomist.

Yeasts are extremely important commercially. They obtain their food from plant substances or sugars. The chemical process involved, called **fermentation**, produces alcohol and carbon dioxide gas. This same fermentation process of a fruit or cereal by a yeast and sugar produces all alcohol. Alcohol is used industrially as a solvent; it is the most commonly employed solvent next to water. It is the basis of alcoholic beverages, and its germicidal qualities make it useful in medicine. It is also used as a preservative. Yeast is used in baking. It acts on the sugar in the dough, producing tiny bubbles of gas that make the bread puffy and light. The alcohol that the yeast produces is broken down by the heat when the bread is baked and the yeast is killed. Yeasts are used as supplements to other foods, being a good source of vitamin B.

10-10 Fleshy Fungi: Mushrooms and Toadstools

These interesting plants (Figure 10-11) grow in organic matter under the surface of the soil and are examples of **club fungi**. The common mushrooms are classified as *Basidiomycetes* (bə•sĭ´dē•ō•mī´sēts´). Several others are in the group *Ascomycetes* (ăs´kō•mī´sēts´), which also contains some molds and the yeasts. The fibers, or mycelium, form a mass underground. Some fibers form the fruiting body, which is seen above ground. That these structures are composed of fibers can be detected only with a magnifier. The fruiting body consists of a stalk called the **stipe** (stīp´), with a cap that is somewhat like an umbrella. Flat, plate-like structures called gills are found on the lower side of the cap. The gills produce the spores. Many mushrooms are edible; but some, commonly called toadstools, are extremely poisonous. There is no sharp structural difference between mushrooms and toadstools. The **morel** (mə•rĕl´), which resembles a shallow honeycomb with the shape of a corncob, is one type that is easily identified.

Figure 10-11 The meadow mushroom, *Agaricus compestris*, side-view (above) and underside (below), showing gills with ripe spores

Bracket fungi are shelf-like structures growing on the sides of dead trees, stumps, or logs. Some are quite large. Most bracket fungi are parasites, doing great damage to living trees. Spores are produced on the under side of the shelves. The mycelium penetrates the wood.

Figure 10-12 Typical bracket fungus

Figure 10-13 Giant puffball a foot wide (top) releases millions of tiny airborne spores when struck after ripening (below).

10-11 Puffballs

These fungi are similar to mushrooms that never open but are balls with the gills inside. They are edible if they are gathered before the spores mature. When ripe, the brown spores issue in a cloud when something presses the puffball.

10-12 Fungi Pathogenic to Man

Pathogenic (păth´ə•jĕ´nĭk, disease-causing) **fungi** produce some of the most serious infections attacking man. Such infections are extremely difficult to cure and often remain for many years. A fungal infection is called a **mycosis** (mī•kō´səs; *pl.* mycoses [mī•kō´sēs]). In most of the fungi pathogenic to man, no sexual stage is known, so they are classified as the fungi imperfect.

Coccidioidomycosis (kôk•si´dē•oi´dō•mī•kō´səs) is a disease caused by the fungus *Coccidioides* (kôk•si´dē•oi´dəs) *immitis* (ĭm•mī´təs). There are two forms of this disease. The more common, called San Joaquin Valley fever, desert fever, or desert rheumatism, produces symptoms in the early stages similar to those of influenza. Spores are sometimes formed and, in later stages, symptoms may resemble various other diseases. This form of the disease rarely is fatal. In the more serious form, the fatality rate is high. It is believed by some mycologists that the spores are inhaled. The disease occurs in several states. It has been found in dogs, sheep, and rodents. It has now been proved that man can get the disease from spores in the dust. If rodents have the disease, one might expect spores around their burrows. There is no known way to prevent *Coccidioidomycosis.*

Fungal skin infections include the common **athlete's foot**, and **ringworm** of the scalp. Both diseases are spread by contact or by touching articles contacted by an infected person. Athlete's foot is especially hard to treat. Some people carry the infection for many years. Other fungus infections occur on the fingernails and in the ears. Some fungi attack the skin of the feet and legs.

Thrush is a mycosis sometimes found in children. Symptoms include white patches in the throat and mouth. Strange to say, the disease is caused by a type of fungus that normally occurs in the mouths of many people without causing any harm. Thriving in a warm, moist climate, the mycoses are far more prevalent in the tropics than in temperate climates.

It is believed that many human fungal pathogens are saprophytes living off organic matter in soil. Many of the fungi that grow on foods are soil fungi. Sometimes, though rarely, soil fungi that normally are harmless cause human infections. For this reason, mold cultures grown in the laboratory by students as projects should be sterilized before disposal.

