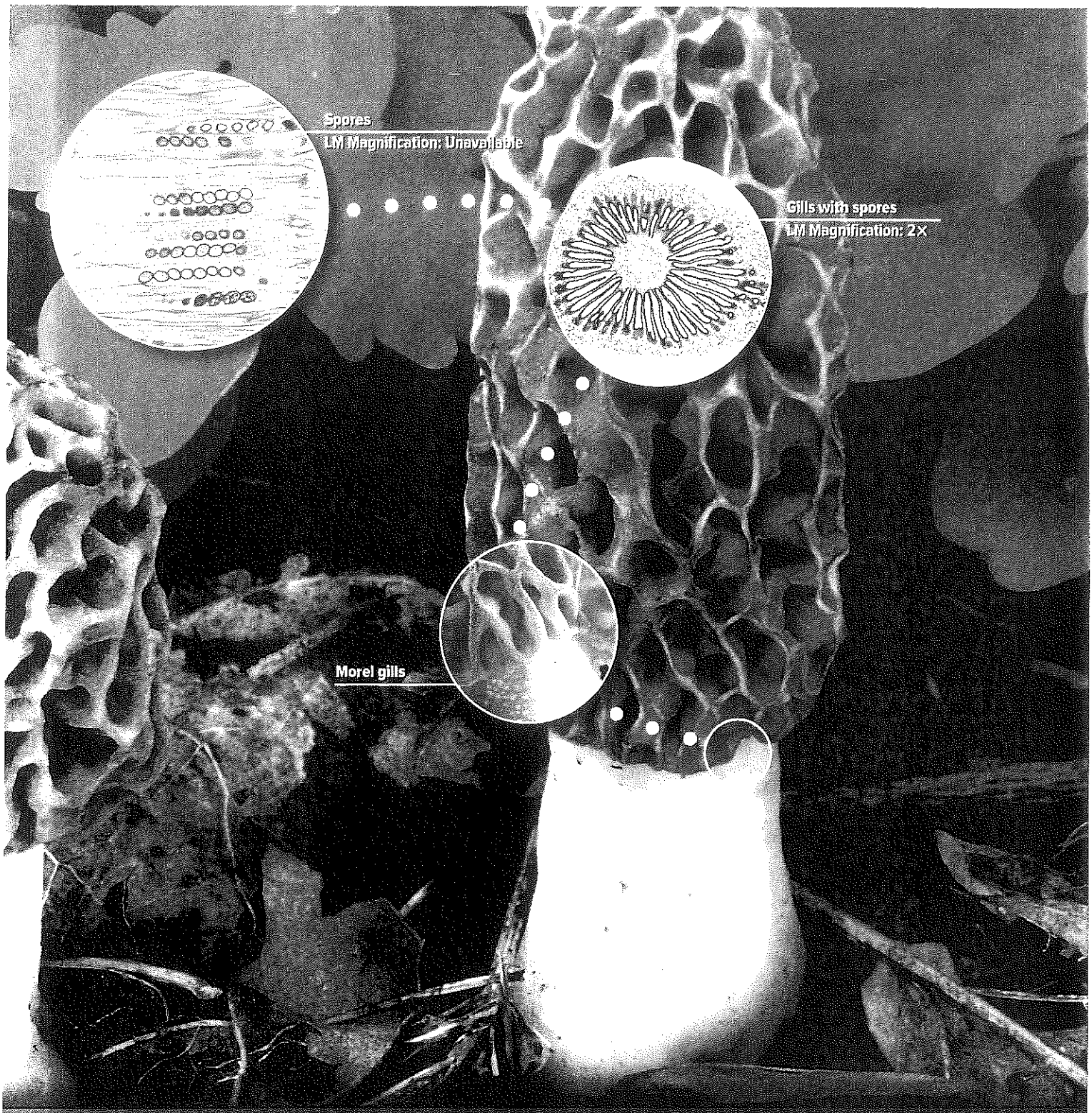


THEME FOCUS **Patterns**
Fungi obtain energy in three ways.

BIG Idea **The Kingdom Fungi is made up of four phyla based on unique structures, methods of nutrition, and methods of reproduction.**

Reading Preview

Essential Questions

- What are the major characteristics of organisms in Kingdom Fungi?
- How do fungi obtain nutrients and how does that include their role as decomposers?
- What are the three types of asexual reproduction in fungi?

Review Vocabulary

decomposer: an organism that feeds on and breaks down dead organisms, recycling nutrients back into food webs

New Vocabulary

chitin
hypha
mycelium
fruiting body
septum
haustorium
spore
sporangium

Multilingual eGlossary

Introduction to Fungi

MAIN Idea **Fungi are unicellular or multicellular eukaryotic heterotrophs that are decomposers.**

Real-World Reading Link When you listen to the radio, how is it that you can always identify your favorite group? Maybe it is by the common characteristics of the band, such as their instruments or the lead singer's voice. Organisms in the same kingdom also share common, identifying characteristics.

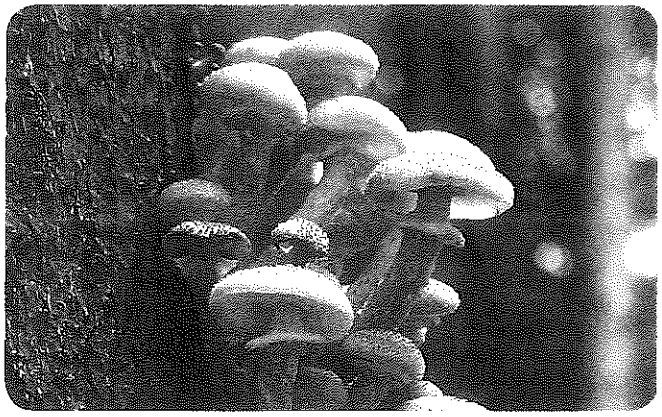
Characteristics of Fungi

Some of the largest and oldest organisms on Earth belong to Kingdom Fungi. When you see the word *fungi* (FUN ji) (singular, fungus), you might envision the mushrooms found in grocery stores or ones that grow in your backyard. In eastern Oregon, there is a honey mushroom that is so big that it is called the "Humongous Fungus." The honey mushroom, similar to the one shown in **Figure 1,** is estimated to be at least 2400 years old. All fungi are eukaryotic heterotrophs. More than 100,000 species of fungi have been identified.

Multicellular fungi Most members of Kingdom Fungi, such as the honey mushroom, are multicellular. At first glance, you might think that these multicellular fungi look like plants. Although they do not contain chloroplasts, at one time fungi were classified as plants because they appeared to have some characteristics similar to plants. However, after careful study, scientists decided that fungi are different enough to be placed in their own kingdom.

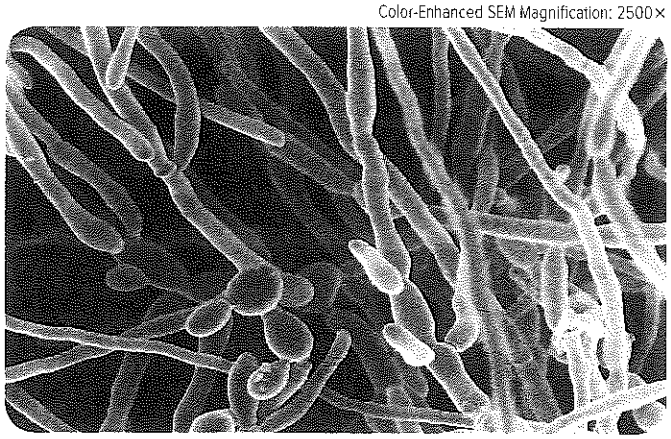
Unicellular fungi Yeasts are unicellular fungi. They are found throughout the world in soils, on plant surfaces, and even in the human body. While there are hundreds of different kinds of yeasts, the most familiar yeasts are used commercially to produce breads, beer, and wine. The yeast *Candida albicans,* shown in **Figure 1,** can cause a yeast infection in humans.

Figure 1 Most fungi are multicellular, such as this honey mushroom growing on a tree. Some fungi are unicellular, such as this yeast colony called *Candida albicans.*



Honey mushroom

Color-Enhanced SEM Magnification: 2500×



Colony of *Candida albicans*

Major Features in Fungi

Some features that distinguish fungi from plants include their cell walls, their hyphae, and their cross walls.

Cell walls One significant difference between plants and fungi is the composition of their cell walls. Plants have cell walls composed of cellulose, while fungi have cell walls composed of chitin. **Chitin** (KI tun) is a strong, flexible polysaccharide that is found in the cell walls of all fungi and in the exoskeletons of insects and crustaceans. Recall that polysaccharides are carbohydrate polymers that are composed of many simple sugar subunits. Chitin is one of the most abundant organic compounds on Earth.

Hyphae The physical structure of fungi also differs from plants. Look at the magnified image of the fungus in **Figure 2** and notice that it is composed of long chains of cells. Without a microscope, they appear to be threadlike filaments. These filaments are the basic structural units that make up the body of a multicellular fungus and are called **hyphae** (HI fee) (singular, hypha). Hyphae grow at their tips and branch repeatedly to form a netlike mass called a **mycelium** (mi SEE lee um) (plural, mycelia). While the mycelium is visible in some fungi, it is packed so tightly in mushrooms that it is almost impossible to distinguish the individual hyphae. The fungus that you see above ground, illustrated in **Figure 2,** is a reproductive structure called the **fruiting body.** The hyphae form all parts of the mushroom, including the fruiting body above ground and the mycelium below ground. The extensive hyphae of fungi give them an advantage in obtaining nutrients by providing a large surface area for nutrient absorption.

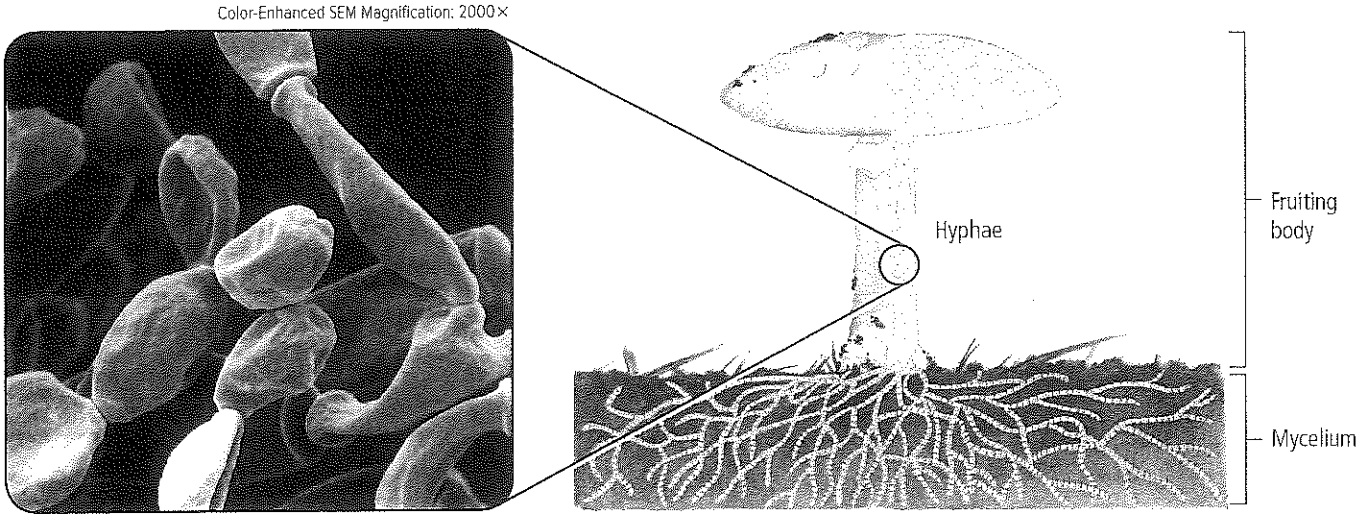
Reading Check **Describe** the structural unit of a mushroom.

