LABORATORY

14

Bacteria and Protists

Learning Objectives

14.1 Bacteria

- Describe how bacteria reproduce.
- Distinguish gram-negative from gram-positive bacteria.
- Identify the three commonly recognized shapes of bacteria.
- Recognize *Gloeocapsa*, *Oscillatoria*, and *Anabaena* as cyanobacteria.

14.2 Protists

- Compare and contrast the characteristics of amoeboids and ciliates and discuss their diversity.
- Describe various types of locomotion used by protozoans.
- Identify and give examples of green, red, and brown algae.
- Describe the structure and importance of diatoms and dinoflagellates.
- Describe sexual reproduction in plasmodial slime molds.

Introduction

For study and comparison, organisms are classified into groups according to their evolutionary relationships. **Taxonomy** is the science of classification. Within the smallest group, the **species**, organisms share the same structure and usually can interbreed and produce fertile offspring. Closely related species are placed in the same **genus.** The genus and specific epithet indicate the organism's **scientific name.** For example, *Zea mays* is the scientific name for corn, and *Homo sapiens* is the scientific name for humans. (The genus name is capitalized, while the specific epithet is not. Both names are italicized.) Closely related genera are placed in the same **family,** closely related families in the same **order,** and so on, with each category becoming larger and more inclusive up to the largest category—**domain.** The major categories of classification are shown in Table 14.1.

Table 14.1 Classification of Organisms

Categories	Corn
Domain	Eukarya
Kingdom	Plantae
Phylum	Anthophyta
Class	Monocotyledones
Order	Commelinales
Family	Poaceae
Genus	*Zea*
Species*	*mays*

*To specify an organism, you must use the full name, such as *Zea mays*.

Modern biochemical analyses have shown that a common ancestor gave rise to three distinct lineages which we call domains. Domain Bacteria and domain Archaea contain unicellular *prokaryotes* (lack a membrane-bounded nucleus), whereas domain Eukarya contains *eukaryotes* (have a true nucleus). The organization within domains Bacteria and Archaea are currently being debated so there is no agreement on kingdoms within these domains. Domain Eukarya includes four kingdoms: Protista, Plantae, Fungi, and Animalia.

14.1 Bacteria

Bacteria, including **cyanobacteria** (formerly called blue-green algae), are the simplest of organisms. Their cells are prokaryotic and lack the organelles found in eukaryotic cells. For example, while prokaryotes do contain DNA, they have no defined nucleus, and while some prokaryotes have thylakoids (membranous bags or disks), there are no chloroplasts. Reproduction is primarily asexual by **fission** (cell division without a spindle apparatus). Most bacteria are **saprotrophic,** meaning that they send out digestive enzymes into the environment and thereafter take up the resulting nutrient molecules. Some bacteria are **parasitic** and cause diseases, such as strep throat or gangrene. Other bacteria are **photosynthetic** or **chemosynthetic** and thus are able to make organic molecules utilizing inorganic molecules. Cyanobacteria are always photosynthetic. They contain chlorophyll, but the green color often is masked by other pigments. In fact, some cyanobacteria are red, brown, or even black.

Gram Stain

Most bacterial cells are protected by a cell wall that contains a unique molecule called peptidoglycan. Bacteria are commonly differentiated by using the Gram stain procedure, which distinguishes bacteria with a thick layer of peptidoglycan (Gram-positive) from those that have a thin layer of peptidoglycan (Gram-negative). Gram-positive retain a crystal violet-iodine complex and stain blue-purple, whereas gram-negative bacteria decolorize and counterstain red-pink with safranin.

Experimental Procedure: Gram Stain

1. Use one designated square of a slide that has six squares for samples.
2. With a sterile cotton swab, obtain a sample from around your teeth or inside your nose.
3. Carefully roll the swab across your allotted square. Body samples must be spread out thinly and evenly on the slide.
4. Allow the smear to air dry.
5. Fix the smear by flooding the slide with absolute methanol for 1 minute. Allow the smear to dry before staining.
6. Flood the smear with Gram Crystal Violet, and wait for 1 to 2 minutes.
7. Gently rinse off the crystal violet with cold tap water.
8. Flood the smear with Gram Iodine, and allow it to react for 1 minute.
9. Gently rinse off the iodine with cold tap water.
10. Gently rinse the smear with Gram Decolorizer until the solution rinses colorlessly from the slide (approximately 20 to 30 seconds).
11. Immediately rinse the smear with cold tap water.
12. Flood the smear with Gram Safranin, and allow it to stain for 15 to 30 seconds.
13. Gently rinse off the safranin with cold tap water.
14. Blot off excess water with a paper towel, and allow the smear to air dry.
15. Examine microscopically. (This will require the use of the oil immersion lens.)

Structure of Bacteria

On a nutrient material called agar, bacteria grow as colonies. A **colony** contains cells that are descended from one original cell. It is possible to identify the type of bacterium by the appearance of the colony and the type of agar they prefer for growth.

Most bacteria are found in three basic shapes: **bacillus** (rod), **coccus** (round or spherical), and spirillum (spiral or helical). Cocci may form clusters or chains, and rods may form long filaments. Some bacteria form endospores. An **endospore** contains a copy of the genetic material encased by heavy protective spore coats. Spores survive unfavorable conditions and germinate to form vegetative cells when conditions improve.

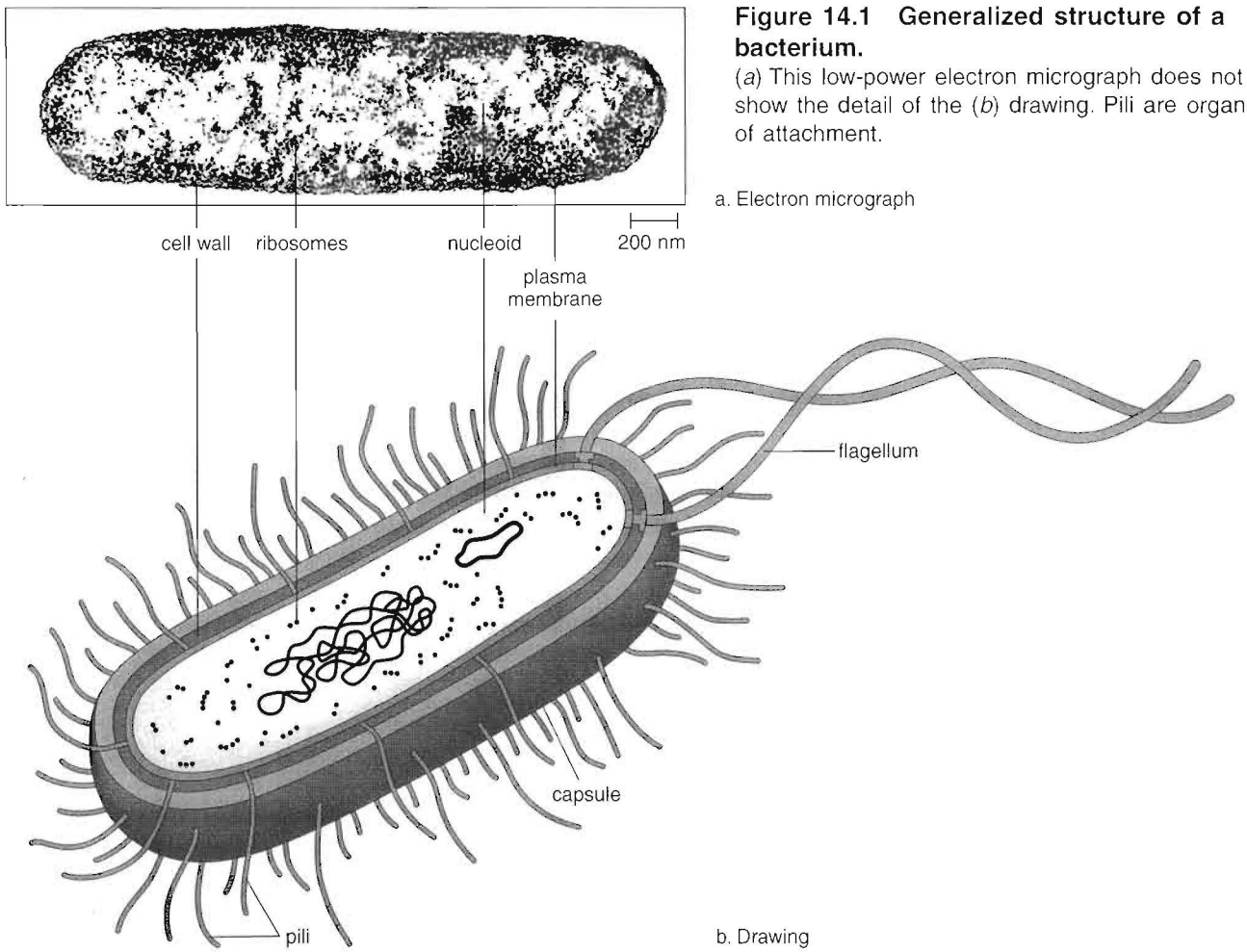


Figure 14.1 Generalized structure of a bacterium.
(*a*) This low-power electron micrograph does not show the detail of the (*b*) drawing. Pili are organs of attachment.

Bacteria are so small their size is measured in micrometers (μm). Therefore, an electron microscope is needed to show their makeup. Figure 14.1 indicates that the cytoplasm is bounded by a cell wall that may be enclosed by a capsule. Some bacteria move by flagella, which are composed of helical strands of a protein known as flagellin. Although bacteria do not have a nucleus, they do have a dense area called a nucleoid where a single circular strand of a DNA double helix is found. Protein synthesis is carried out by thousands of ribosomes.

Observation: Structure of Bacteria

Agar Plates

1. View agar plates that have been inoculated with bacteria and then incubated. Notice the "colonies" of bacteria growing on the plates.
2. Compare the colonies' color, surface, and margin, and note your observations in Table 14.2.

Table 14.2 Agar Plates

Plate Number	Description of Colonies

3. If available, obtain a sterile agar plate, and inoculate the plate with your thumbprint, or use a swab and inoculate the plate with material from around your teeth or inside your nose. Put your name on the plate, and place it where directed by your instructor. Remember to view the plate next laboratory period.
4. If available, obtain a sterile agar plate, and expose it briefly (at most for 10 minutes) anywhere you choose, such as in the library, your room, or your car. No matter where the plate is exposed, it subsequently will show bacterial colonies.