Questions: Other Fungi

1. To what phylum do the *sac*, *club*, and *imperfect fungi* belong?
2. What is a *mycosis*?
3. Why do rusts require two hosts?

Taking It Further: Other Fungi

1. Give an example of each type of fungi and describe its method of reproduction.

BENEFITS FROM FUNGI

10-13 Fungi and Medicine

The art of healing has gone through a series of changes. For hundreds of years, the only medicines known were derived from plants, and some of these still are used. **Quinine** is an example. A direct, synthetic process now makes some of these drugs. A great forward step was made after it was learned that many diseases are caused by tiny organisms. Then means were developed to kill these germs of disease, but it is hard to kill them without killing the patient also. The healing art greatly expanded after it was discovered that certain molds give off substances that control or even kill bacteria. These substances are called *antibiotics*.

Penicillin was the first antibiotic discovered and was the one most widely used until resistant strains of bacteria became more abundant. **Sir Alexander Fleming** (1881–1955), a Scottish bacteriologist, was studying influenza. He had a number of cultures of bacteria in covered glass dishes, which were supposed to keep out undesired organisms. As Fleming looked at these cultures, he saw that some of them had been contaminated with a mold that he recognized as *Penicillium notatum* (nō•tā´təm). Then he made an observation that has become famous: around the mold was a circle free of bacteria colonies. Evidently the mold produced a substance that kept bacteria from growing. Other men took up the study of the substance. The end of the dramatic study took place in the United States, where the drug finally was produced in sufficient quantities for wide use.

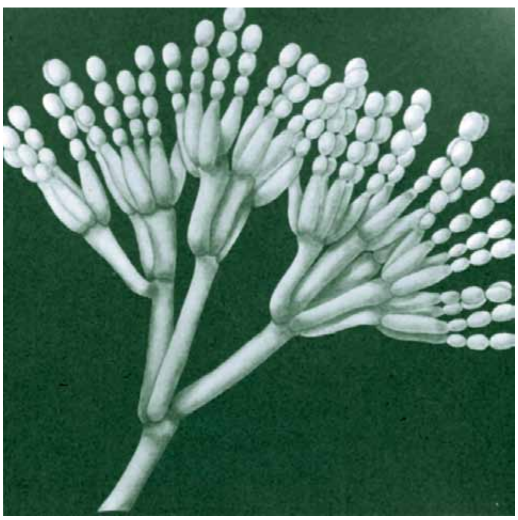

Figure 10-14 Characteristic structure of *Penicillium chrysogenum* stalk (greatly enlarged), showing chains of spores that can initiate new growth

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Following the success of penicillin, other antibiotics were discovered. These drugs clear up infections caused by certain types of bacteria. Perhaps some students using this text are living today because of antibiotics.

Figure 10-15 Some species of puffballs are edible if harvested in the early stages.

10-14 Fungi as Foods

Edible mushrooms have already been mentioned but not elaborated on. Mushrooms can be purchased canned or fresh in the grocery stores. Nearly all of these mushrooms are grown in the eastern United States. They are grown in flat trays with a thin layer of soil over a layer of compost, usually horse manure. The plants must be kept in a dark area with both temperature and humidity under careful control. Light does not harm mushrooms directly, but it causes fluctuations of temperature and humidity. Coal mines and caves are often used for growing them.

In France, truffles, fleshy fungi that grow underground, are relished. Dogs or pigs are trained to locate these fruiting bodies.

Cheeses are produced by the action of bacteria or molds on milk. (See “Bacteria in Industry” in chapter 11.)

10-15 Ecological Importance of Fungi

Fungi and bacteria are **decomposers**. That is, they attack dead plants and animals and break them down, returning the elements to the soil and atmosphere. The odor of newly plowed earth is due largely to the fungi in the soil. Decomposers perform a vital function. Living things utilize a great many chemical elements in their cytoplasm; some of these elements are not very abundant in nature. When the organism dies, these elements must be released through the breakdown of the complex chemicals that make up the organism, and the decomposers do this. Then plants use the minerals produced by the action of fungi to grow. In this way the Creator has provided a never-ending source for these elements, and at the same time a means of clearing away dead plants and animals. Herbivores eat the plants and carnivores eat the herbivores. The complex chemicals of plants, herbivores, carnivores, and waste products of animals are broken down by the fungi and returned to the earth. This completes the cycle. Were it not for this action of the fungi and other organisms that perform the same role, the earth would be littered with dead bodies.