Connection to History Fungal hyphae are found in the works of many medieval painters. Victorian illustrators often linked fairies and toadstools (another name for mushrooms). Today, the colorful spotted cap of a *Fly Agaric* mushroom often is associated with a gnome or sprite in children's stories.

VOCABULARY

Hypha
comes from the Greek word *hyphos*, meaning *web*

Figure 2
Left: The visible body and underground structure of a multicellular fungus are made up of long chains of cells called hyphae.
Right: A multicellular fungus consists of an above-ground fruiting body and a below-ground mycelium.
Infer ***What are the advantages of a fungus having a filamentous body?***



Hyphae **Above-ground fruiting body**

Scimat/Photo Researchers

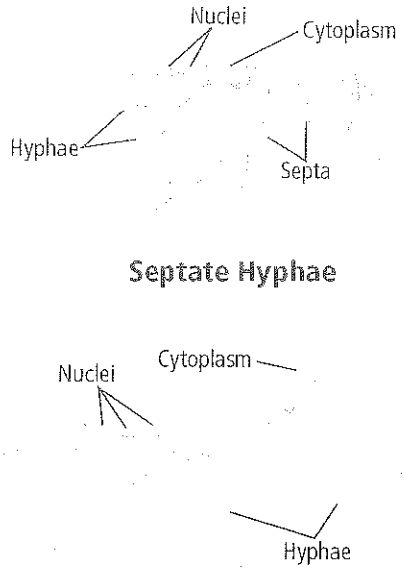


Figure 3
Top: Some fungi have hyphae that are divided by cross walls called septa.
Bottom: Other fungi do not have hyphae with septa.

Cross walls In many fungi, hyphae are divided into cells by cross walls called **septa** (singular, septum), as shown in **Figure 3.** The septa have large pores that allow nutrients, cytoplasm, organelles, and, in some cases, nuclei to flow between cells.

Some fungi are aseptate, meaning that they have no septa. The cytoplasm, containing hundreds or thousands of nuclei, flows freely through the hyphae. This condition is a result of repeated mitosis without cytokinesis. Nutrients and other materials flow very quickly through aseptate hyphae.

Nutrition in Fungi

Unlike humans, who ingest their food and then digest it, fungi digest their food before they ingest it. Many fungi produce enzymes that break down organic material, allowing the nutrients to be absorbed through their thin cell walls. All fungi are heterotrophs, but there are three types of fungi that differ in how they obtain their nutrients.

Saprophytic fungi A saprobe is an organism that feeds on dead organisms or organic wastes. Saprophytic fungi, such as the bracket fungus shown in **Figure 4,** are decomposers and recycle nutrients from dead organisms back into food webs. The fungus in **Figure 5** also is a saprobe.

Parasitic fungi Parasitic fungi absorb nutrients from the living cells of another organism, called a host. Many parasitic fungi produce specialized hyphae called **haustoria** (haws TOH ree ah), which grow into the host's tissues and absorb their nutrients. *Arthrobotrys* is a group of parasitic soil fungi that trap prey with rings of hyphae.

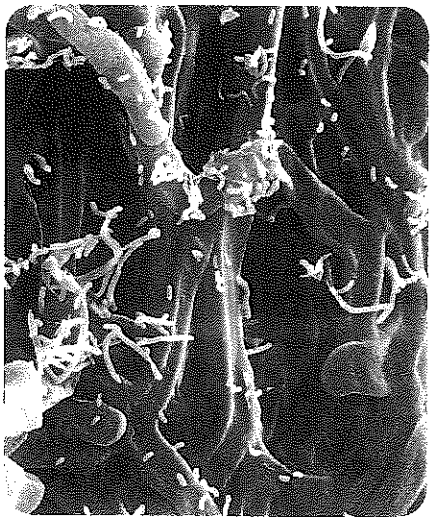
Mutualistic fungi Some fungi live in a mutualistic relationship with another organism, such as a plant or an alga. The mycelia of a particular fungus cover the root of a soybean plant. The fungus receives sugar from the host plant. The mycelia increase water uptake and mineral absorption for the host plant.

Figure 4 Fungi can obtain food in one of three different ways: through decomposition, through parasitism, and through mutualism.

Bracket fungus feeding on a log (decomposition)

***Arthrobotrys* hyphae trapping a nematode (parasitism)**

Color-Enhanced SEM Magnification: 2500×

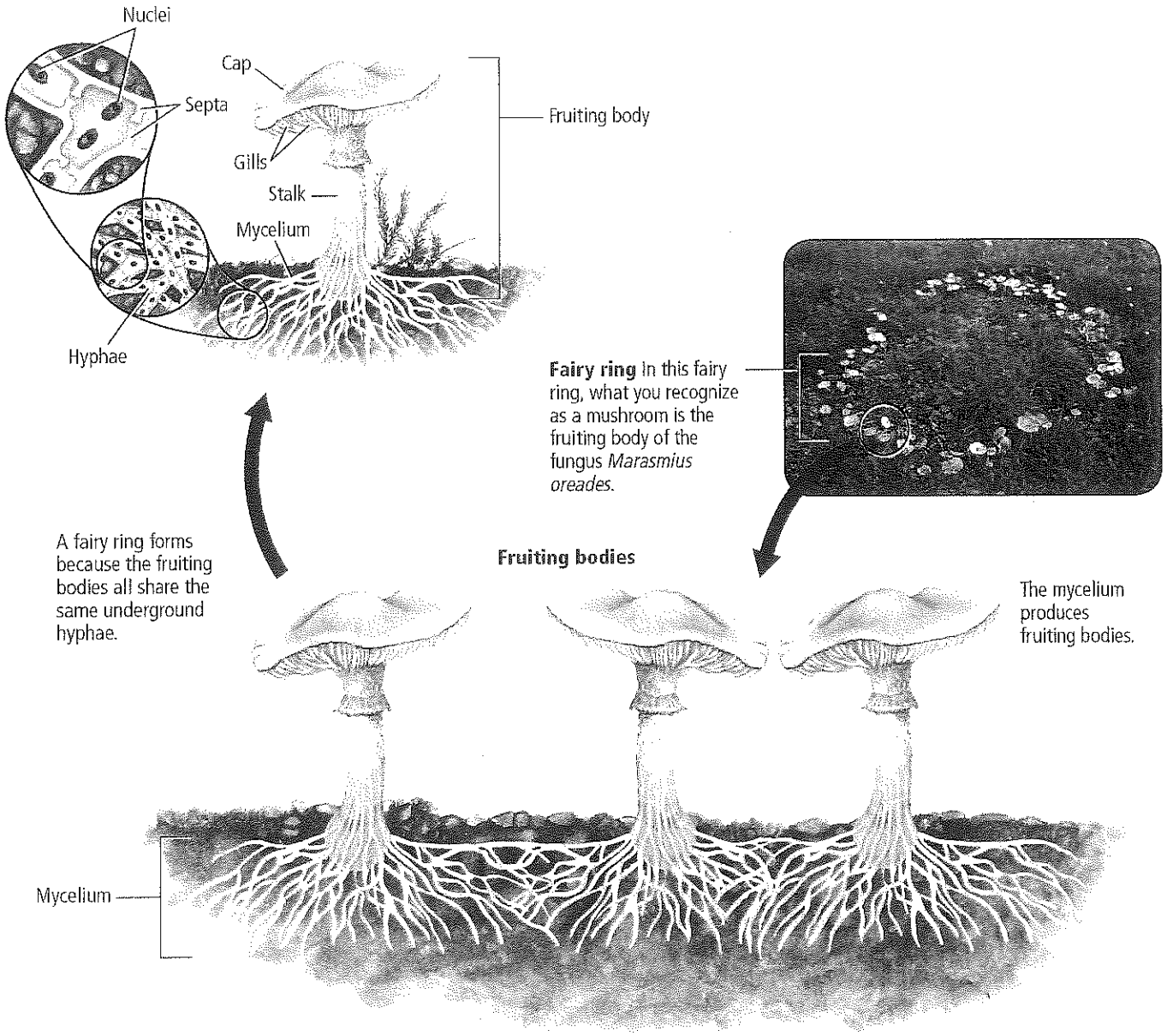


Mycelia on a root (mutualism)

Visualizing a Fairy Ring

Figure 5

Fungi produce spores in reproductive structures called *fruiting bodies*. A fruiting body is made up of hyphae that grow outward by extending their lengths, growing into new areas where a fresh supply of nutrients can be found in the soil. This creates a ring of mushrooms called a fairy ring.



Roel Meijer/Alamy

Animation

Color-Enhanced SEM Magnification: 3000×

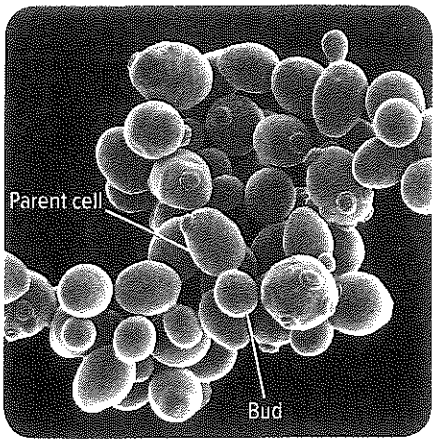


Figure 6 Notice how the plasma membrane is begining to separate the bud from the parent cell.
Identify *what type of reproduction is shown.*

Video Lab

Reproduction in Fungi

Fungi are classified by their structure and patterns of reproduction. Some fungi can reproduce only asexually through mitosis. Asexual reproduction in fungi also includes fragmentation, budding, and spore production. Many fungi can reproduce both asexually and sexually. Sexually reproducing fungi produce spores by the process of meiosis.

Budding Unicellular yeast cells reproduce asexually by budding. As shown in **Figure 6,** the new cell develops while attached to the parent cell. The plasma membrane pinches off to partially separate the new individual from the parent cell.

Fragmentation Fragmentation is a form of asexual reproduction that occurs when the mycelium of a fungus is physically broken apart, or fragmented. This can occur in a number of different ways. One example is by an animal digging in the soil where a fungus is growing. If the fragments of mycelia land in a location with suitable growing conditions, the hyphae will grow into new mycelia.