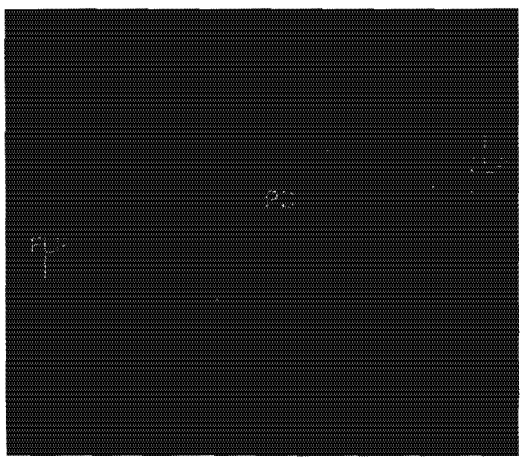
Microscope Slides

1. View the microscope slides of bacteria on display. What magnification is required to view bacteria?

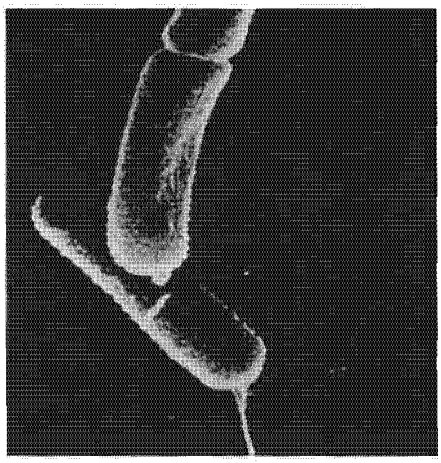
_____

2. Identify the three different shapes of bacteria using Figure 14.2 as a guide.
3. Do any of the slides on display show bacterial cells with endospores? _____ What is an endospore? _____

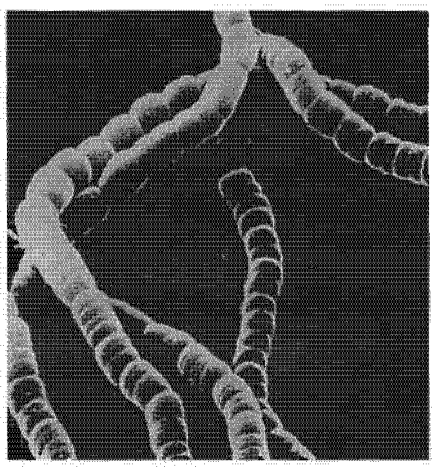
Figure 14.2 Shapes of bacteria.
Bacteria can be (*a*) spirillum (spiral or corkscrew-shaped); (*b*) bacillus (rod-shaped, sometimes with flagella or in chains); (*c*) coccus (round, sometimes in chains).



a. A spirillum with flagella



b. Bacilli in pairs



c. Cocci in chains

250 nm

Cyanobacteria

Cyanobacteria were formerly called blue-green algae because their general growth habit and appearance through a compound light microscope are similar to green algae. Electron microscopic study of cyanobacteria, however, revealed that they are structurally similar to other bacteria, particularly other photosynthetic bacteria. Although cyanobacteria do not have chloroplasts, they do have thylakoid membranes, where photosynthesis occurs.

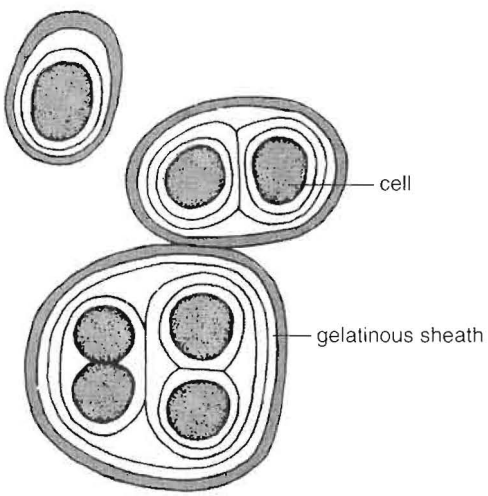
Observation: Cyanobacteria

Gloeocapsa

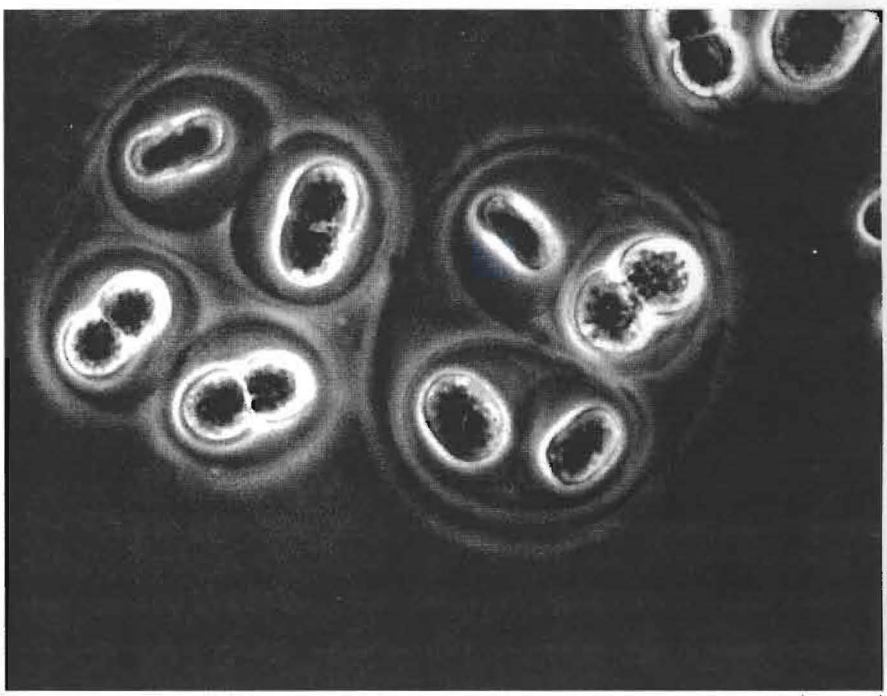
1. ~~Prepare a wet mount of a~~ *Gloeocapsa* ~~culture, if available, or~~ examine a prepared slide, using high power (45×) or oil immersion (if available). The single cells adhere together because each is surrounded by a sticky, gelatinous sheath (Fig. 14.3).

2. What is the estimated size of a single cell? _____

Figure 14.3 *Gloeocapsa.*
Gloeocapsa is a cyanobacterium, a unicellular organism that sticks to others because of the gelatinous sheath.



a. Drawing



b. Photomicrograph

Oscillatoria

1. ~~Prepare a wet mount of an~~ *Oscillatoria* ~~culture, if available, or~~ examine a prepared slide, using high power (45×) or oil immersion (if available). This is a filamentous cyanobacterium with individual cells that resemble a stack of pennies (Fig. 14.4).
2. *Oscillatoria* takes its name from the characteristic oscillations that you may be able to see if your sample is alive. ~~If you have a living culture, are oscillations visible?~~

WHAT IS THE SIZE OF CELL?

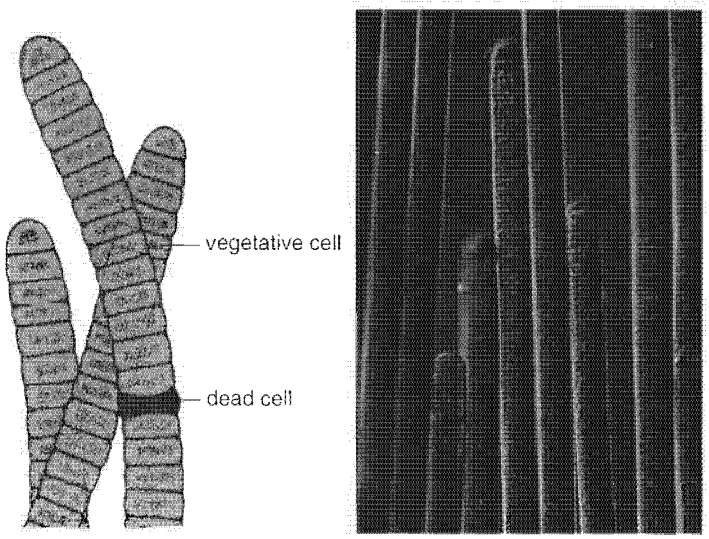


Figure 14.4 ***Oscillatoria.***
Oscillatoria is a filamentous cyanobacterium.

Anabaena

1. ~~Prepare a wet mount of an~~ *Anabaena* ~~culture, if available,~~ or examine a prepared slide, using high power (45×) or oil immersion (if available). This is also a filamentous cyanobacterium, although its individual cells are barrel-shaped (Fig. 14.5).
2. Note the thin nature of this strand. ~~If you have a living culture,~~ what is its color? _____

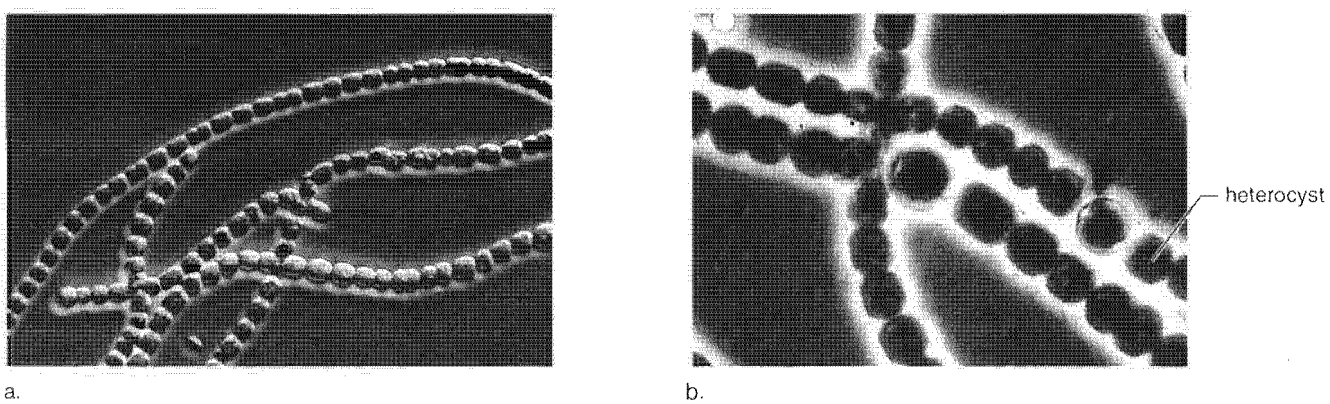


Figure 14.5 ***Anabaena.***
(*a*) *Anabaena* is a filamentous cyanobacterium with (*b*) heterocysts where atmospheric nitrogen (N_2) is converted to ammonia.

14.2 Protists

Protists belong to domain Eukarya and kingdom Protista. The complexity and diversity of protists makes it difficult to classify them. Some protists are photosynthetic, but unlike plants they do not protect their gametes or zygotes in specialized tissue. Heterotrophic protists are not multicellular and do not pass through embryonic development as found in animals. Those protists which resemble fungi lack chitin in their cell walls and possess flagella, which are always lacking in fungi. The following classification is used to further subdivide the protists:

CLASSIFICATION: KINGDOM PROTISTA

Eukaryotic, primarily unicellular. Metabolically diverse and structurally complex. Asexual reproduction usual; sexual reproduction diverse.