Some fungi form a strange and interesting association with the roots of certain plants, especially trees such as the pines. The hyphae may grow within the cells of the roots and extend their mycelium out into the soil. This structure composed of a fungus and a root in close association is called a *mycorrhiza* (mī′kə•rī′zə, *myc* [fungus] + *rhiza* [root]). There are differences of opinions regarding *mycorrhizae* (mī′kə•rī′zē). Some scientists think the fungi are parasites, some think they aid the root in absorption, and some have other ideas as to their role. Experiments have shown that mycorrhizae do help pine trees. Much research, however, remains to be done on this fascinating subject.

There are several species of fungi that **parasitize** (pâr′ə•sə•tīz′) insects. Some have been used experimentally as a means of insect control and have been very successful in some instances. This is just one of many possibilities for biological control of insects.

Fungi are of great importance to man. This is one of the reasons why scientists have sought to find order in the complexity of this interesting group.

Questions: Benefits From Fungi

1. List several benefits of fungi.
2. What is a *decomposer*, and why are they so important?
3. How are fungi used in medicine? In the production of food?

Taking It Further: Benefits From Fungi

1. Find an article on the use of any fungus as an insecticide and summarize the findings.

Questions: Chapter Review

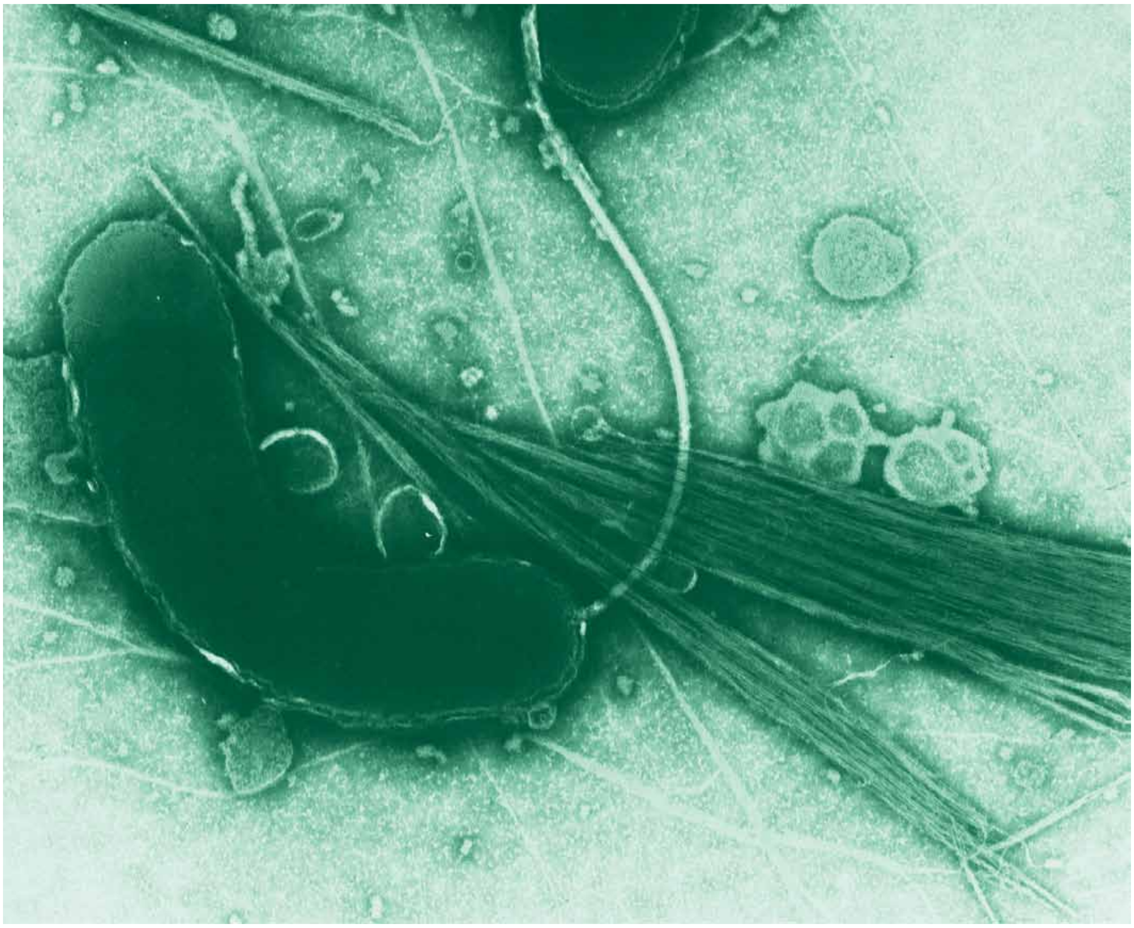
1. Are the majority of molds parasites or saprophytes?
2. What are the principal structures of the true fungi?
3. How is the reproduction of yeast different from that of *Penicillium*?
4. How do barberry bushes illustrate the importance of correct naming, which was stressed in chapter 2?
5. Why do people not become intoxicated when they eat bread?
6. What precautions should be taken to avoid athlete's foot?
7. Why is a coal mine a good place to raise mushrooms?
8. Why can a person not raise mushrooms in ordinary garden soil?
9. Lumber is stacked with slats between the layers. How does this arrangement protect the lumber from molds?
10. To what extent was Sir Alexander Fleming's discovery based on chance, and to what extent on training?