Spore production Most fungi are able to reproduce sexually and asexually by producing spores. A **spore** is a haploid reproductive cell with a hard outer coat. Spores develop into a new organism without the fusion of gametes. When one of these microscopic spores lands in suitable conditions, it generates haploid hyphae. These hyphae can fuse with the hyphae of other compatible fungi to become diploid. The diploid hyphae can then produce fruiting bodies that will produce zygotes. The zygotes go through meiosis to produce haploid spores, and the cycle repeats.

MiniLab 1

MiniLab

Examine Yeast Growth

What is the relationship between yeast reproduction and the availability of food? Yeasts are unicellular fungi. These organisms feed on sugars, producing carbon dioxide and ethyl alcohol in the process. Yeasts reproduce asexually and multiply quickly under optimal growth conditions.

Procedure

1. Read and complete the lab safety form.
2. Label four **250-mL Erlenmeyer flasks** 1–4.
3. Create a data table to record your results.
4. Add **100 mL warm water** to each flask, and do not cover the flasks.
5. Add 0.0 g; 0.5 g, 1.0 g, or 1.5 g of **table sugar** to each one of the flasks.
6. Add one packet of **dry yeast** to each flask. Stir the contents of the flasks with a **glass rod** until the contents are thoroughly mixed.
7. Observe and record the changes in the flasks every five minutes for 20 minutes.
8. Clean up your work station according to your teacher's instructions.

Analysis

1. **Conclude** What is the relationship between yeast reproduction and the availability of sugar?
2. **Analyze** How might your results have changed if the flasks had been covered during your experiment?

Science Photo Library RF/Getty Images

Adaptations for survival Most fungi, like the puffball fungi shown in **Figure 7**, produce trillions of spores. Producing such large quantities of spores is an adaptation for survival. This adaptation ensures that at least a small percentage of the spores will land in suitable locations and begin to grow, producing the next generation.

Additional adaptations for survival include the physical traits of the spores. They are so small and lightweight that wind and even the smallest animals, such as insects, can disperse them. A spore also is protected by its cell wall. This wall often is tough and waterproof, which allows the spore to survive extremes of temperature and moisture.

Examine **Figure 7** again to see the cloud of spores being released. When spores are dispersed by wind, the spores can travel hundreds of miles across land and water. In fact, fungal spores can be found almost everywhere.

Sporophores The fruiting body of a spore-forming fungus is called a sporophore (SPOH ruh for) and is characteristic of that species of fungus. The classification of a fungus is based primarily on the type of sporophore that it produces. For example, in some primitive fungi, such as black bread mold, specialized hyphae called sporangiophores (spuh RAN jee uh forz) have a spore-containing structure called a sporangium (plural, sporangia) on each of their tips. A **sporangium** is a sac or case in which spores are produced. The sporangia provide protection for the spores, preventing them from drying out prematurely.

In Section 2, you will learn that some fungi have common names such as sac fungi and club fungi. These names are descriptive for the type of sporophores that these fungi produce. Section 2 also contains information about the life cycles and the types of spores and sporophores produced by members of each of the major phyla of fungi.

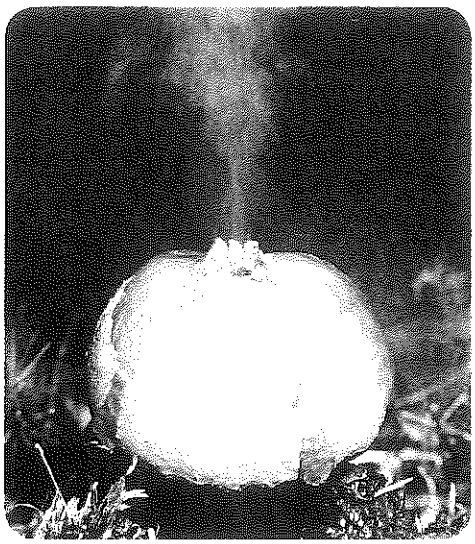


Figure 7 Puffball fungi can produce trillions of spores. The slight touch of an animal brushing against the fungus or a falling raindrop can trigger the release of spores.

Kenneth H. Thomas/Photo Researchers

Section 1 Assessment

Section Summary

- Fungi produce hyphae that form a netlike mass called a mycelium.
- There are three different methods by which fungi obtain food.
- Fungi can reproduce asexually by budding, fragmentation, or producing spores.
- Most fungi can reproduce sexually, also by producing spores.

Understand Main Ideas

1. **Name** three major characteristics of Kingdom Fungi.
2. **Diagram** the difference between septate and aseptate hyphae.
3. **State** how fungi feeding differs from animal feeding.
4. **Contrast** the methods that parasitic, saprophytic, and mutualistic fungi use to obtain food.
5. **Explain** three methods of asexual reproduction in fungi.

Think Critically

6. **Predict** how a slice of bread that is left out on a table for a few weeks can become covered with bread mold. From where does the mold come?

WRITING IN Biology

7. Fungi can be used as a biocontrol to control common insect pests. Research and write an article for a gardening magazine about the value of fungi in your garden. Include several examples of fungi used in gardens.

Online Quiz

Diversity of Fungi

Reading Preview

Essential Questions

- What are the four major phyla of fungi?
- What are the distinguishing traits of each fungus phylum?
- What are the reproductive strategies of each fungus phylum?

Review Vocabulary

flagellated: having projections that propel organisms with a whiplike motion

New Vocabulary

stolon
rhizoid
gametangium
conidiophore
ascocarp
ascus
ascospore
basidiocarp
basidium
basidiospore

Multilingual eGlossary

Key Idea **Fungi exhibit a broad range of diversity and are classified into four major phyla.**

Real-World Reading Link Think of the many sizes, shapes, and colors of insects that you might have seen. While they are all insects, they are very diverse. Within Kingdom Fungi, there is also much diversity in structures and life cycles.

Classification of Fungi

Biologists use fungal structure and methods of reproduction to divide fungi into four major phyla–Chytridiomycota, Zygomycota, Ascomycota, and Basidiomycota. The cladogram shown in **Figure 8** shows the evolutionary relationships among the phyla of fungi as they currently are understood.

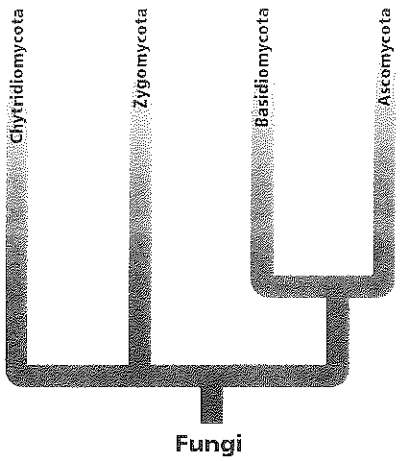
Fungi are likely to have colonized land with plants more than 450 million years ago, possibly as a result of mutualistic associations with plants. Yet, molecular evidence supports the view that fungi are more closely related to animals than to plants. Evidence suggests that fungi and animals diverged from a common protist ancestor.

Chytrids

The fungi in the phylum Chytridiomycota (ki TRIHD ee oh mi koh tuh) often are referred to as chytrids (KI trihdz). Some chytrids are saprophytes, whereas others parasitize protists, plants, and animals. Most chytrids are aquatic, and they are unique among fungi because they produce flagellated spores. For this reason, scientists originally grouped chytrids with protists.

Chytrids, like the one in **Figure 8,** have been reclassified as new information about them has become available. Recent molecular evidence suggests that chytrids are related more closely to fungi than to protists because of similar protein and DNA sequences. Another characteristic that indicates a close relationship with fungi is chitin-containing cell walls. There is evidence that chytrids were perhaps the first fungi and are the evolutionary link between funguslike protists and fungi.

Figure 8 **Left:** This phylogenetic tree shows the evolutionary relationships of the phyla of fungi. **Right:** Chytrids have reproductive cells with flagella. No other types of fungi have this structure.



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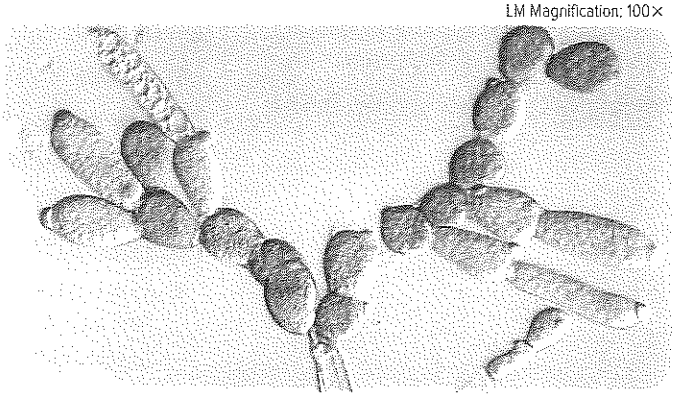


Chytrid

Carolina Biological Supply Company/Photolake

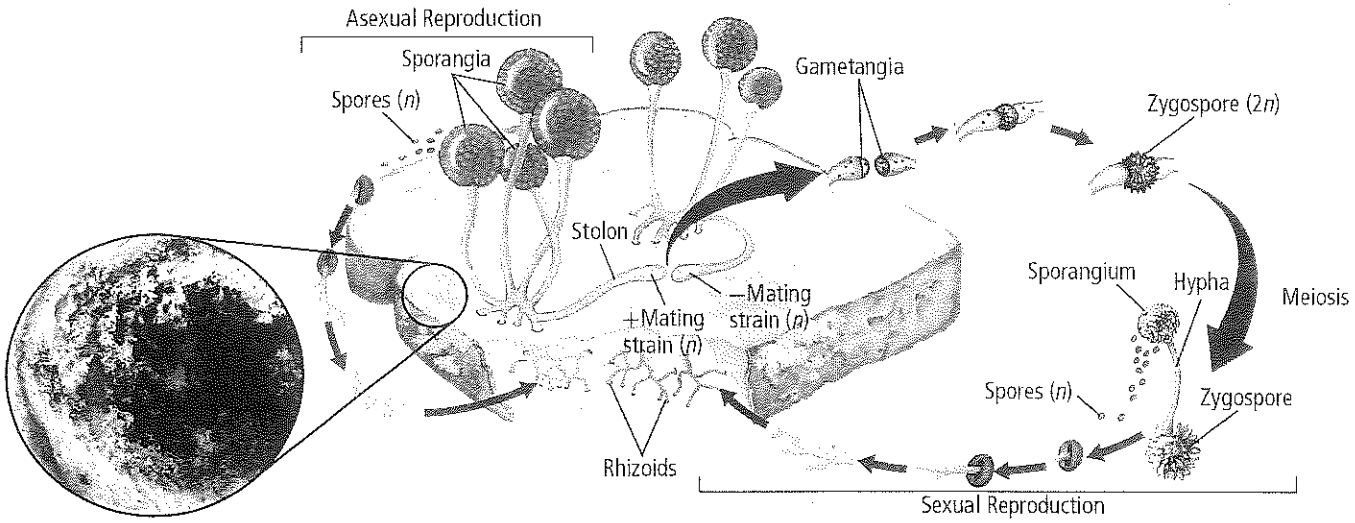
Common Molds

The most familiar member of the phylum Zygomycota (zi goh mi KOH tuh) is a common mold that grows on bread and other foods called *Rhizopus stolonifer.* Common molds are mostly terrestrial, and some live in mutualistic relationships with plants. Molds form a type of hyphae called **stolons** (STOH lunz) that spread across the surface of food. Another type of hyphae, called **rhizoids** (RIH zoydz), penetrates the food and absorbs nutrients, as shown in **Figure 9.** Other functions of rhizoids include anchoring the mycelium and producing digestive enzymes. Zygomycetes also can be found on decaying plant and animal material.