Photoautotrophs*

- **Phylum Chlorophyta:** green algae
- **Phylum Rhodophyta:** red algae
- **Phylum Phaeophyta:** brown algae
- **Phylum Bacillariophyta:** diatoms, golden-brown algae
- **Phylum Pyrrophyta:** dinoflagellates
- **Phylum Euglenophyta:** euglenoids

Heterotrophs by Ingestion or Parasitic*

- **Phylum Zoomastigophora:** zooflagellates
- **Phylum Rhizopoda:** amoeboids
- **Phylum Foraminifera:** foraminiferans
- **Phylum Actinopoda:** radiolarians
- **Phylum Ciliophora:** ciliates
- **Phylum Apicomplexa:** sporozoans
- **Phylum Myxomycota:** plasmodial slime molds
- **Phylum Acrasiomycota:** cellular slime molds

Heterotrophs by Absorption or Parasitic*

- **Phylum Oomycota:** water molds

*Not in the classification of organisms, but added here for clarity.

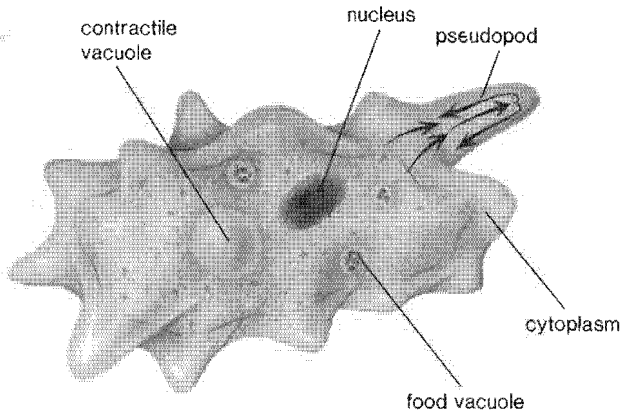
Heterotrophic Protists

The term *protozoan* refers to unicellular eukaryotes and is often restricted to heterotrophic organisms that ingest food by forming **food vacuoles.** Other vacuoles, such as **contractile vacuoles** that rid the cell of excess water, are also typical. Usually protozoans have some form of locomotion; some use **pseudopodia,** some move by **cilia,** and some use **flagella** (Fig. 14.6). Sporozoans, such as *Plasmodium vivax* which causes a common form of malaria, do not locomote at all.

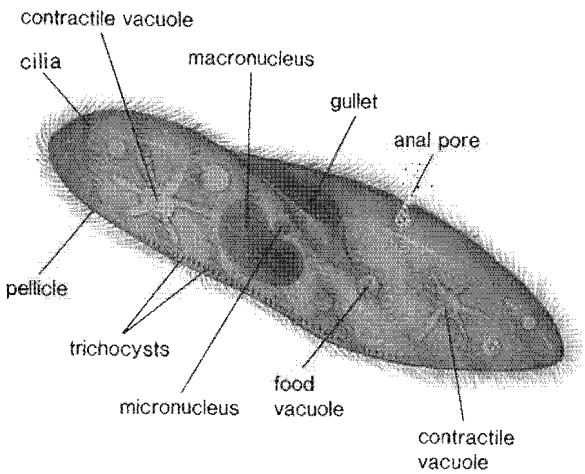
Observation: Heterotrophic Protists

1. You may already have had the opportunity to observe a protozoan such as *Euglena* or *Paramecium* in Laboratory 2. However, your instructor may want you to observe these organisms again.
2. Watch a video if available, and note the various forms of protozoans.
3. Prepare wet mounts or examine prepared slides of protozoans as directed by your instructor.
4. Complete Table 14.3, listing the structures for locomotion in the types of protozoans you have observed.

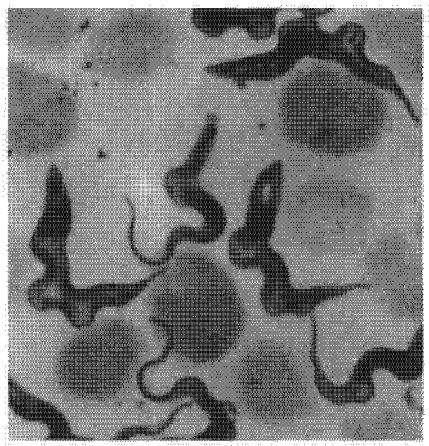
Figure 14.6 Protozoan diversity.
Protozoans are motile by the means illustrated: (*a*) *Amoeba;* (*b*) *Paramecium;* (*c*) *Trypanosoma* in host; (*d*) *Trypanosoma* structure.



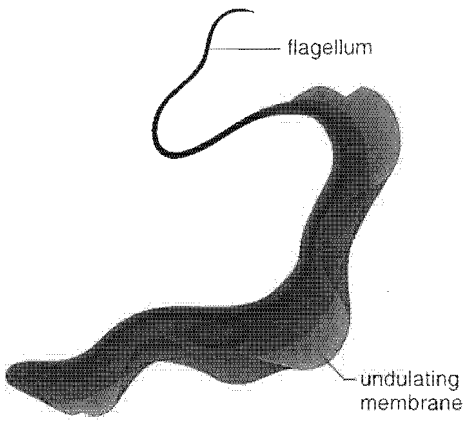
a. *Amoeba* moves by pseudopodia.



b. *Paramecium* moves by cilia.



c. *Trypanosoma* in host bloodstream



d. *Trypanosoma* moves by flagella.

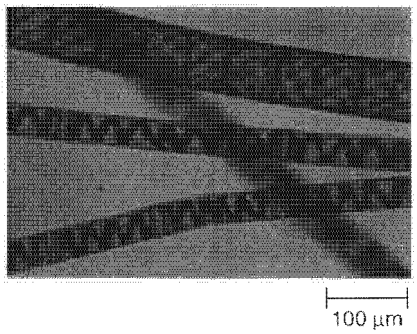
Table 14.3 Heterotrophic Protists

Name	Structures for Locomotion	Observations
Amoeba		
Paramecium		
Stentor		
Vorticella		
Trypanosoma		
Trichomonas		
Plasmodium		

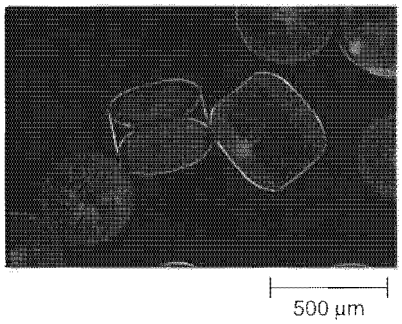
Photosynthetic Protists

Algae is a term that has been used for aquatic organisms that photosynthesize like terrestrial plants. This term is now reserved primarily for the green algae, brown algae, and red algae. The photosynthetic protists lack multicellular sex organs in which reproductive cells are protected by several layers of nonreproductive cells. Consequently, the protists do not protect the zygote, whereas plants do. All photosynthetic protists contain green chlorophyll, but they also may contain other pigments that mask the chlorophyll color. These organisms are often grouped by pigment types and are further categorized by the chemistry of the cell wall and the chemical compound used to store excess food. Photosynthetic protists are shown in Figure 14.7.

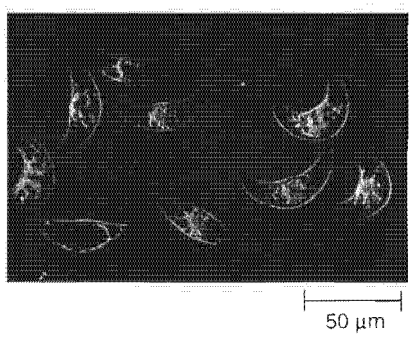
Figure 14.7 Photosynthetic protists.



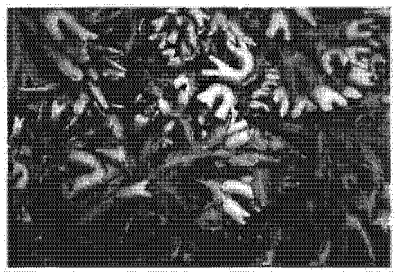
a. *Spirogyra*, a green alga



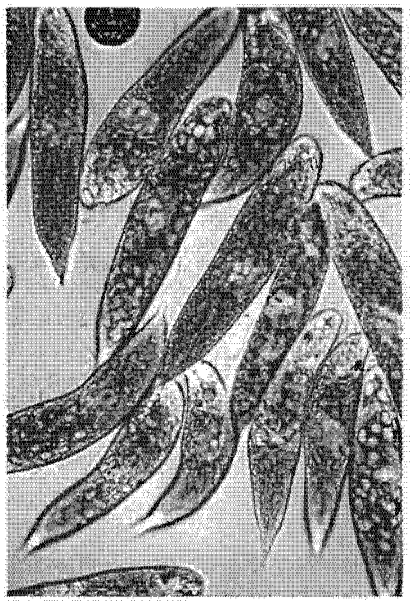
b. *Coscinodiscus concinnus*, a diatom



c. *Pyrocystis*, a dinoflagellate



d. *Fucus*, a brown alga



e. *Euglena*, a euglenoid flagellate

Observation: Green Algae

The green algae (phylum Chlorophyta) may be ancestral to the first plants because both of these groups possess chlorophylls *a* and *b*, both store reserve food as starch, and both have cell walls that contain cellulose.

If available, view a film loop showing the many forms of green algae. Notice that green algae can be single cells, filaments, colonies, or multicellular sheets. You will examine a filamentous form *(Spirogyra)* and a colonial form *(Volvox)*. A **colony** is a loose association of cells.

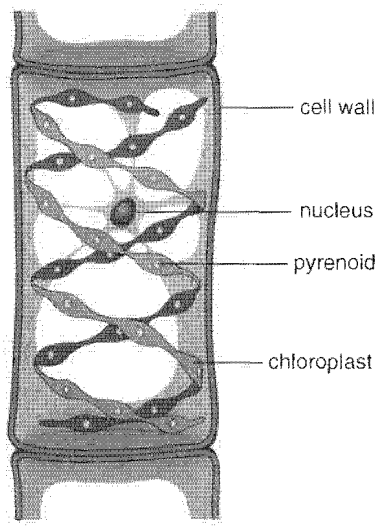
TYPE "GREEN ALGAE" INTO GOOGLE AND SELECT IMAGES

Spirogyra

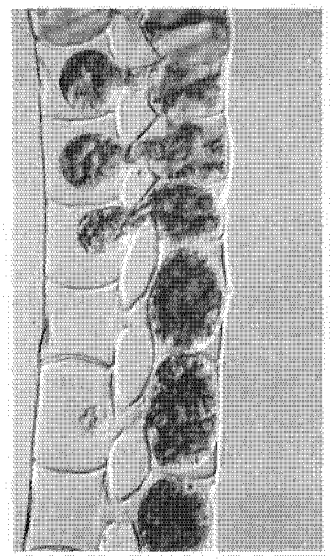
Spirogyra is a filamentous alga, lives in fresh water, and often is seen as a green scum on the surface of ponds and lakes. The most prominent feature of the cells is the spiral, ribbonlike chloroplast (Fig. 14.8).