Spalting–Fungus and Wood

Bracket fungi known as "conks," such as on this hard maple, are tell-tale signs of spalting. Spores produced on the underside of these conks will be carried by wind to other hosts.

Spalted hard maple boards have been planed to reveal interesting patterns. Such boards were once discarded as "seconds" but are now highly prized.

Wood-inhabiting fungi are the principle agents in the decomposition of wood. They break down dead wood such as stumps and roots of fallen trees. Sometimes, these fungi are hard at work in trees long before they die. They invade the cell structure, dissolving the cell walls by enzyme action. As the decay process continues, dark staining occurs at the edges of certain "zones." If the tree is harvested and sawn before the decay has advanced too far, beautiful, irregular patterns of light and dark are revealed between these zones. This fungus-induced coloring is known as "spalting" and occurs in many species. It has become a favorite among many woodworkers.



O395 Cholera wild type. Transmission electron microscope (TEM) image of *Vibrio cholerae* that has been negatively stained. *Vibrio cholerae* is the bacteria responsible for the gastrointestinal disease cholera. In order to get the disease cholera, the bacteria must be able to colonize in the small intestine, and a critical factor necessary for this colonization is the toxin-coregulated pilus (TCP). 0395 is a wild type strain, showing the normal bundling of toxin-coregulated pilus (TCP). Wild-type pili are clearly visible as 7 nm fibres that form bundles @ 0.2 Ð 0.3 µm wide and 3 Ð 6 µm long.

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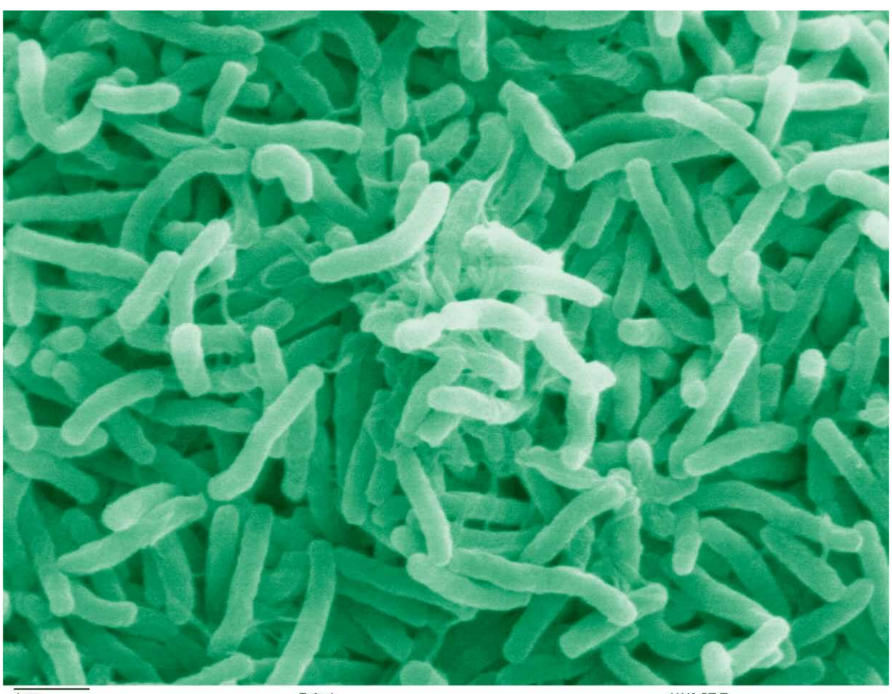

Scanning electron microscope (SEM) image of *Vibrio cholerae* bacteria, which infect the digestive system

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