Life cycle Zygomycetes reproduce both asexually and sexually, as illustrated in **Figure 9.** Asexual reproduction occurs when sporangia form at the tips of upright hyphae called sporangiophores. Within each sporangium are thousands of haploid spores that can be spread by wind or other air movements. When released, spores will produce new hyphae if they land in a favorable environment.

If conditions in the environment are no longer favorable to sustain life, zygomycetes can reproduce sexually. There are no defined male and female fungi, but rather plus (+) and minus (-) mating strains. Haploid hyphae from two compatible mating strains–one plus and one minus–fuse. Each hypha produces a **gametangium** (ga muh TAN jee um) (plural, gametangia), which is a reproductive structure that contains a haploid nucleus. As shown in **Figure 9,** the two haploid nuclei from each gametangium fuse to form a diploid zygote. The zygote develops a thick wall and becomes a dormant zygospore (ZI guh spor), sometimes called a zygosporangium.

Figure 9 *Rhizopus stolonifer,* a common bread mold, is an example of a zygomycete that undergoes both asexual and sexual reproduction.



Vaughan Fleming/SPL/Photo Researchers

MiniLab 2

MiniLab

Investigate Mold Growth

How does salt affect mold growth? Chemical preservatives, including salt (sodium chloride), often are used to influence mold growth on a variety of foods.

Procedure

1. Read and complete the lab safety form.
2. Obtain two slices of **bread.** Touch one object in the room with both sides of both slices.
3. Using a **spray bottle** filled with **water,** lightly moisten both sides of both slices of bread evenly.
4. Place one bread slice in a **self-sealing bag.** Seal the bag and label it with your name, date, and the object that touched the bread.
5. Sprinkle **salt** on both sides of the second slice of bread. Place the slice in another bag and seal it. Label this bag as you did the first, but note that salt was added.
6. Create a table to record your observations.
7. Record observations daily for ten days. Your table should include descriptions, as well as measurements of any mold that has formed.

Analysis

1. **Identify** Which slice grew more mold?
2. **Conclude** Did the salt affect mold growth?
3. **Analyze** Why did the salt affect the mold?

CAREERS IN BIOLOGY

Mycologist A mycologist studies various aspects about fungi such as their biochemistry, genetics, evolution, classification, and economic uses.

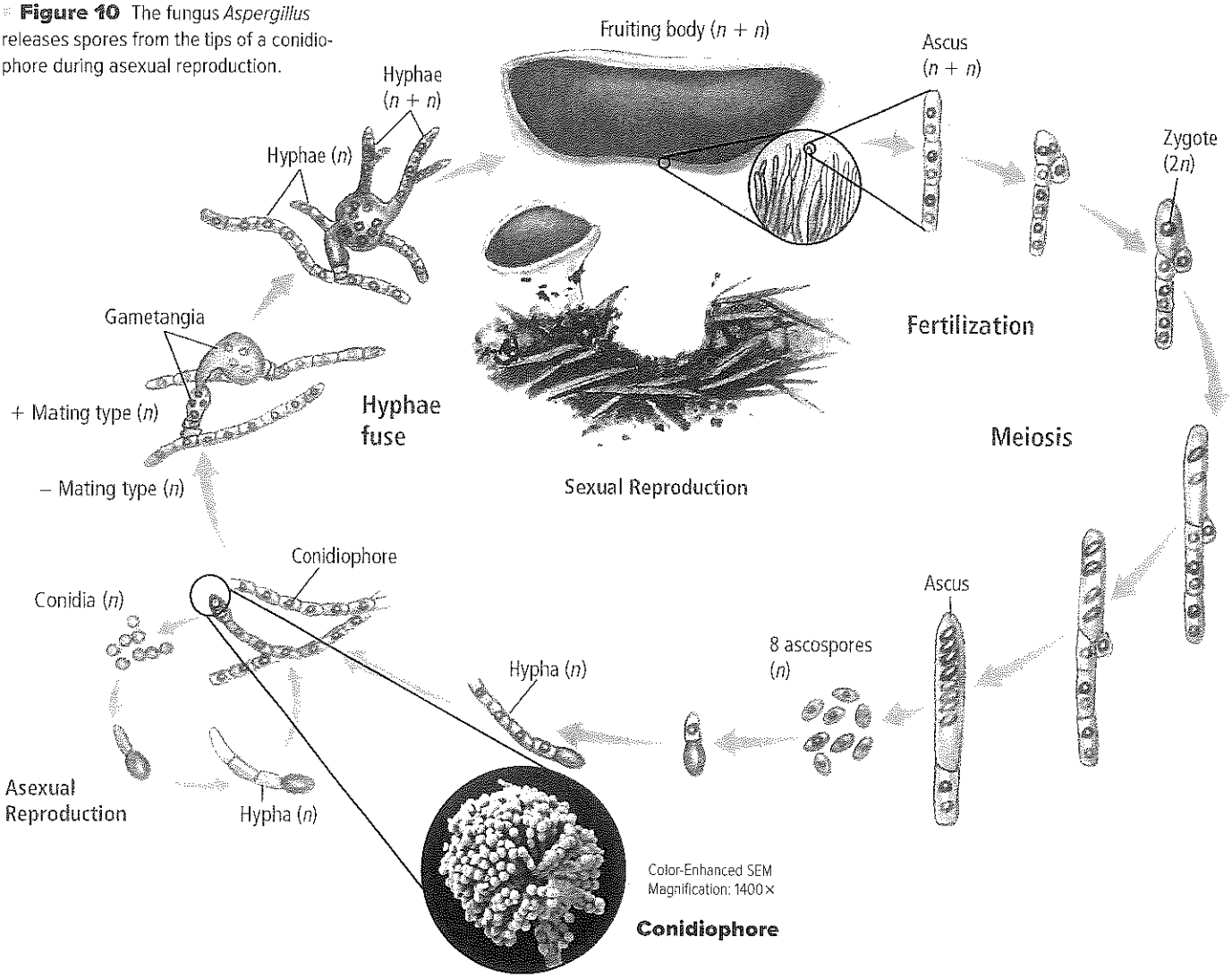
The zygospore can remain dormant for months until environmental conditions improve. Then, the zygospore germinates and undergoes meiosis to produce hyphae with a sporangium. Each haploid spore formed in the new sporangium can grow into a new mycelium. This process of sexual reproduction provides greater genetic diversity that helps ensure the survival of the species by allowing zygomycetes to survive in changing environments.

Sac Fungi

There are more than 60,000 species of sac fungi found in the phylum Ascomycota (AS koh mi koh tuh). It contains more species than any other phylum of fungi. Species found in this phylum are referred to as ascomycetes or sac fungi. Although the most well-known ascomycetes–yeasts–are unicellular and microscopic, most members of this group are multicellular.

Life Cycle Sac fungi can reproduce both sexually and asexually. During asexual reproduction, spores are formed at the tips of the hyphae. These spore-producing hyphae are called **conidiophores** (koh NIH dee uh forz), and the spores they generate are called conidia. Instead of forming inside sporangia, conidia form externally at the tips of the conidiophore. These spores are dispersed easily by wind, water, and animals.

Figure 10 The fungus *Aspergillus* releases spores from the tips of a conidiophore during asexual reproduction.



Eye of Science/Photo Researchers

Ascomycete sexual reproduction is a complicated process, illustrated in **Figure 10.** It takes place when hyphae from opposite mating types fuse and one nucleus from each type pairs off in separate cells. The hyphae that continue to grow are septate. Each cell contains two haploid nuclei—one from each mating type. Eventually, the hyphae will develop a specialized reproductive structure called an **ascocarp.** Within the ascocarp, the haploid nuclei fuse to form a zygote. The zygote divides by meiosis, producing four haploid nuclei. These nuclei then divide by mitosis, forming a total of eight haploid nuclei. The nuclei develop into spores in the **ascus,** a saclike structure. Spores produced by an ascus are called **ascospores.** Just like other spores, when growing conditions are favorable, each ascospore can develop into a haploid mycelium.

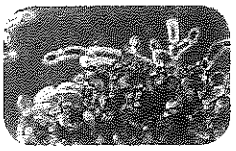
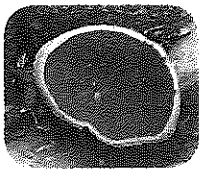
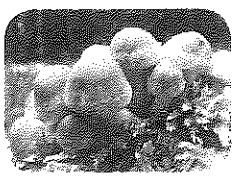
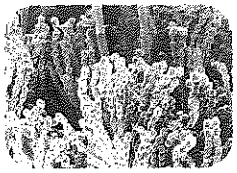
Study Tip

Tables Write a short paragraph using the table below to compare the number of phyla and the approximate number of species in each phylum. Predict how these numbers will compare to the numbers for plants and animals.

Club Fungi

Table 1 compares the characteristics of the fungi in phylum Basidiomycota with the fungi in other phyla. Among the 25,000 members of the Basidiomycota (buh SIH dee oh mi koh tuh) phylum are the mushrooms, perhaps the most commonly recognized type of fungus.

Table 1 Fungi Phyla — Interactive Table

Phylum (Common Name)	Example	Number of Species	Characteristics
Chytridiomycota (chytrids)	LM Magnification: 100× 	1300+	• Unicellular • Most are aquatic • Some are saprophytic, while others are parasitic • Produce flagellated spores
Zygomycota (common molds)	LM Magnification: 4× 	800	• Multicellular • Most are terrestrial • Many form mutualistic relationships with plants • Reproduce sexually and asexually
Ascomycota (sac fungi)		60,000+	• Most are multicellular, but some are unicellular • Variety of habitats • Saprophytic, parasitic, or mutualistic • Reproduce sexually and asexually
Basidiomycota (club fungi)		25,000	• Most are multicellular • Most are terrestrial • Saprophytic, parasitic, or mutualistic • Rarely reproduce asexually
Deuteromycota (imperfect fungi)		25,000	• No sexual stage observed • Very diverse group • Might not be considered a true phylum

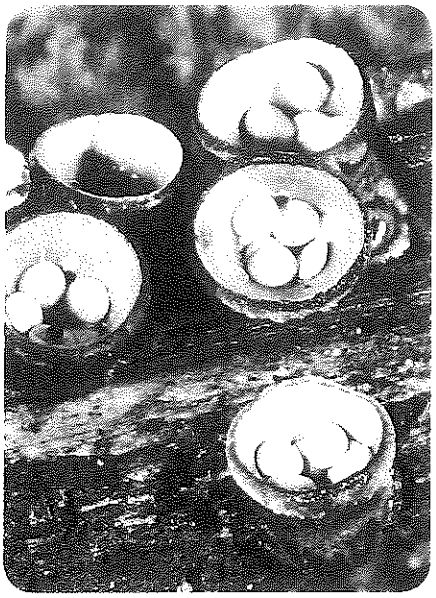


Figure 11 This club fungus, called bird's nest fungus or *Crucibulum vulgare*, has basidiocarps that resemble eggs in a bird's nest.