How do you think *Spirogyra* got its name? _____

Figure 14.8 *Spirogyra*.
(*a*) *Spirogyra* is a filamentous green alga, in which each cell has a ribbonlike chloroplast. (*b*) During conjugation, the cell contents of one filament enter the cells of another filament. Zygote formation follows.



a. Individual cell



20 μm

b. Conjugation

Spirogyra's chloroplast contains a number of circular bodies, the **pyrenoids**, which are centers of starch polymerization. The nucleus is in the center of the cell, anchored by cytoplasmic strands. Your slide may show **conjugation**, a sexual means of reproduction illustrated in Figure 14.8*b*. If it does not, obtain a slide that does show this process. Conjugation tubes form between two adjacent filaments, and the contents of one set of cells enter the other set. As the nuclei fuse, a zygote is formed. The zygote overwinters, and in the spring, meiosis and, subsequently, germination occur.

~~Make a wet mount of live~~ *Spirogyra*, or observe a prepared slide.

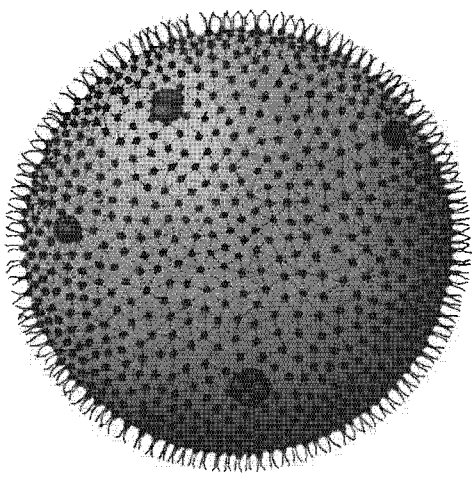
Volvox

Volvox is a green algal colony. It is motile (capable of locomotion) because the thousands of cells that make up the colony have flagella. These cells are connected by delicate cytoplasmic extensions (Fig. 14.9).

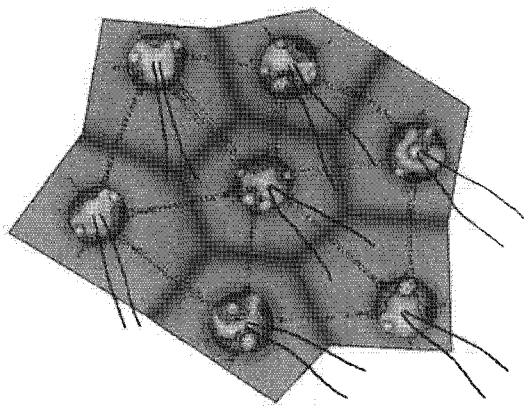
Volvox is capable of both asexual and sexual reproduction. Certain cells of the adult colony can divide to produce **daughter colonies** (Fig. 14.9*c*) that reside for a time within the parental colony. A daughter colony escapes the parental colony by releasing an enzyme that dissolves away a portion of the matrix of the parental colony. During sexual reproduction, some colonies of *Volvox* have cells that produce sperm, and others have cells that produce eggs.

* ~~Using a depression slide, make a wet mount of live~~ *Volvox*, or study a prepared slide.

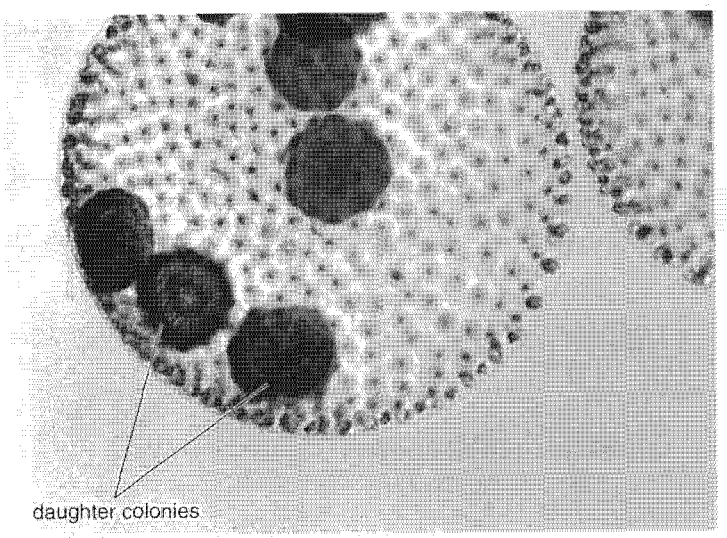
Figure 14.9 ***Volvox.***
The adult colony (*a*) contains (*b*) many individual cells and (*c*) produces daughter colonies.



a. Adult colony



b. Individual cells



c. Daughter colonies

* WHY IS THIS CALLED A COLONY?

Observation: Brown Algae

Brown algae (phylum Phaeophyta) are commonly called *seaweed*, along with the multicellular green and red algae. Brown algae contain brown pigments that mask chlorophyll's green color. These algae are large and have specialized parts.

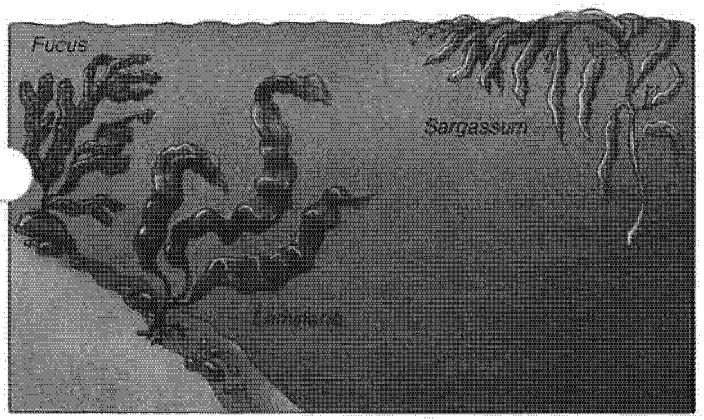
Fucus

Fucus is called rockweed because it is seen attached to rocks at the seashore when the tide is out (Fig. 14.10*a*). If available, view a preserved specimen. Note the dichotomously branched body plan, so called because the **thallus** (body) repeatedly divides into two branches (Fig. 14.10*b*). Note also the **holdfast** by which the alga anchors itself to the rock, the **air vesicles,** or bladders, that help hold the thallus erect in the water, and the **receptacles,** or swollen tips. The receptacles (see Fig. 14.7*d*) are covered by small raised areas, each with a hole in the center. These areas are cavities in which the sex organs are located, with the gametes escaping to the outside through the holes. *Fucus* is unique among algae in that it is diploid (2n) and always reproduces sexually.

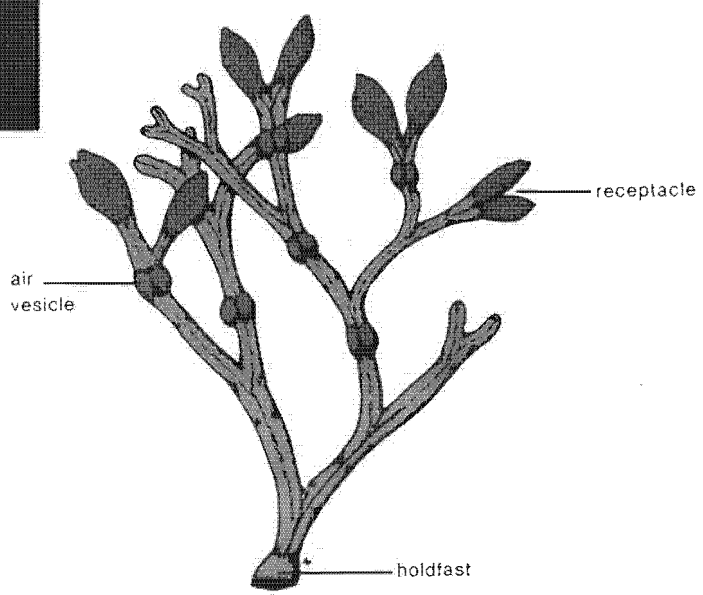
Kelps

If available, study preserved specimens of *Sargassum* and *Laminaria* (Fig. 14.10*a*). These brown algae are called **kelps.**

Figure 14.10 Brown algae.
(*a*) Brown algae include the seaweeds *Fucus*, *Sargassum*, and *Laminaria*. (*b*) Enlargement of a *Fucus* thallus.



a. Representative brown algae



b. *Fucus* thallus

Brown Algae Diversity

In Table 14.4, list the genus names of each of the brown algae specimens available, and identify and indicate (using Fig. 14.10*b*) if the following structures are present on your specimens: *holdfast, air vesicle,* and *receptacle.*

Table 14.4 Brown Algae

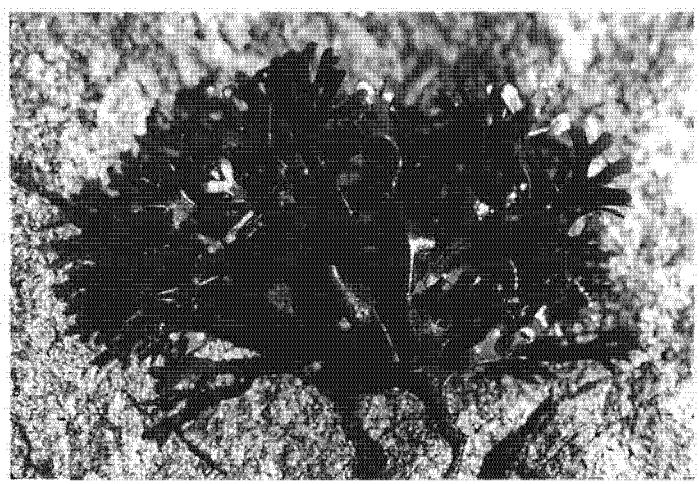
Specimen	Name (Genus)	Holdfast	Air Vesicle	Receptacle
1				
2				
3				
4				

Observation: Red Algae

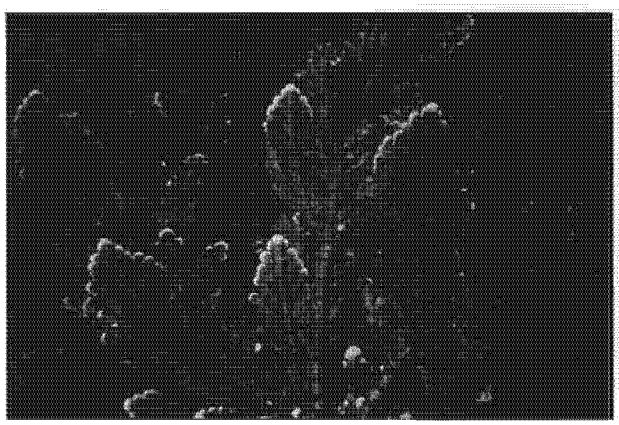
Like most brown algae, the red algae (phylum Rhodophyta) (Fig. 14.11) are multicellular, but they occur chiefly in warmer seawater, growing both in shallow waters and as deep as light penetrates. Some forms of red algae are filamentous, but more often, they are complexly branched with a feathery, flat, and expanded or ribbonlike appearance. Coralline algae are red algae that have cell walls impregnated with calcium carbonate ($CaCO_3$).