Species found in phylum Basidiomycota also are called basidiomycetes (buh SIH dee ah mi see teez) or club fungi. They can be saprophytic, parasitic, or mutualistic. The saprophytic basidiomycetes are major decomposers of wood. They produce enzymes that can break down complex polymers found in wood, such as lignin.

Life Cycle Basidiomycetes rarely produce asexual spores. They spend most of their life cycle as dikaryotic mycelia, meaning that each cell has two nuclei. The mycelium periodically will reproduce sexually by forming **basidiocarps** (buh SIH dee oh karpz), or fruiting bodies, as shown in **Figure 11.** The mushrooms that you see growing in the woods or that you add to your salad are basidiocarps.

Basidiocarps can grow quickly, sometimes appearing full-grown in a few hours or overnight, with rapid growth resulting from cell enlargement rather than cell division. The underside of the cap is composed of **basidia** (singular, basidium), club-shaped hyphae that produce spores. Within the basidia, the two nuclei fuse to form a diploid nucleus. This nucleus divides meiotically into four haploid nuclei that will develop into **basidiospores,** the haploid spores released by basidia during reproduction. The basidiospores can be dispersed by wind, water, or animals. It is estimated that some mushrooms will produce as many as a billion basidiospores.

Other Fungi

Organisms in phylum Deuteromycota share only one unique trait–sexual reproduction in these fungi never has been observed. Because these fungi appear to lack a sexual stage, they are referred to as imperfect fungi. Scientists currently use modern genetic techniques, such as DNA and protein comparisons, to reassign some of these fungi into one of the other four phyla.

Section 2 Assessment

Section Summary

- There are four major phyla of fungi.
- Zygomycetes reproduce sexually by forming zygospores.
- Ascomycetes produce ascospores within a saclike structure called an ascus during sexual reproduction.
- Basidiomycetes produce basidiospores during sexual reproduction.
- Sexual reproduction in the phylum Deuteromycota has never been observed.

Understand Main Ideas

1. **Identify** two characteristics of each of the four major phyla of fungi.
2. **Explain** why fungi produce so many spores.
3. **Diagram** the life cycle of ascomycetes.
4. **Describe** What are imperfect fungi?
5. **Compare** sexual reproduction in ascomycetes and basidiomycetes.

Think Critically

6. **Predict** what might happen to an ecosystem if a virus destroyed all of the basidiomycetes. What effect would that have on the recycling of nutrients in a forest?

WRITING in Biology

7. Write a news story detailing how a scientist reclassified a species of imperfect fungi once sexual reproduction was identified.

Stuart Wilson/Photo Researchers

Online Quiz

Reading Preview

Essential Questions

- What are the characteristics of lichens?
- What are the characteristics of mycorrhorizal relationships?
- What are some beneficial and harmful effects that fungi can have on humans?

Review Vocabulary

bioremediation: the use of organisms to detoxify a polluted area

New Vocabulary

lichen
bioindicator
mycorrhiza

Multilingual eGlossary

Ecology of Fungi

Key Idea Lichens and mycorrhizae demonstrate important symbiotic relationships between fungi and other organisms.

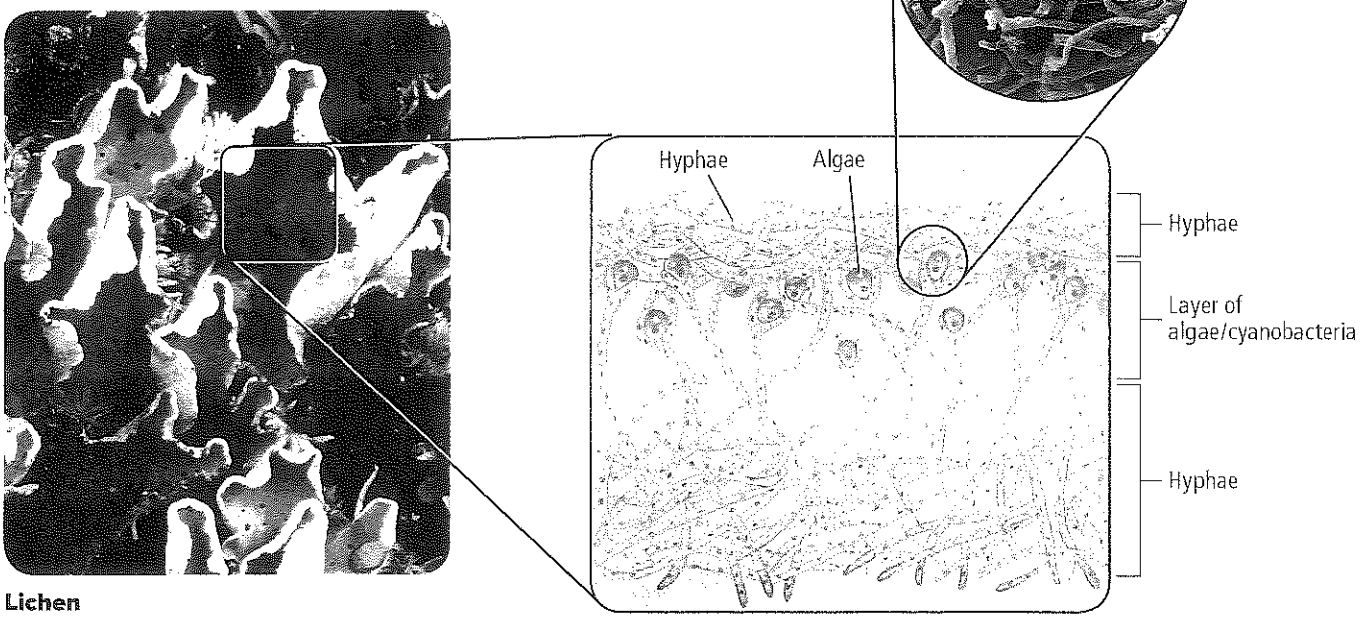
Real-World Reading Link You might think that the only time you encounter fungi is when you order mushrooms on pizza or when you take a nature walk. You might be surprised to know that some antibiotics are derived from fungi, and that athlete's foot is caused by fungi.

Fungi and Photosynthesizers

Lichens and mycorrhizae are two examples of mutualistic relationships between fungi and other organisms. Recall that mutualism is a type of symbiosis in which both organisms benefit from the relationship.

Lichens A symbiotic relationship between a fungus and an alga or a photosynthetic partner is called a **lichen** (LI ken). The fungus usually is an ascomycete, but lichens also may contain basidiomycetes. The photosynthetic partner is either a green alga or cyanobacterium, which provides food for both organisms. The fungus provides a dense web of hyphae in which the alga or cyanobacterium can grow. Examine **Figure 12** to see the structure of a lichen. Notice that fungal tissues account for most of the mass of a lichen.

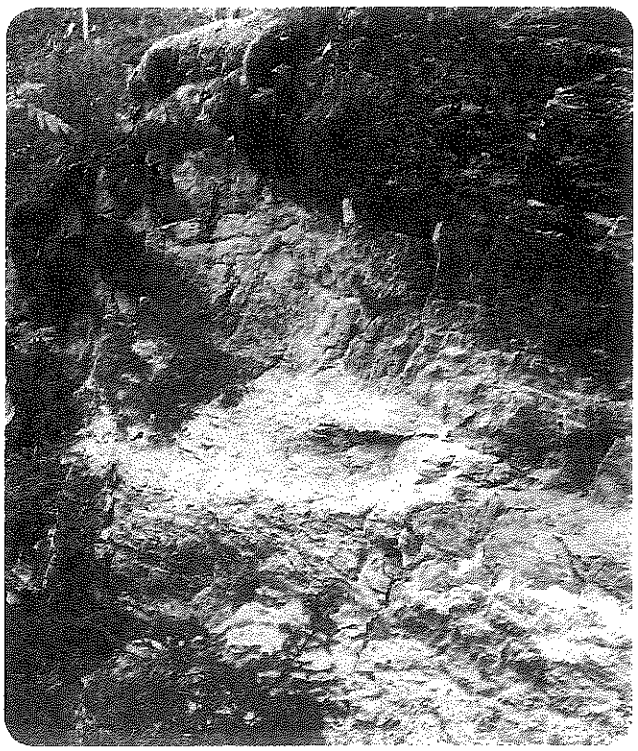
Figure 12 This felt lichen growing on the forest floor is a mutualistic organism made up of algae and fungi. The hyphae, shown as threadlike strands in the photomicrograph, protect the pigmented algae found between the layers of hyphae.



Lichen

(l)blickwinkel/Alamy; (r)Eye of Science/Photo Researchers

Red blanket lichen



***Lepraria* on a rock**

Figure 13 Lichens grow in harsh enviroments, such as the surfaces of trees or bare rocks, where fungi, algae, and cyanobacteria would not grow alone.
Explain *why lichens often are pioneer species.*

Diversity of lichens There are over 25,000 species of lichens. To see two of the different forms, examine **Figure 13.** Because they need only light, air, and minerals to grow, lichens are found in some of the harshest environments. Lichens absorb needed minerals from rainwater or from dust in the air. The fungus traps rainwater, but it also can absorb moisture from the air. Some fungi produce toxic compounds that keep animals, including insects, from eating the lichen. Fungi also inhibit moss and bacterial growth.

Although a few types of lichens can be found in deserts or the tropics, the majority of these organisms grow in temperate or arctic areas. They form the primary ground cover on the tundra, providing food for grazing animals. Caribou utilize an enzyme called lichenase (LI kun ayz) to help them digest the lichen.

Lichens also survive severe drought. They dry out, stop photosynthesis, and become brittle. Pieces can break off, blow away, and reestablish in another location–a form of asexual reproduction. When water is available again, the lichens rapidly absorb large quantities of the water and begin photosynthesis again.

Recall that a pioneer species is a species that can grow with little soil or on rocks. Lichens often are the pioneer species in an area of newly cleared soil or rock following natural disasters, such as fire or volcanic activity. Acids produced by the fungal portion of the lichen help penetrate and break down rocks to help form soil. As lichens become established, they help trap soil and fix nitrogen, which helps plants colonize the new soil.

Lichens as bioindicators Because they absorb much of their water and minerals from the air and rain, lichens are especially sensitive to airborne pollutants. When air pollution levels rise in an area, lichens often will die. In addition, lichens typically do not grow in or near cities where air pollution is high. They usually are found in rural areas where there is little or no air pollution. Lichens absorb pollutants that are dissolved in rain and dew. Because of their sensitivity to pollution, lichens are important bioindicators.