In Table 14.5, list the genus names of each of the red algae specimens available, and give a brief description.

Figure 14.11 Red algae.
Generally, red algae are smaller and more delicate than brown algae. (*a*) *Sebdenia* has a pronounced filamentous structure. (*b*) Calcium carbonate is deposited in the walls of the red alga, *Corallina.*



a.



b.

Table 14.5 Red Algae

Specimen	Genus	Description
1		
2		
3		
4		

Observation: Diatoms

The golden-brown algae have a yellow-brown pigment that, in addition to chlorophyll, gives them their color.

The cell wall of **diatoms** (phylum Bacillariophyta) is in two sections, with the larger one fitting over the smaller as a lid fits over a box. Since the cell wall is impregnated with silica, diatoms are said to "live in glass houses." The glass cell walls of diatoms do not decompose, so they accumulate in thick layers that are subsequently mined as diatomaceous earth and used in filters and as a natural insecticide. Diatoms, being photosynthetic and extremely abundant, are important food sources for the small heterotrophs (organisms that must acquire food from external sources) in both marine and fresh-water environment.

Make a wet mount of live diatoms, or view a prepared slide (see Fig. 14.7*b*).

Observation: Dinoflagellates

Dinoflagellates (phylum Pyrrophyta) have two flagella; one is free, but the other is located in a transverse groove that encircles the animal. The beating of these flagella causes the organism to spin like a top. The cell wall, when present, is frequently divided into closely joined polygonal plates of cellulose. At times there are so many of these organisms in the ocean that they cause a condition called "red tide." The toxins given off in these red tides cause widespread fish kills and can cause paralysis in humans who eat shellfishes that have fed on the dinoflagellates.

Make a wet mount of live dinoflagellates or view a prepared slide (see Fig. 14.7*c*).

Observation: Pond Water

Pond water typically contains various examples of the protists studied in this laboratory. Your instructor may have an illustrated manual that will help you to identify the ones unfamiliar to you.

1. Prepare a wet mount of a sample of pond water. Be sure to select some of the sediment on the bottom and a few strands of filamentous algae.
2. Identify and classify them as fully as possible.

Slime Molds

Slime molds were once classified as fungi, but unlike fungi they have flagellated cells at one time during their life cycle. Also, unlike fungi, which are saprotrophic, slime molds phagocytize their food like amoeboids.

There are two types of slime molds: cellular slime molds and plasmodial slime molds. **Cellular slime molds** (phylum Acrasiomycota) usually exist as individual amoeboid cells, which aggregate on occasion to form a pseudoplasmodium. **Plasmodial slime molds** (phylum Myxomycota) usually exist as a **plasmodium**, a fan-shaped, multinucleated mass of cytoplasm.

The plasmodium of a plasmodial slime mold creeps along, phagocytizing decaying plant material in a forest or agricultural field. During times unfavorable for growth, such as a drought, the plasmodium develops many sporangia. A **sporangium** is a reproductive structure that produces spores by meiosis. In some plasmodial slime molds, the spores become flagellated cells, and in others, they are amoeboid. In any case, they fuse to form a zygote that develops into a plasmodium (Fig. 14.12).

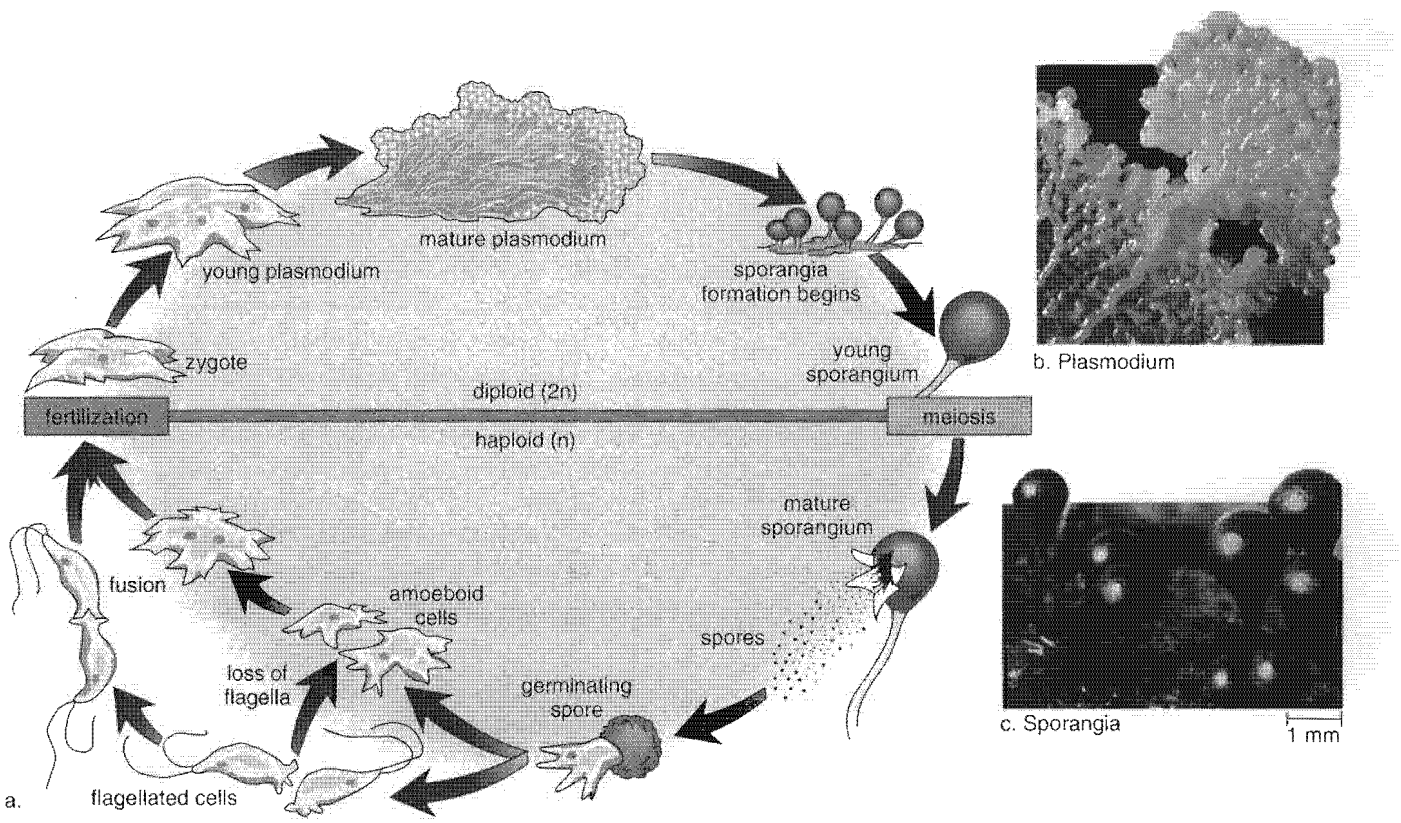
Observation: Plasmodial Slime Molds

1. LOCATE A PICTURE OF ~~Obtain a plate of~~ *Physarum* growing on agar. ON GOOGLE. ~~Carefully examine the plate under the dissecting microscope.~~

2. Describe what you see. _____

_____

Figure 14.12 Plasmodial slime mold.
(*a*) Life cycle. (*b*) Micrograph of a plasmodium. (*c*) Micrograph of sporangia.



Laboratory Review 14

1. What is the major difference between prokaryotic and eukaryotic cells? _____

_____

2. In what ways are cyanobacteria like plants? _____

How are they different? _____

3. How can cyanobacteria, in contrast to saprotrophic bacteria, live in an environment that lacks organic nutrients?

_____

_____

4. List the three major types of protists and the type of nutrition of each.

	Type	Nutrition
a.	_____	_____
b.	_____	_____
c.	_____	_____

5. List the three different structures for locomotion found among protozoans, and name an organism that utilizes each structure.

	Structure	Organism Name
a.	_____	_____
b.	_____	_____
c.	_____	_____

6. Name two characteristics of slime molds by stating their mode of nutrition and how they survive conditions unfavorable for growth. _____

_____

7. Complete the following sentence: Plasmodial slime molds usually exist as a _____

_____.

LABORATORY

15

Fungi

Learning Objectives

15.1 Zygospore Fungi
- Identify the structures typical of black bread mold, and describe both the sexual and asexual life cycles.

15.2 Sac Fungi
- Identify the structures typical of sac fungi, including both the sexual and asexual reproductive structures.

15.3 Club Fungi
- Identify the structures typical of club fungi, including both the sexual and asexual reproductive structures.

15.4 Imperfect Fungi
- Identify the structures typical of imperfect fungi, including asexual reproductive structures.

15.5 Fungal Diversity
- Explain the phylum names: Zygomycota, Ascomycota, Basidiomycota, Deuteromycota.

15.6 Fungi as Symbionts
- Explain the symbiotic relationship between algae and fungi.

Introduction

Fungi are saprotrophic in the same manner as bacteria. Both fungi and bacteria are often referred to as "organisms of decay" because they break down dead organic matter and release inorganic nutrients for plants. A fungal body, called a **mycelium,** is composed of many strands, called **hyphae.** Sometimes, the nuclei within a hypha are separated by walls called **septae,** and sometimes they are not.

Fungi produce windblown **spores** (small, haploid bodies with a protective covering) when they reproduce sexually or asexually. Following sexual union, a collection of specialized hyphae, called a **fruiting body,** is found in some groups. Fungi are classified according to differences in their life cycle and the type of structure that produces spores during sexual reproduction.

CLASSIFICATION: KINGDOM FUNGI

Multicellular eukaryotes; heterotrophic by absorption; lack flagella; nonmotile spores form during both asexual and sexual reproduction.