A **bioindicator** is a living organism that is sensitive to changes in environmental conditions and is one of the first organisms to respond to changing conditions. The levels of air pollutants in an area can be correlated to the changes in lichen growth. As the level of pollution decreases, the populations of lichens increase.

Reading Check **Explain** why lichens are bioindicators.

(t)Florida Images/Alamy; (b)blickwinkel/Alamy

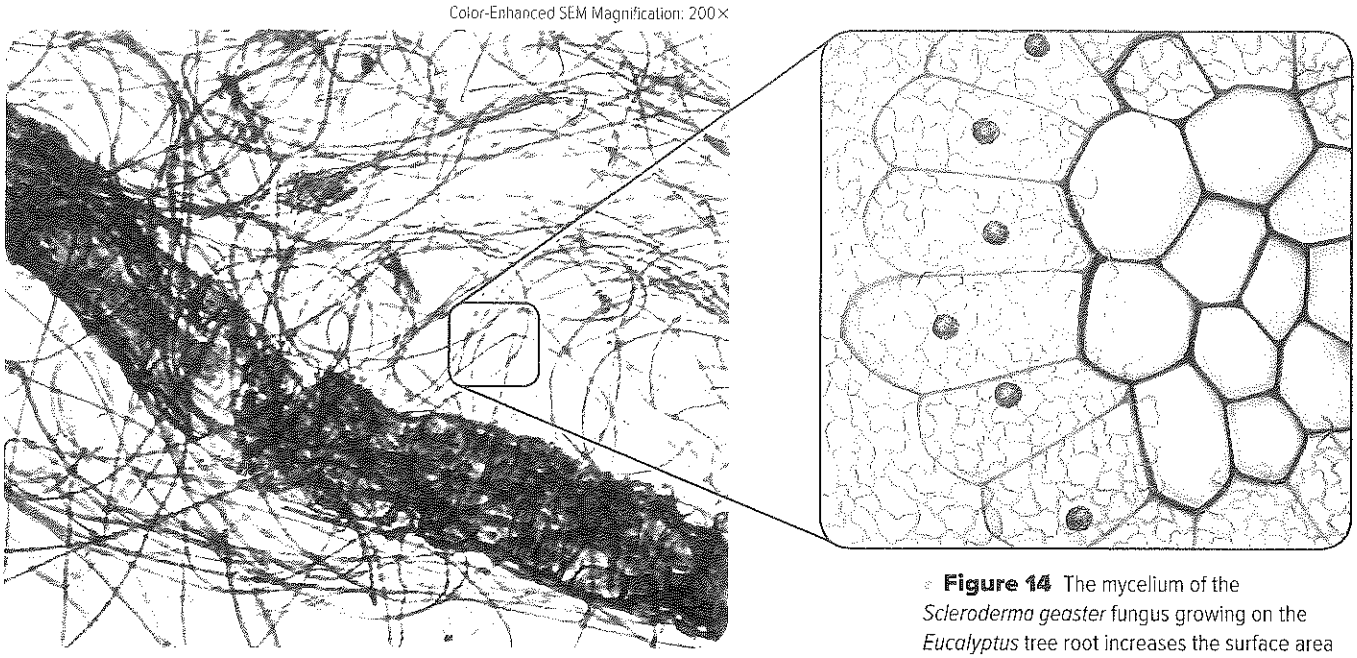


Figure 14 The mycelium of the *Scleroderma geaster* fungus growing on the *Eucalyptus* tree root increases the surface area in which water and nutrients can be absorbed by the root.

Explain ***How does the fungus benefit from this relationship?***

Mycorrhizae Another mutualistic relationship involving a fungus is a **mycorrhiza** (my kuh RHY zuh) (plural, mycorrhizae)–a symbiotic relationship between a specialized fungus and plant roots. Plants with mycorrhizae are healthier and more vigorous than similar plants that lack mycorrhizae. Other plant species, such as orchids, cannot survive without mutualistic partners. Orchid seeds will not germinate unless they are infected by a fungal partner or provided with the fungal carbohydrate trehalose.

Figure 14 shows a mycorrhizal relationship between a *Schleroderma geaster* fungus and a *Eucalyptus* tree. The fungus absorbs and concentrates various minerals for the plant. The hyphae of the fungus also increase the plant's root surface area for water and mineral absorption. In return, the fungus receives carbohydrates and amino acids from the plant.

Between 80 and 90 percent of plants, including primitive plants, have mycorrhizae. Mycorrhizae are extremely important in natural habitats and for agricultural crops. Crops associated with mycorrhizae include corn, carrots, potatoes, tomatoes, and strawberries.

VOCABULARY

ACADEMIC VOCABULARY

Cooperate
to work or act together toward a common end or purpose
Organisms that cooperate with members of their own or different species might be more successful than those organisms that do not cooperate.

Fungi and Humans

For the most part, fungi have a positive effect on the lives of humans. Their most important role is as decomposers, assisting with the recycling of nutrients found in dead organisms. Decomposing organic matter makes nutrients available for other organisms and prevents dead organisms and their wastes from littering the surface of Earth.

Beneficial fungi Fungi have many medical uses. The ascomycete *Penicillium notatum* can be used as a source of penicillin. This antibiotic has saved countless lives. Chemical compounds found in the fungus *Claviceps purpurea* are used to reduce high blood pressure, to control excessive bleeding, to treat migraine headaches, and to promote contractions during childbirth. The Norwegian deuteromycete *Tolypocladium inflatum* is the source for cyclosporine. Cyclosporine is an immune suppressant drug given to organ transplant patients to keep their bodies from rejecting new organs.

CAREERS IN BIOLOGY

Food Technologist A food technologist can choose from a range of jobs, including the development of new food products and setting standards for producing, packaging, and marketing food technologies. They also might test products for nutritional and microbiological quality.

Foods Many of the foods we eat are made from fungi or fungal products. The most obvious are the many different mushrooms that we eat. Yeast makes bread rise by releasing carbon dioxide gas during fermentation. Another product of fermentation is the alcohol found in beer and wine. Truffles are fungi and are one of the most expensive food items. Many other fungi are enjoyed similarly as delicacies. The flavors of some cheeses, such as Brie, Camembert, and Roquefort, are the result of fungi. The citrus flavor found in sodas is created by the fungus *Aspergillus*. This fungus also is used to make soy sauce.

Bioremediation Fungi also can be used for cleaning the environment of pollutants that are threatening some ecosystems. The fungi are mixed with water or soil, where they decompose organic materials in the pollutants. During this process, called bioremediation, the pollutants are broken down into harmless substances. The rate at which microorganisms, such as fungi and bacteria, remove environmental pollutants can be increased if additional nutrients are added to the water or soil. Bioremediation is a relatively new scientific field, and new discoveries and processes are being developed to be used in environmental clean-up projects.

Connection to Chemistry Researchers are using white-rot fungi to break down top priority pollutants, such as dyes and polycyclic aromatic hydrocarbons (PAHs). PAHs are carcinogenic (cancer-causing) molecules. Researchers also are taking advantage of the fact that these fungi contain enzymes that degrade lignin, a molecule found in wood fiber that hardens and strengthens the cell walls of plants, enabling wood to be recycled. These enzymes also can attach to structurally similar chemicals, including many human-made pollutants.

DATA ANALYSIS LAB 1

Based on Real Data*

Interpret the Data

Does the addition of salt to soil affect asparagus production? *Fusarium oxysporum* is a disease-causing organism of many crops, including asparagus. The fungus penetrates the roots and spreads up through the plant, often reducing the flow of water to the stem and leaves. Infected plants produce fewer and smaller spears than healthy plants do. The fungus stays in the soil year after year.

Data and Observations

Salt (sodium chloride) treatment is a common method for suppressing disease in plants. The table shows data collected after an asparagus field was treated with a dusting of salt.

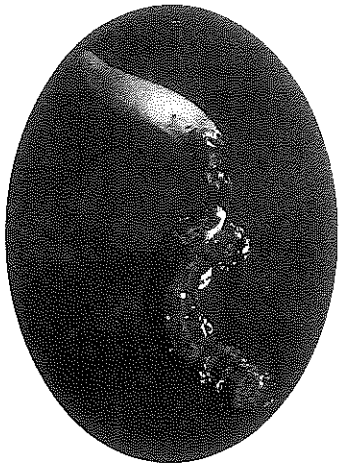
*Data obtained from: Elmer, W.H. 2002. Influence of formononetin and NaCl on mycorrhizal colonization and fusarium crown and root rot of asparagus. *Plant Disease* 86(12): 1318-1324.

Asparagus Production

	Spear number	Spear mass
Before treatment with salt	78.2	1843.2
After treatment with salt	89.1	2266.1

Think Critically

1. **Calculate** the percentage change in spear number and spear mass.
2. **Interpret** how the salt treatment affects the asparagus crop.
3. **Hypothesize** why salt might have this effect on the plants. How would you test your hypothesis?



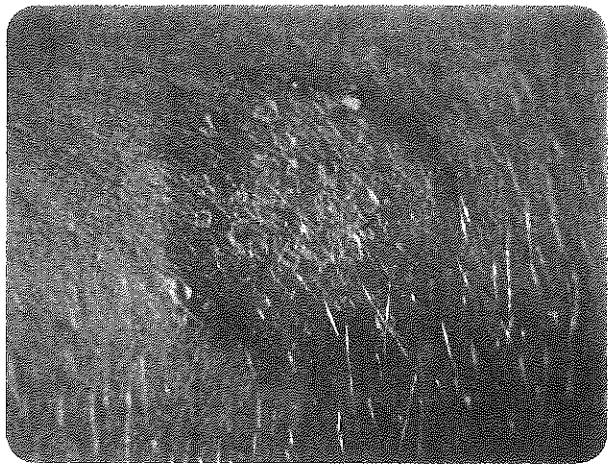


Figure 15 Parasitic fungi can be harmful to humans as well as to other organisms.
Left: Grapes are infected by a fungus that causes noble rot.
Middle: Scarlet caterpillar fungus can kill caterpillars.
Right: Ringworm is caused by a fungus.

Harmful fungi Some fungi can be harmful to other organisms. For example, American elm trees are killed by the fungus *Ceratocystis ulmi* and American chestnut trees are killed by the fungus *Endothia parasitica*. The fungi quickly spread from tree to tree, and they have killed many trees in North America. Agricultural crops are also damaged by fungi. The fungal parasite *Leptoterochila medicaginis* causes leaf blotch in alfalfa plants and can diminish crop production by as much as 80 percent. The ripe grapes shown in **Figure 15** have been infected with the parasitic fungus *Botrytis cinerea*, causing what is known as noble rot. The fungus attacks the grapes and causes an increase in their sugar content, making most of them unusable. However, certain wines are produced from such grapes in France.