Phylum Zygomycota: zygospore fungi
Phylum Ascomycota: sac fungi
Phylum Basidiomycota: club fungi
Phylum Deuteromycota: imperfect fungi (i.e., means of sexual reproduction not known)

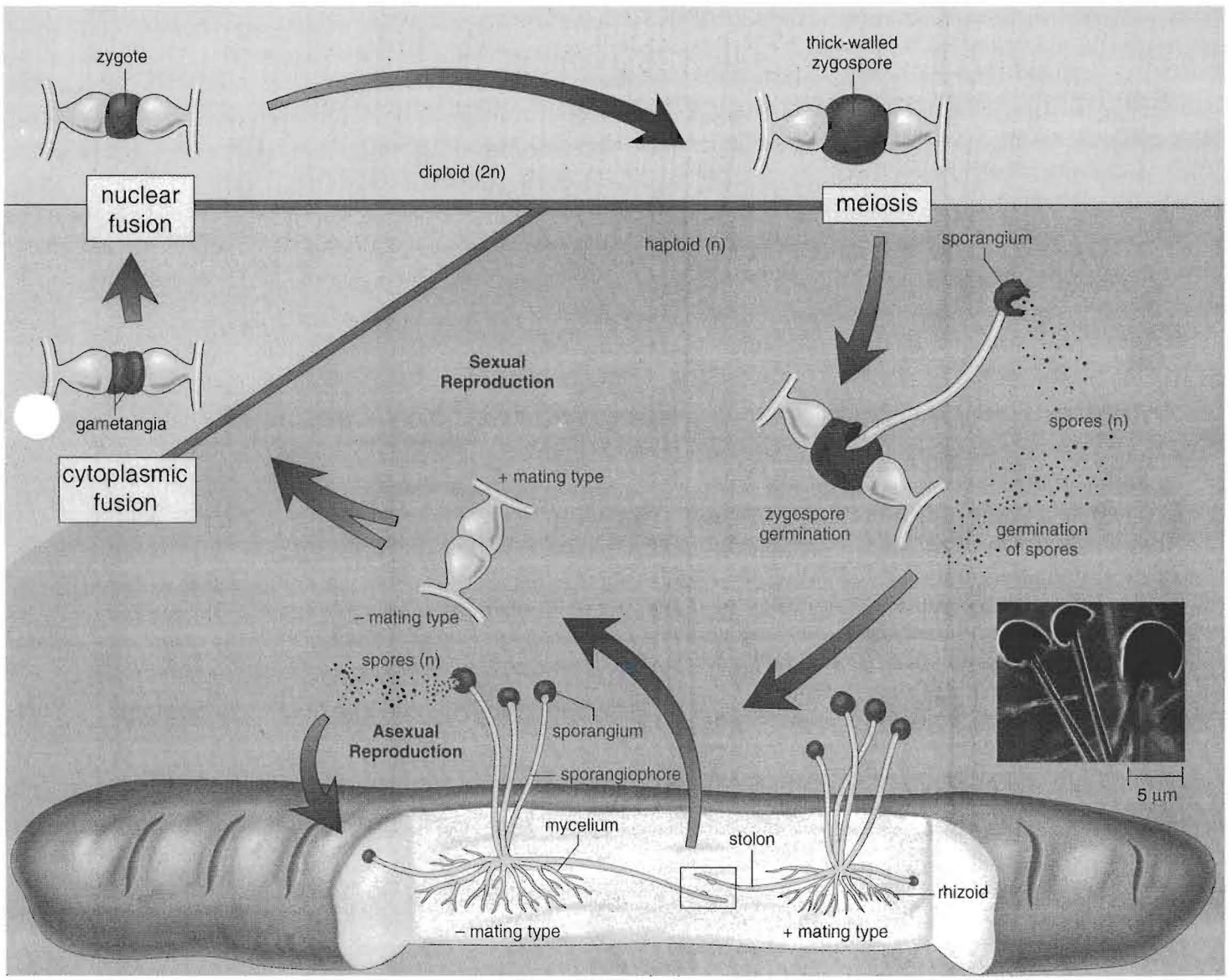
15.1 Zygospore Fungi

Zygospore fungi (phylum Zygomycota), such as black bread mold, commonly grow on bread or any bakery goods kept at room temperature. Identify the sexual and the asexual portion of the life cycle of *Rhizopus*, the black mold shown in Figure 15.1.

✳ Is the nucleus in the mycelium of *Rhizopus* haploid or diploid? _____ Where does meiosis occur in the *Rhizopus* life cycle? _____ Where are spores produced? _____

In zygomycota, the hyphae are nonseptate (without cross walls), and therefore, the hyphae are multinucleate.

Figure 15.1 Life cycle of black bread mold, *Rhizopus stolonifer.*
Windblown spores are produced during both asexual and sexual reproduction.



Black Bread Mold

Identify the following structures in Figure 15.1: CIRCLE THEM.

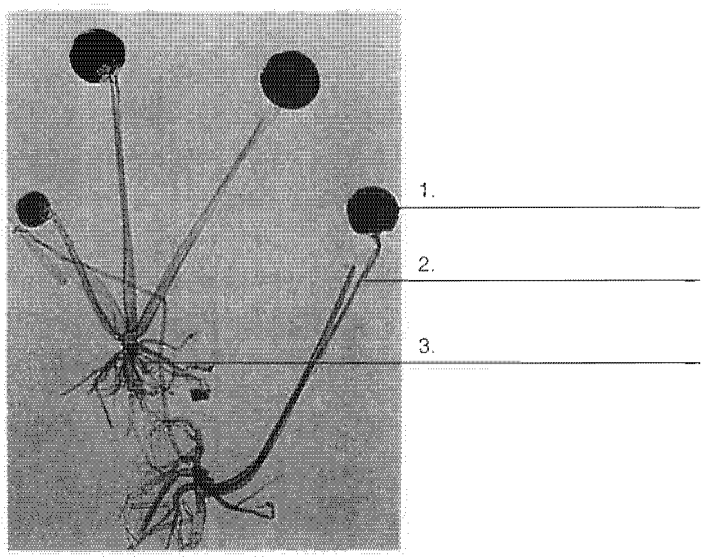
1. **Mycelium:** A network of filaments called hyphae, of which there are three types: **Rhizoids** are somewhat rootlike hyphae that penetrate the bread, **stolons** are horizontal hyphae, and **sporangiophores** are hyphal stalks that bear sporangia.
2. **Sporangium:** A capsule that produces spores, which are black.
3. **Zygospore:** A thick, black, protective coat that forms around the zygote nuclei during sexual reproduction. Meiosis occurs during zygospore germination, and asexual sporangia are produced on sporangiophores.

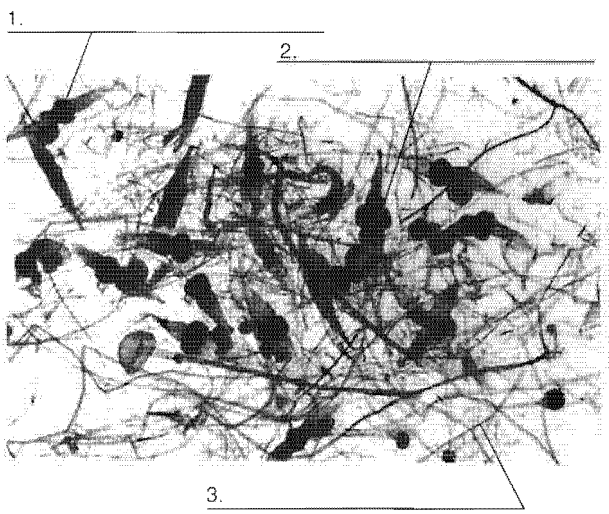
Observation: Black Bread Mold

1. If available, examine bread that has become moldy. Do you recognize black bread mold on the bread? _____ Describe the mold you see. _____

2. Obtain a petri dish that contains living black bread mold. Observe with a dissecting microscope. Identify the three types of hyphae and the sporangia (black dots). _____
3. View a prepared slide of *Rhizopus,* using both a dissecting microscope and the low-power setting of a light microscope. The absence of cross walls in the hyphae is an identifying feature of zygomycota. List the structures you can identify. _____

4. In the micrograph on the left, label structures seen during asexual reproduction: sporangiophore, rhizoid, and sporangium. In the micrograph on the right, label structures seen during sexual reproduction: stolon, gametangium, and zygospore.





15.2 Sac Fungi

Sac fungi (phylum Ascomycota) are composed of septate hyphae. The phylum name refers to the **ascus,** a fingerlike sac that develops during sexual reproduction. Each ascus contains eight haploid nuclei and produces eight **ascospores.** The asci are usually surrounded and protected by sterile hyphae within a fruiting body. A **fruiting body** is a reproductive structure where spores are produced and released.

Some sac fungi are not known to reproduce sexually. Such fungi reproduce asexually by producing **conidiospores** (conidia) on upright hyphae known as **conidiophores**.

Various molds, including red bread mold *(Neurospora)*, are sac fungi, as are cup fungi, morels, and truffles. Other ascomycetous fungi, such as Dutch elm disease, ergot, and powdery mildews, cause serious plant diseases. Ergot contains LSD, and this hallucinogenic substance sometimes has been ingested accidentally.

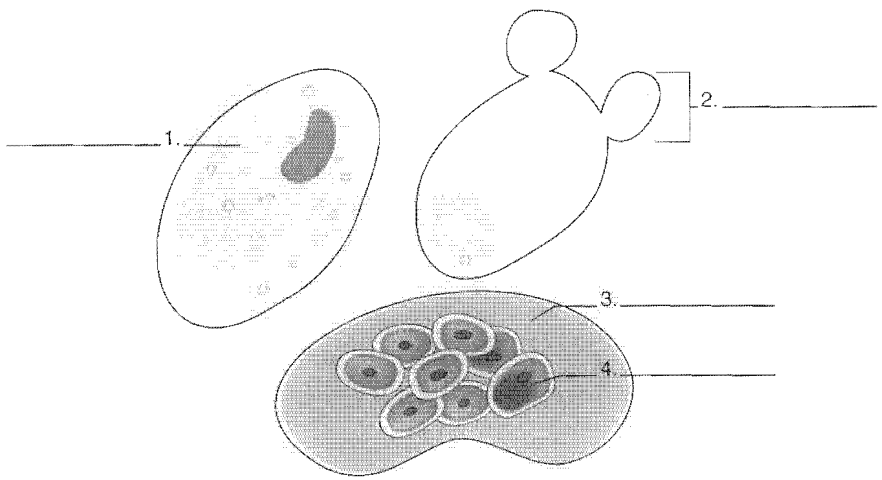
Yeasts

Yeasts differ from most other fungi because they are not composed of hyphae. Even though yeasts are unicellular, they form an ascus during sexual reproduction. Usually, however, yeasts reproduce asexually, either by mitosis and cell division or by **budding.** Budding involves an unequal distribution of cytoplasm during cytokinesis.

Yeasts are used during the production of wine and beer because of the alcohol they produce when fermenting. Yeasts are also helpful in that the carbon dioxide they give off makes bread rise.

Observation: Yeast

1. Obtain a sample of *Saccharomyces* ~~(yeast) culture, and make a wet mount.~~ BUDDING PREPARED SLIDE
2. ~~Observe, using all three objectives of your microscope. Add a drop of methylene blue stain if you cannot see the cells well. Identify and sketch cells that are budding in the space below.~~
3. Label the vegetative cell, bud, ascus, and ascospore in the following diagram of *Saccharomyces:*



4. View a prepared slide of *Schizosaccharomyces.* Identify an ascus and ascospores. How many ascospores are in each ascus? _____

Cup Fungi

Cup fungi are representative of sac fungi because they produce an **ascocarp** (fruiting body) in which saclike asci develop (Fig. 15.2*a*). The fruiting body contains a mass of sterile hyphae intertwined with reproductive hyphae. The sterile hyphae protect the asci. A diploid (2n) nucleus is produced in each ascus when two haploid nuclei unite. This zygote nucleus undergoes meiosis and then divides mitotically to produce ascospores. In some cup fungi, the ascocarp is cup-shaped (Fig. 15.2*a*). In morels, the ascocarp is stalked and crowned by bell-shaped, convoluted tissue that bears the asci (Fig. 15.2*b*).

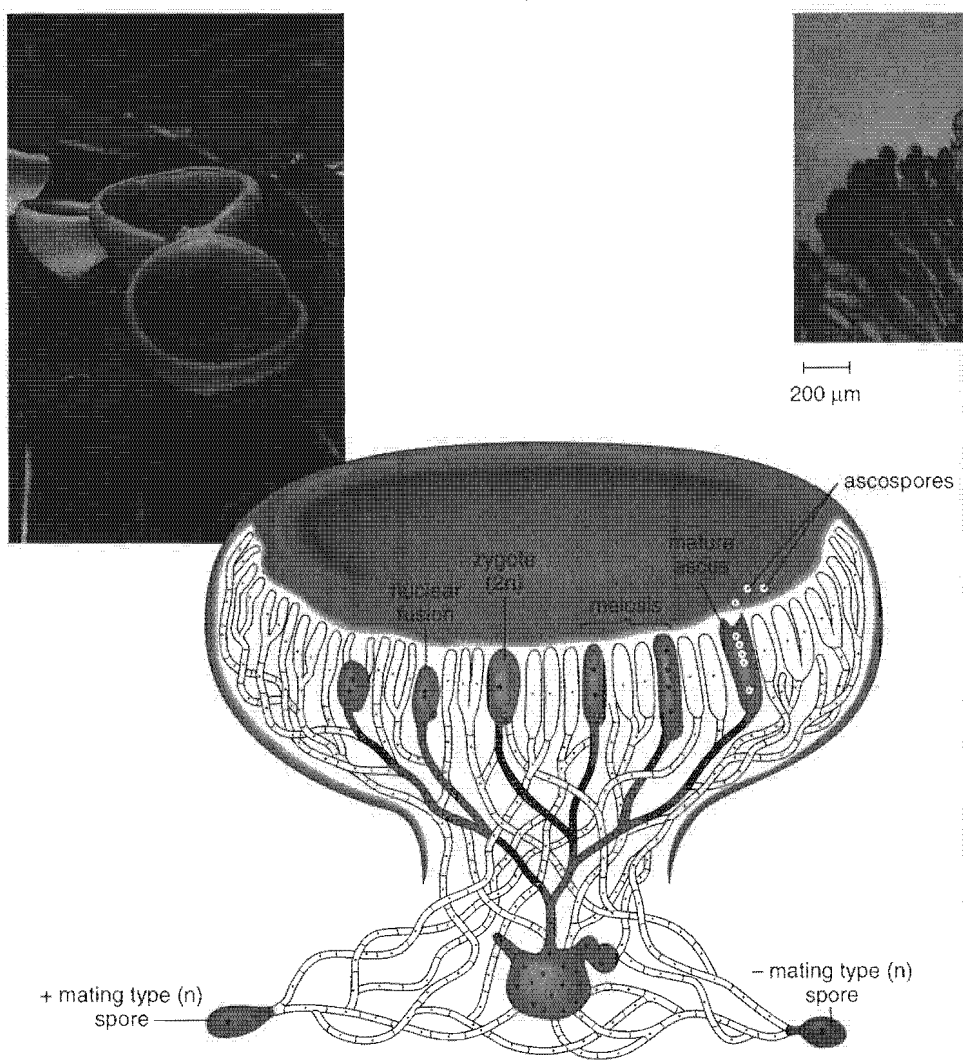
Observation: Cup Fungi

View a prepared slide of *Peziza*, and identify the ascocarp, asci, ascospores, and sterile hyphae.

Are the ascospores inside or outside the asci? _____

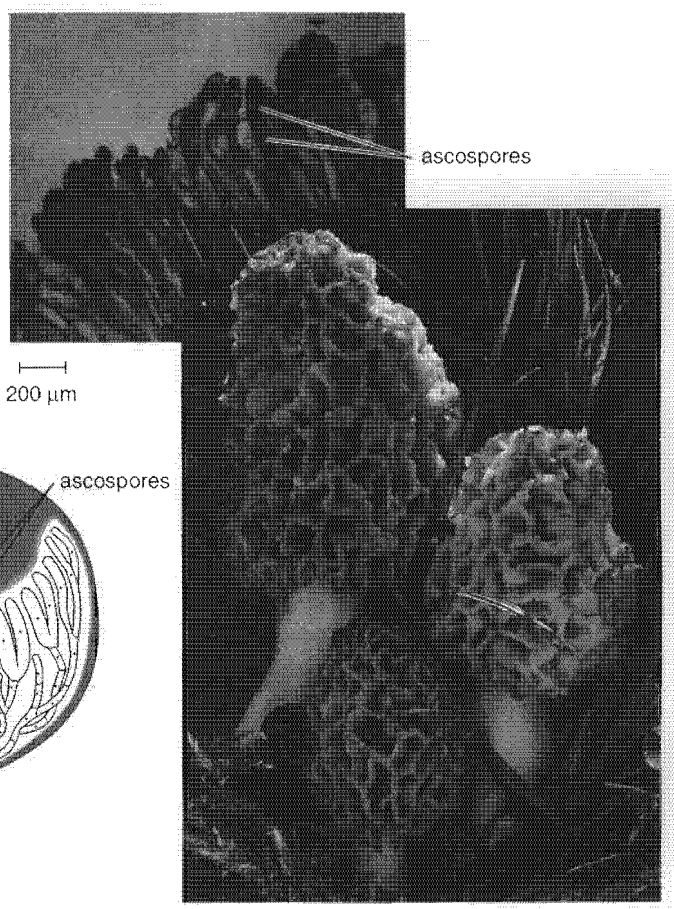
If available, obtain and view samples of morels and other cup fungi.

Figure 15.2 Sac fungi.
(*a*) A cup fungus such as *Sarcoscypha* has a fruiting body shaped like a cup. (*b*) A morel such as *Morchella* has a bell-shaped fruiting body.



Cup fungus, *Sarcoscypha*

a. Photo and drawing of ascocarp section of cup fungi



Morel, *Morchella*

b. Photo of light micrograph of ascocarp section of morel.

15.3 Club Fungi

Club fungi (phylum Basidiomycota) usually reproduce sexually. When monokaryotic hyphae of two different mating types meet, they fuse and produce a dikaryotic (n + n) mycelium. This dikaryotic mycelium may exist for hundreds of years and occasionally produces fruiting bodies.

Club fungi include the familiar mushrooms (Fig. 15.3*a, b, c*), as well as shelf, or bracket, fungi. Some mushrooms are edible, but others are poisonous. Less well-known club fungi are puffballs (Fig. 15.3*d*), bird's-nest fungi, and stinkhorns in which the spores develop within an enclosed fruiting body. When mature the enclosure breaks down and spores are released. Rusts and smuts are club fungi that parasitize cereal crops, such as corn, wheat, oats, and rye. These infections sometimes have significant economic effects.

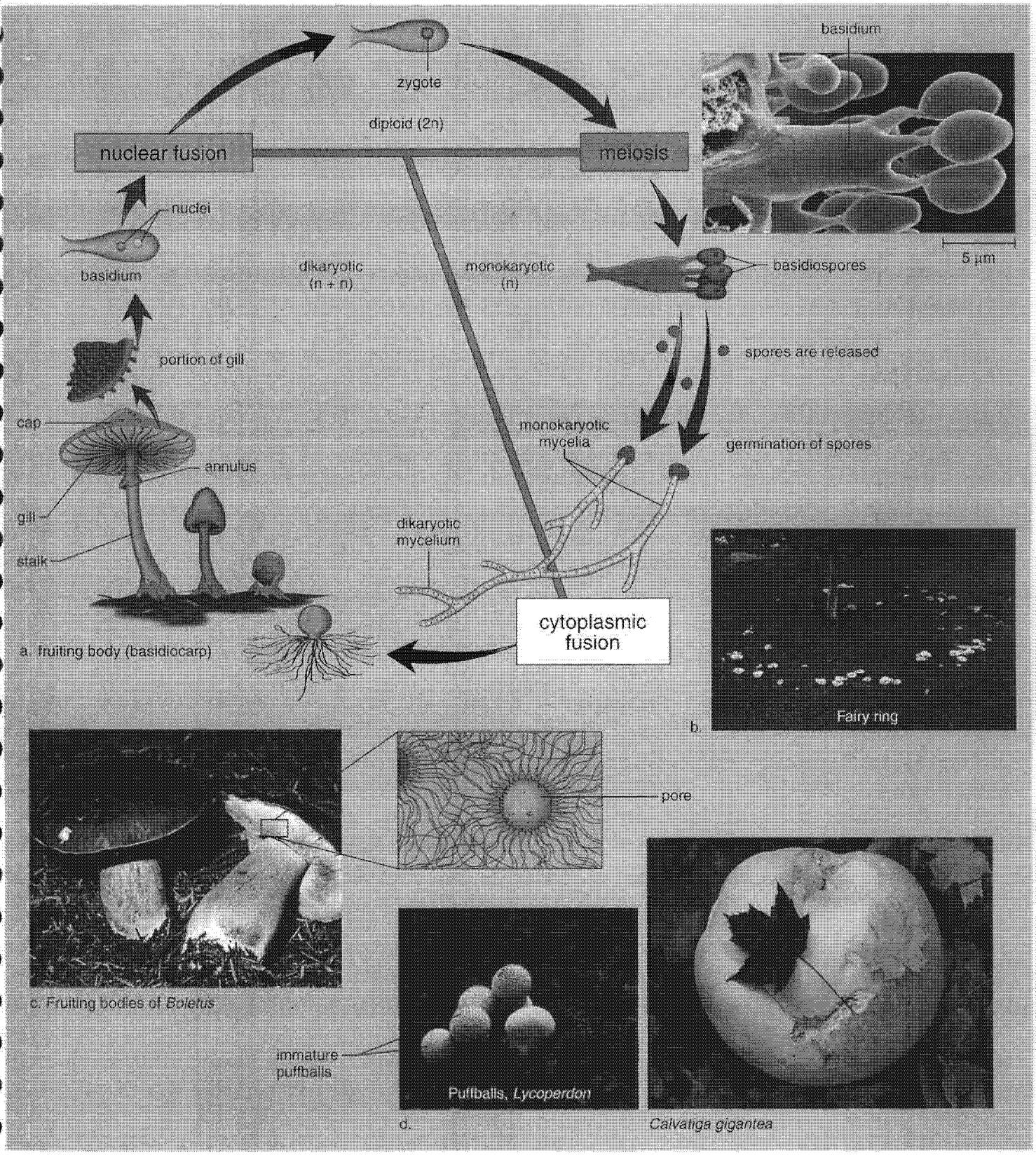
Mushrooms

Study Figure 15.3*a*, and note that when monokaryotic (n) hyphae from two different strains meet, they fuse to produce a dikaryotic (n + n) mycelium that, in turn, produces a **basidiocarp,** commonly known as a mushroom. In gill mushrooms, a button-shaped structure expands to become a full-sized mushroom, which consists of a stalk or stipe, and a terminal cap or pileus with gills on the underside. The gills are thin plates (lamellae) on which the basidia develop. Each basidium produces four basidiospores. Pore mushrooms have pores (tubes) instead of gills (Fig. 15.3*c*).