Fungi can also parasitize humans and other animals. The parasitic fungus *Cordyceps militaris* can infect the larvae and pupae of butterflies and moths, as shown in **Figure 15.** Athlete's foot, ringworm, yeast infections, and oral thrush are infections in humans that are caused by fungi. **Figure 15** shows skin infected with ringworm, which can be caused by several species of fungi.

Section 3 Assessment

Section Summary

- Lichens are examples of mutualistic relationships between a fungus and an alga or a cyanobacterium.
- Mycorrhizae help plants obtain water and minerals by increasing the surface area of their roots.
- Compounds obtained from fungi are used for a variety of medicines.
- Many foods eaten by people are made from fungi.
- Fungi can have adverse effects on humans and plants.

Understand Main Ideas

1. **Identify** the characteristics of the mutualistic relationship between fungi and algae.
2. **Explain** why lichens are important for the environment.
3. **Apply** what you know about enzymes to design a lichenase enzyme for lichen-eating animals.
4. **Construct** a table to show the beneficial and harmful effects of fungi on humans.

Think Critically

5. **Infer** the effect on world food production if a fungicide was discovered that destroys all of the fungi in agricultural settings.

MATH in Biology

6. Lichens grow an average of one centimeter per year. How long would it take for a lichen to grow the width of your hand?

Biology & Society

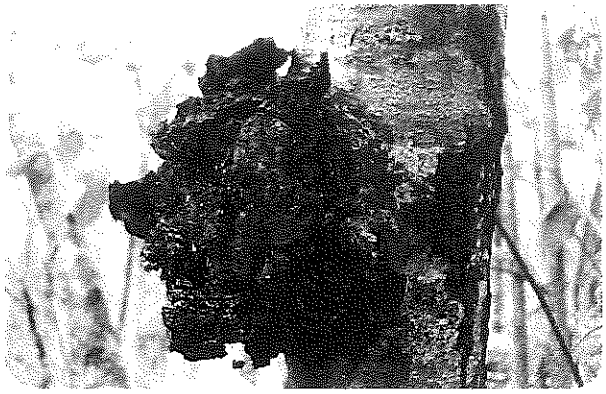
Fungi Superheroes

The Iceman, whose mummified corpse was discovered in 1991, provided a picture of what life was like 5000 years ago in the Stone Age. In his belt were two walnut-sized lumps of birch fungus (known as the chaga mushroom). This fungus can both cause diarrhea and serve as an antibiotic. The chaga mushroom helped alleviate the effects of the parasites that were living in the Iceman's colon by helping his body eliminate the parasite's eggs.

A folk hero The chaga mushroom has been used as a traditional folk remedy in Eastern European countries since the sixteenth century and has been mentioned in Chinese texts dating back 4600 years. Chaga mushrooms have been used as a treatment for tuberculosis, various cancers, and intestinal ailments, usually crushed up and ingested as an herbal tea.

Chaga mushroom Chaga is a parasitic fungus that grows from the trunks of birch trees. In Russia, chaga is known as the "birch-killer" because it leads to the tree's death within five to seven years. It is estimated that as few as 1 in 15,000 birch trees have chaga. Chaga which grow on birch trees in Siberia are particularly prized among herbalists. Their high concentration of beneficial compounds is attributed to their ability to persist in the relatively harsh environment.

Making better cancer drugs Current scientific research is backing up the claims that folk medicine has maintained for generations. Chaga transforms the compound "betulin" found in the bark of the birch tree into a form which can be ingested. Betulin has been shown to exhibit anti-malarial, anti-inflammatory, and anti-HIV activity, in addition to being toxic toward some tumor cells. In 1998, a study showed that betulin, in the form of betulinic acid, triggered apoptosis (programmed cell death) when injected into tumor cells.



The chaga mushroom is a parasitic fungus that feeds off birch, alder, and beech trees.

Chaga mushrooms contain high levels of antioxidants, known to inhibit the cell-damaging effects of free radicals (highly reactive, unpaired electrons). A 2005 study revealed that extracts from the mushroom protected DNA in human lymphocytes against oxidative damage. In addition, active polysaccharides present in the mushroom have been found to stimulate the immune system.

Scientists estimate that more than one million species of fungi exist and many are unidentified. The National Cancer Institute is collecting 1000 fungi samples yearly from the tropical rain forests to see if the fungi might contain disease-fighting compounds. In the meantime, researchers continue to study existing herbal remedies in order to reinforce or dispel the claims made of these natural curatives.

MAKE A BOARD GAME

Work with a Team Create a board game depicting the development of a cancer treatment based on the discovery of a fungus found living on a plant in the rain forest. Conduct additional research regarding drug development, drugs developed from fungi, and drug treatment in cancer research.

WebQuest

BIOLAB

Design Your Own

HOW DO ENVIRONMENTAL FACTORS AFFECT MOLD GROWTH?

Molds can grow under a wide range of conditions. Consider the differences in your kitchen alone. Molds can grow in a cool refrigerator or in a dark bread box on the counter. They grow on foods that contain varying amounts of sugar, protein, and moisture.

Question: *How does a specific environmental factor change the rate of mold growth?*

Materials

Choose materials that would be appropriate for this lab. Possible materials include:

mold from a food source
plain powdered gelatin (containing protein only)
bread
sugar
prepared gelatin in a small cup
cotton swab
aluminum foil or plastic wrap
small cup
thermometer
graduated cylinder
spray bottle

Safety Precautions

WARNING: ***Never eat food used in the lab.***

Plan and Perform the Experiment

1. Read and complete the lab safety form.
2. Make a list of environmental factors that might affect mold growth. Based on this list, develop a question to investigate.
3. Design an experiment that will help you answer this question. Remember, only one environmental factor should vary in your experimental conditions.
4. Write your hypothesis and design a data table.
5. Make sure your teacher has approved your experiment before you proceed.
6. Use cotton swabs to transfer mold from the food source to your trial cups.
7. Record observations for 5–7 days.
8. **Cleanup and Disposal** Place trial cups in the area designated by your teacher. Clean and return all equipment used in the lab. Wash your hands thoroughly.

Analyze and Conclude

1. **Identify** What is the independent variable and dependent variable in your experiment? Explain how the independent variable was changed.
2. **Compare** Describe differences that you noticed among trial samples.
3. **Describe** What steps did you take to limit variables in this experiment? Make a list of constants.
4. **Interpret the Data** How did the environmental factor that you changed affect the rate of mold growth?
5. **Conclude** Was your hypothesis supported? Explain.
6. **Error Analysis** Is it possible that more than one variable was introduced in your experiment? How would you change your experimental plans?

WRITING in Biology

Communicate Share your results with other groups. Develop a class list of environmental factors tested and results obtained. Based on these results, create a list of environmental factors that lead to optimal growth of the mold utilized in this experiment.

Chapter 20 Study Guide

THEME FOCUS Patterns A fungus obtains energy in one of three ways: decomposition, parasitism, or mutualism.

BIG idea Kingdom fungi is made up of four phyla based on unique structures, methods of nutrition, and methods of reproduction.

Section 1 Introduction to Fungi

chitin (p. 577)
hypha (p. 577)
mycelium (p. 577)
fruiting body (p. 577)
septum (p. 578)
haustorium (p. 578)
spore (p. 580)
sporangium (p. 581)

BIG idea **Fungi are unicellular or multicellular eukaryotic heterotrophs that are decomposers.**

- Fungi produce hyphae that form a netlike mass called a mycelium.
- There are three different methods by which fungi obtain food.
- Fungi can reproduce asexually by budding, fragmentation, or producing spores.
- Most fungi can reproduce sexually, also by producing spores.

Section 2 Diversity of Fungi

stolon (p. 583)
rhizoid (p. 583)
gametangium (p. 583)
conidiophore (p. 584)
ascocarp (p. 585)
ascus (p. 585)
ascospore (p. 585)
basidiocarp (p. 586)
basidium (p. 586)
basidiospore (p. 586)

BIG idea **Fungi exhibit a broad range of diversity and are classified into four major phyla.**

- There are four major phyla of fungi.
- Zygomycetes reproduce sexually by forming zygospores.
- Ascomycetes produce ascospores within a saclike structure called an ascus during sexual reproduction.
- Basidiomycetes produce basidiospores during sexual reproduction.
- Sexual reproduction in the phylum Deuteromycota has never been observed.

Section 3 Ecology of Fungi

lichen (p. 587)
bioindicator (p. 588)
mycorrhiza (p. 589)

BIG idea **Lichens and mycorrhizae demonstrate important symbiotic relationships between fungi and other organisms.**

- Lichens are examples of mutualistic relationships between a fungus and an alga or a cyanobacterium.
- Mycorrhizae help plants obtain water and minerals by increasing the surface area of their roots.
- Compounds obtained from fungi are used for a variety of medicines.
- Many foods eaten by people are made from fungi.
- Fungi can have adverse effects on humans and plants.

Vocabulary eGames

Chapter 20 Assessment

Section 1

Vocabulary Review

Each of the following sentences is false. Make each sentence true by replacing the italicized word with a vocabulary term found on the Study Guide page.

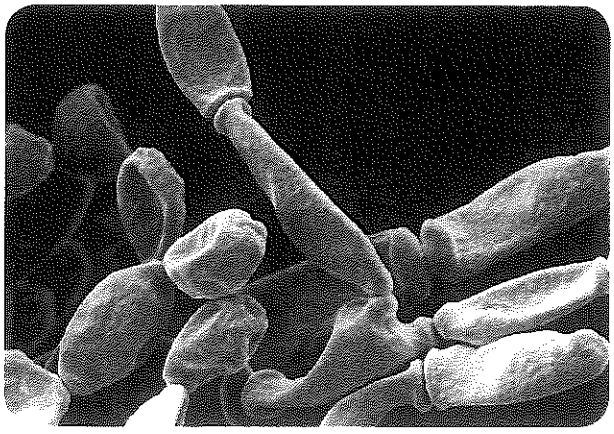
1. *Hyphae* is/are the cross walls between fungal cells.
2. *Chitin* is/are the threadlike filaments found in certain fungi.
3. A tough, flexible polysaccharide is called *septa*.

Understand Main Ideas

4. MAIN Idea Which does not describe a method by which fungi obtain food?
   A. parasitism
   B. decomposition
   C. photosynthesis
   D. mutualism
5. Which structure of fungi is different from plants?
   A. composition of cytoplasm
   B. composition of cell walls
   C. exoskeletons
   D. cellulose

Use the image to answer question 6.

Color-Enhanced SEM Magnification: 1100×



6. What is the structure shown above?
   A. hyphae
   B. septae
   C. chitin
   D. spores
7. Which can be used for asexual and sexual reproduction?
   A. gametes
   B. budding
   C. fragmentation
   D. spores

Use the diagram to answer question 8.

8. What is the structure shown above?
   A. mycelium
   B. spore
   C. septate hyphae
   D. aseptate hyphae

Constructed Response

9. THEME FOCUS Patterns Distinguish between parasitic fungi and saprophytic fungi.
10. **Short Answer** Distinguish between hyphae and mycelia.
11. **Open Ended** Hypothesize the best method of reducing the number of mold spores in your classroom. How would you test your hypothesis?