Observation: Mushrooms

1. Obtain an edible mushroom—for example, *Agaricus*—and identify as many of the following structures as possible:
   a. **Stalk:** The upright portion that supports the cap
   b. **Annulus:** A membrane surrounding the stalk where the immature (button-shaped) mushroom was attached
   c. **Cap:** The umbrella-shaped portion of the mushroom
   d. **Gills:** On the underside of the cap, radiating lamellae on which the basidia are located
   e. **Basidia:** On the gills, club-shaped structures where basidiospores are produced
   f. **Basidiospores:** Spores produced by basidia
2. View a prepared slide of cross section of *Coprinus*. Using all three microscope objectives, look for the gills, basidia, and basidiospores.
3. Can you see individual hyphae in the gills? Sketch what you see in the space below.
4. Are the basidiospores inside or outside of the basidia? _____
5. Can you suggest a reason for some of the basidia having fewer than four basidiospores? _____
6. What type of nuclear division(s) took place just before the basidiospores were produced? _____
7. What happens to the basidiospores after they are released? _____

Figure 15.3 Club fungi.
(*a*) Life cycle of a gilled mushroom in which sexual reproduction is the norm. (*b*) Mushrooms occur in a ring where nutrients are available. (*c*) Pore mushrooms have pores, not gills. (*d*) Puffballs fully enclose their spores.



15.4 Imperfect Fungi

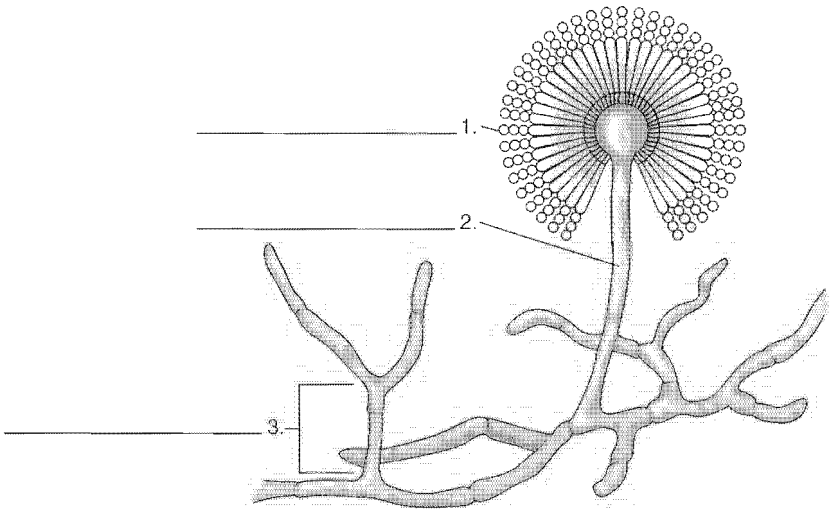
Imperfect fungi (phylum Deuteromycota) reproduce asexually by forming conidiospores on upright hyphae known as conidiophores as seen in sac fungi. They are "imperfect" in the sense that no sexual stage has yet been observed (leading to the use of *deutero*, meaning second) and may not exist. Although the imperfect fungi include the asexual forms of a variety of fungi from the other divisions, a number of imperfect fungi have the cell structure and biochemistry of sac fungi.

Imperfect fungi include blue mold *Penicillium* species, which are famous for the production of the antibiotic penicillin, and the green mold *Aspergillus* species, which are used in the manufacture of products ranging from soy sauce to chewing gum. These molds grow on a variety of materials, such as fruits, cheese, leather, paper, cloth, etc. *Candida albicans* is a yeastlike imperfect fungus that causes vaginal infection in females.

Observation: Imperfect Fungi

1. Obtain a ~~petri dish~~ PREPARED SLIDE of an *Aspergillus* culture. ~~Use a dropper bottle of *methylene blue* to make a streak of stain 2.5 cm long on a microscope slide. Place the center of a 4 cm piece of clear tape over the *Aspergillus* culture so that a sample of the mold sticks to the tape.~~ Put this mold sample on the microscope slide on which the methylene blue stain has been placed. Observe with all three objectives of your microscope. What do you see?

2. Obtain a prepared slide of *Penicillium*. Locate the periphery of the mass under low power, and then switch to high power. You should now be able to see conidiophores.
3. View a prepared slide of *Aspergillus*, and observe how the conidiophore arrangement differs from that of *Penicillium*.
4. Label the following diagram of *Aspergillus:*



15.5 Fungal Diversity

1. Table 15.1 may be helpful when comparing phylum Zygomycota, phylum Ascomycota, phylum Basidiomycota, and phylum Deuteromycota.

Table 15.1 Comparisons of Fungi

	Sexual Reproduction	Asexual Reproduction	Septae*
Zygomycota	Zygospores	Sporangia	Absent
Ascomycota	Asci	Conidiospores	Present
Basidiomycota	Basidia	Conidiospores	Present
Deuteromycota	None	Conidiospores	Present in most cases

*The reproductive structures are cut off by complete septae in all fungi; these descriptions refer to the septae in the ordinary, nonreproductive hyphae.

2. After observing various fungi on display, complete Table 15.2.

Table 15.2 Fungal Diversity

Phylum	Common Name	Scientific Name	Description

15.6 Fungi as Symbionts

When two different organisms live and function together, they have a special relationship to each other called **symbiosis.** In **mutualism,** both symbionts benefit. In **parasitism,** one symbiont benefits from the relationship while the other is harmed. Two symbiotic relationships are studied: lichens and mycorrhizas.

Lichens

Lichens are an association between a fungus and a cyanobacterium or a green alga. The body of a lichen has three layers: The fungus forms a thin, tough upper layer and a loosely packed lower layer. These upper and lower fungal layers shield the photosynthetic cells in the middle layer. The exact relationship between the fungus and the photosynthetic cell is uncertain, but getting the fungus to grow alone is difficult. One possibility is that the fungus benefits from the relationship by utilizing substances produced by the algae and, in turn, the fungus provides its partner with a protected environment.

Does it seem as if the fungus is dependent on the photosynthetic cell? _____

What does this suggest? _____

Would you describe the relationship as mutualistic or parasitic? _____ Explain. _____

_____

_____

Lichens can be compact and crustose, leaflike and foliose, or shrublike and fruticose (Fig. 15.4).

Observation: Lichens

1. Observe numbered samples of lichens, and identify each as crustose, foliose, or fruticose. Check your answers with your instructor.

   Sample 1 _____

   Sample 2 _____

   Sample 3 _____

2. View a prepared slide of a lichen that shows the placement of the photosynthetic cells and fungal hyphae. Describe the placement. _____

   _____

   _____

Mycorrhizas

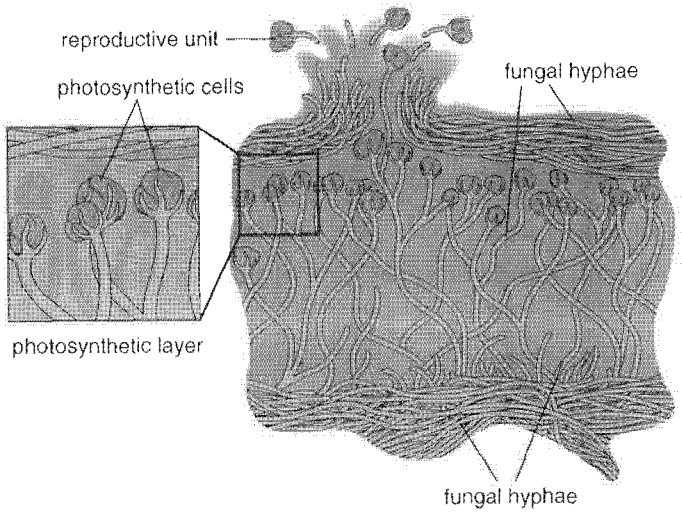
Mycorrhizas are mutualistic relationships between soil fungi and the roots of most plants. The fungal partner in this case makes inorganic nutrients available to the plant, and the plant, in turn, passes organic nutrients to the fungus.

There are two major groups of mycorrhizas: ectomycorrhizas and endomycorrhizas. In **ectomycorrhizas,** the hyphae grow between cells, while in **endomycorrhizas,** the hyphae penetrate cells, where they may form treelike arbuscles or swellings (vesicles).

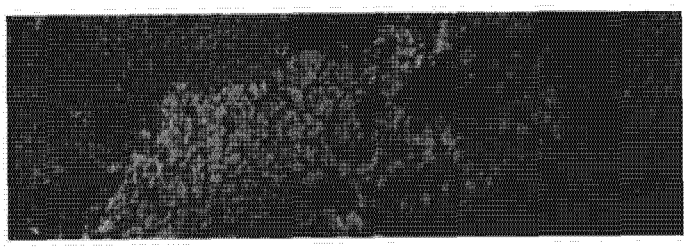
Observation: Mycorrhizas

ew a prepared microscope slide of a mycorrhiza and observe the penetration of the root by the fungal hyphae. What type of mycorrhiza are you observing? _____

Figure 15.4 Lichen morphology.

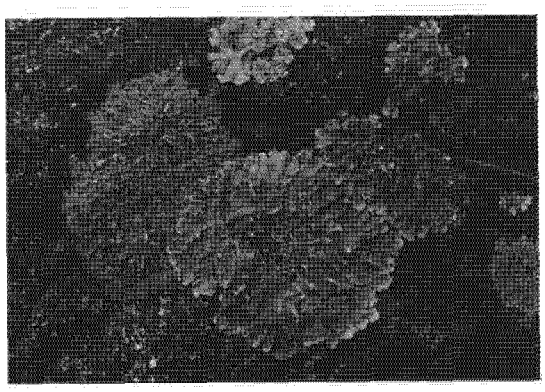


a. This section of a lichen shows the placement of the photosynthetic cells and the fungal hyphae, which encircle and sometimes penetrate them.



b. Crustose lichens are compact.

c. Fruticose lichens are shrublike.



d. Foliose lichens are leaflike.

Laboratory Review 15

1. Explain the basis for the following phylum names:

   a. Zygomycota _____

   b. Ascomycota _____

   c. Basidiomycota _____

   d. Deuteromycota _____

2. Tell what type of spore is produced within or on each of the following structures, and cite the phylum name.

	Type of Spore	Phylum Name
a. Sporangium	_____	_____
b. Ascus	_____	_____
c. Basidium	_____	_____

3. Ascomycota and Deuteromycota both produce what type of spore during asexual reproduction?

   _____

   _____

4. Explain the designation "imperfect fungi." _____

   _____

5. A student is observing fruiting bodies. If the spores are produced externally, the fungus is a _____

   _____.

   If the spores are produced within enclosed structures, the fungus is a _____.

6. Mycorrhizas are sometimes referred to as "fungus roots." Explain. _____

   _____

   _____