Think Critically

12. **Infer** how the structure of the aseptate hyphae allows for more rapid growth.
13. **Assess** the ability of fungi to disperse their spores.

Section 2

Vocabulary Review

Explain the differences between the vocabulary terms in the following sets.

14. stolon, rhizoid
15. ascospore, ascus
16. basidiocarp, basidia

Chapter 20 Assessment

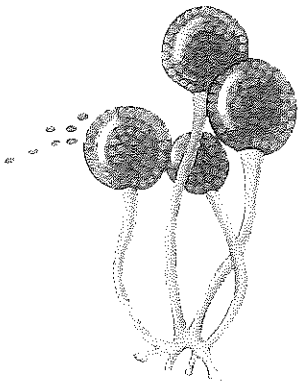
Understand Main Ideas

17. Which fungi have flagellated spores?
   A. basidiomycetes
   B. zygomycetes
   C. ascomycetes
   D. chytridiomycetes

18. What is the function of stolons?
   A. to penetrate the food
   B. to spread across the surface of food
   C. to digest the food
   D. to reproduce

19. Which is a unicellular fungi?
   A. bread mold
   B. yeast
   C. mushroom
   D. Bird's Nest fungus

Use the diagram to answer question 20.



20. Within which structure do the fungi in the diagram form their spores?
   A. ascocarp
   B. sporangium
   C. ascus
   D. ascophore

21. What word best describes the structure you identified in question 20?
   A. bud
   B. haploid
   C. diploid
   D. fragmented

Constructed Response

22. **Short Answer** Choose one type of fungus that reproduces asexually and describe the process.

23. **Open Ended** Research the different size spores produced by basidiomycetes and prepare a graphic organizer for the class.

24. **Think Key Idea** Compose an argument to defend the placement of chytrids in Kingdom Fungi instead of Kingdom Protista.

Think Critically

25. **Design an experiment** to determine if homemade bread is more or less likely to grow fungus than commercially produced bread.

26. **Collect and interpret data** on how many of your classmates have mold allergies. Calculate the percentage of allergic classmates.

Section 3

Vocabulary Review

Use what you know about the vocabulary terms found on the Study Guide page to answer the following questions.

27. What term describes a symbiotic relationship between a fungus and an alga?

28. **Think Key Idea** What term describes a symbiotic relationship between a fungus and a plant root?

29. What is the name of a living organism that is sensitive to environmental pollutants?

Understand Main Ideas

Use the image to answer question 30.

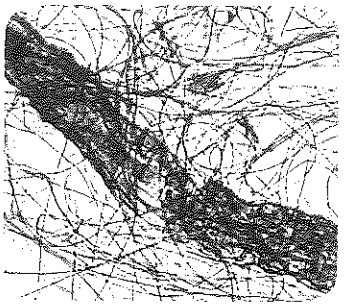
30. In an area recovering from a forest fire, what is this lichen's main function?
   A. absorbing water
   B. bioindicator
   C. pioneer species
   D. keeping insects away

blickwinkel/Alamy

Online Test Practice

31. Why are lichens important bioindicators?
   A. They are susceptible to drought.
   B. They are unicellular.
   C. They are mutualistic.
   D. They are susceptible to air pollutants.

Use the image below to answer question 32.



32. How is this mycorrhiza benefiting the plant?
   A. increases the surface area for gathering light
   B. decreases the need for water
   C. increases the surface area of the roots
   D. decreases the temperature

Constructed Response

33. **Short Answer** In what ways are fungi beneficial to humans?

34. **Short Answer** Evaluate the role of lichens in arctic environments.

Think Critically

35. **Predict** how the availability of the antibiotic penicillin during World War II impacted the soldiers.

36. **Design an experiment** that will allow you to test the antibiotic effects of two or three common fungi.

37. CAREERS IN BIOLOGY Write a want ad for a mycologist in a research laboratory.

38. **Design** an organism that cultivates its own food production using fungi. How might the fungi benefit from this relationship?

39. **Hypothesize** why mycorrhizae might have been important for the colonization of land by plants. What kind of evidence would you look for to support your hypothesis?

Summative Assessment

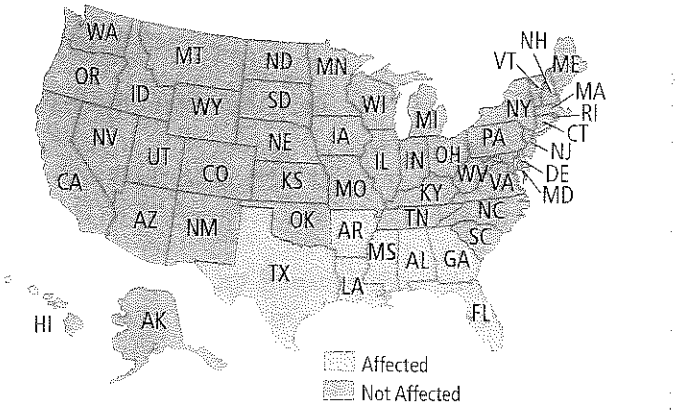
40. BIG Idea Imagine that you are a scientist that has discovered a new species of fungi. Describe its physical characteristics, method of obtaining nutrition, and method of reproduction. How would you classify this new species of fungi?

41. WRITING IN Biology Imagine yourself as a fungal spore landing near your home or school. Evaluate your chances of survival.

Document-Based Questions

Data obtained from: http://sbr.ipmpipe.org/cgi-bin/sbr/public.cgi

This map shows where Asian soybean rust Phakopsora pachyrhizi *is found in the United States. It is a recent arrival from Brazil and other parts of South America. Its presence in each state was officially diagnosed by the USDA. Soybean rust is a disease caused by the fungus* Phakopsora pachyrhizi, *which recently has become a problem for soybean farmers in the United States. Losses from this infection can amount to 80 percent of the crop.*



42. Evaluate the map and speculate about the factors affecting the distribution of soybean rust in the U.S.

43. Apply what you know about fungi to recommend a course of action to eradicate this fungus.

44. Estimate the impact of this fungus on the future of soybean production in the U.S.

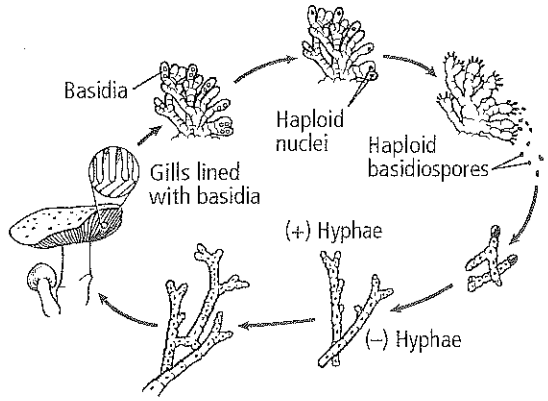
Standardized Test Practice

Cumulative

Multiple Choice

1. Which are autotrophic protists commonly referred to as?
   A. algae
   B. protozoans
   C. slime molds
   D. water molds

Use the diagram below to answer questions 2 and 3.



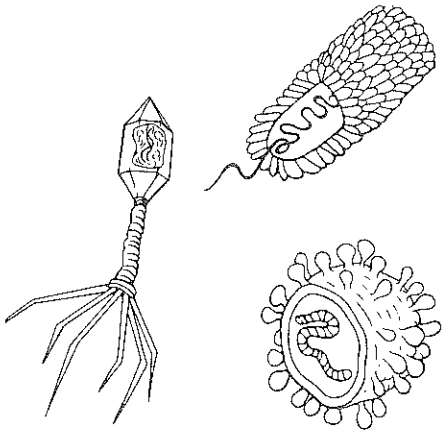
2. What part of this life cycle can be used to explain why many mushrooms grow quickly?
   A. The cap pulls in organic matter from the soil to fill the mushroom.
   B. The gills in the cap rapidly divide to form the mushroom.
   C. The hyphae grow and extend rapidly to form the mushroom.
   D. The basidia grow and lengthen the mushroom.

3. Which occurrence pictured in the diagram allows the mating types to fuse?
   A. basidia form
   B. hyphae unite
   C. mushroom forms
   D. spores release

4. A certain tree-dwelling primate has a prehensile tail and nails on its digits. To which group of primates would you expect this animal to belong?
   A. Asian apes
   B. New World monkeys
   C. Old World monkeys
   D. prosimians

5. Which occurs during the lytic cycle of a viral infection?
   A. The host cell becomes a factory that continually makes more copies of the virus.
   B. The host cell undergoes cell division that makes more copies of the virus.
   C. The virus incorporates its nucleic acid into the DNA of the host cell and lies dormant.
   D. The virus takes over the cell, makes copies of itself, and usually kills the host cell.

Use the figure below to answer question 6.



6. On what property do scientists base their classification of viruses?
   A. capsid proteins
   B. chromosome number
   C. host resistance
   D. type of genetic material

7. Which characteristic distinguishes australopithecines from earlier hominoids?
   A. binocular vision
   B. bipedalism
   C. fingernails
   D. opposable thumbs

8. Which is a characteristic of an acellular slime mold?
   A. cytoplasm with many cells
   B. locomotion by means of cilia
   C. plasmodium with many nuclei
   D. reproduction by fragmentation

Short Answer

Use the diagram below to answer question 9.

9. Identify the structure used for locomotion in each of these organisms. Briefly describe how each structure functions.

10. Imagine that you found a unicellular organism living in the mud at the bottom of a pond. Write a plan to determine how you would classify it.

11. Some people think that technology can solve all human problems. Name and critique an example of a problem that technology might not be able to solve.

12. What characteristics are used to classify protists into three groups? Explain your answer.

13. Describe how sexual reproduction begins in ascomycetes and assess its significance.

14. Give examples of three ways that fungi are important for human foods.

Extended Response

15. Create a flowchart to show how isolation of a small population can lead to speciation.

16. Assess the value of mycorrhizae for plants.

17. Evaluate how viruses benefit from their small size and simple composition.

18. Imagine that you've noticed that mushrooms grow in one corner of a field every time it rains. Give a reason why picking the mushrooms immediately following a rainshower will not stop them from growing back.

Essay Question

Light is needed for photosynthesis to take place. Algae depend on the energy from light to carry out photosynthesis. The main photosynthetic pigment of green algae is chlorophyll. Sunlight is composed of all of the different wavelengths of visible light, but only blue light and red light are absorbed by chlorophyll. Other algae contain larger amounts of other pigments, such as carotenoids. Carotenoids absorb energy from green light. Because algae live in water, this becomes important because water absorbs the different colors of light at different rates.

Using the information in the paragraph above, answer the following question in essay format.

19. Red light does not penetrate into water. Algae in water must be able to use light energy that is available under water. Write an essay about why carotenoids are better than chlorophyll for algae living well below the surface of water.

NEED EXTRA HELP?

If You Missed Question . . .	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Review Section . . .	19.3	20.2	20.2	16.1	18.2	18.2	16.2	19.4	19.2	19.2	18.1	1.2	20.2	20.3	15.3	20.2	18.2	20.2	19.3