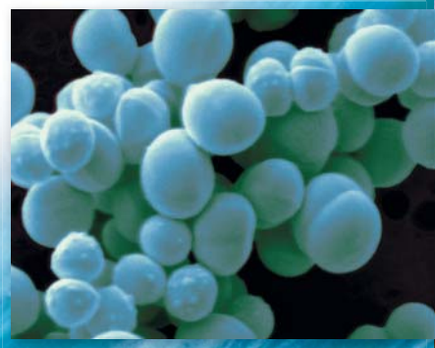
UNIT 6 Microbes

Giant kelp



Staphylococcus xylosus

UNIT 6

Fossilized diatoms

DISCOVERIES IN SCIENCE

Microbiology

1300

The bubonic plague kills 25 million people in Europe. The bacterium that causes the disease is carried by rats and transmitted to humans by fleas.

Rat, a carrier of the bubonic plague

1862

Louis Pasteur and Claude Bernard use heat to eliminate bacteria in liquid for the first time. The process of heating a liquid to kill bacteria is soon called pasteurization and helps prevent milk from spreading bacterial diseases.

1876

A botanical journal publishes Robert Koch's experiments and observations on anthrax bacilli. Koch demonstrates that the bacteria can still cause disease after growing for several generations in pure culture, without animal contact.

1901

Beatrix Potter, an amateur mycologist, finishes a portfolio of about 270 watercolor illustrations of fungi. Potter is best known as an author and illustrator of children's books, such as *The Tale of Peter Rabbit.*

Beatrix Potter with one of her dogs

1928

Alexander Fleming accidentally discovers antibiotics in his laboratory. He observes that *Penicillium notatum,* a mold that was contaminating culture plates, prevents the growth of a bacterium, *Staphylococcus aureus.*

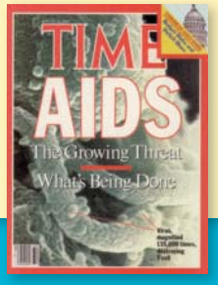
1955

The United States Government permits the widespread use of the polio vaccine developed by Dr. Jonas Salk.

Jonas Salk

1983

Luc Montagnier of the Pasteur Institute in France identifies HIV as the virus that causes AIDS. This discovery made it possible to test blood for HIV.



***Time* magazine cover on AIDS**

2003

In Northeast Oregon, an enormous fungus, *Armillaria ostoyae,* is discovered. The fungus covers 10 km^2, an area the size of 1,600 football fields. This fungus is believed to be the largest single organism on Earth.

Fungi on a moss-covered log

BIOLOGY CAREER

Epidemiologist

Linda Gaul

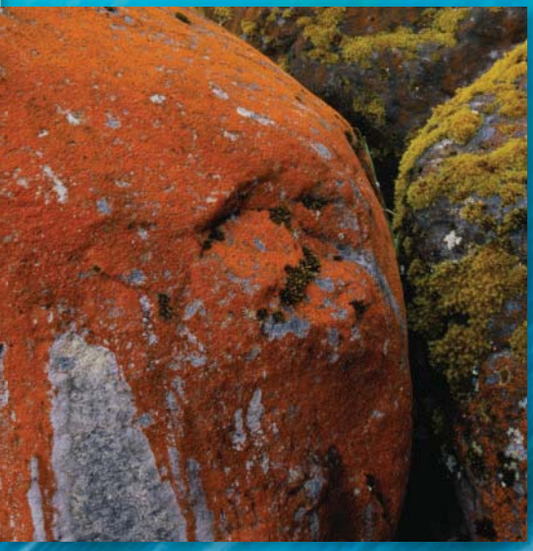
Linda Gaul is an epidemiologist at the Texas Department of State Health Services. She conducts surveillance and epidemiological investigations related to infectious diseases. She has also taught biology and epidemiology at the college level.

Gaul enjoys the process of scientific learning. She especially enjoys discovering connections between seemingly very different organisms that have adapted to a similar environmental constraint.

Gaul also loves teaching and helping others understand and appreciate the living world.

Gaul's father, who is a scientist, and Gaul's mother encouraged Gaul to be inquisitive about the world around her. Gaul credits their encouragement and several enthusiastic college professors for helping her decide to become a scientist.

Gaul also enjoys traveling with her family, gardening, and quilting.



Lichen on rocks

Chapter Planner

22 Fungi

		Standards	Teach Key Ideas
CHAPTER OPENER, pp. 518–519	15 min.	*National Science Education Standards*	
SECTION 1 Characteristics of Fungi, pp. 521–523 › What are Fungi? › Structure and Function › Reproduction	45 min.	LSCell 1, LSCell 2, LSCell 3, LSCell 4, LSCell 6, LSGene 1, LSMat 4, UCP1, UCP5	**Bellringer Transparency** **Transparencies** F21 Penicillium Mold • F24 Structure of a Mushroom **Visual Concepts** Characteristics of Fungi • Body Structure of Fungi • Parts of a Mushroom • Sexual Reproduction
SECTION 2 Groups of Fungi, pp. 524–528 › Chytrid Fungi › Zygote Fungi › Sac Fungi › Club Fungi › Fungal Partnerships	45 min.	LSCell 1, LSCell 2, LSCell 6, LSGene 1, LSEvol 5	**Bellringer Transparency** **Transparencies** F23 Life Cycle of Zygomycetes • F25 Life Cycle of Basidiomycetes • F26 Life Cycle of Ascomycetes **Visual Concepts** Types of Fungi • Asexual Reproduction in Zygomycetes • Sexual Reproduction in Zygomycetes • Asexual Reproduction in Ascomycetes • Sexual Reproduction in Ascomycetes • Sexual Reproduction in Basidiomycetes
SECTION 3 Fungi and Humans, pp. 529–533 › Fungi and Industry › Fungi and the Ecosystem › Fungi and Disease	90 min.	LSInter 3, LSInter 5, SI1, SI2, ESS2, ST2, SPSP1, SPSP3, SPSP5, SPSP6, HNS1	**Bellringer Transparency** **Visual Concepts** Symbiosis
			See also PowerPoint® Resources

Chapter Review and Assessment Resources

- SE Super Summary, p. 534
- SE Chapter Review, p. 535
- SE Standardized Test Prep, p. 537
- Review Resources
- Chapter Tests A and B
- Holt Online Assessment

CHAPTER FastTrack

To shorten instruction due to time limitations, eliminate Section 2 and the Inquiry Lab in Section 3.

Basic Learners

- TE Comparing Fungi and Plants, p. 522
- TE White Button Mushrooms, p. 527
- TE Fungi in Food Webs, p. 530
- Directed Reading Worksheets*
- Active Reading Worksheets*
- Lab Manuals, Level A*
- Study Guide* ■
- Note-taking Workbook*
- Special Needs Activities and Modified Tests*

Advanced Learners

- TE Chestnut Blight, p. 526
- Critical Thinking Worksheets*
- Concept Mapping Worksheets*
- Science Skills Worksheets*
- Lab Datasheets, Level C*

Key

SE Student Edition
TE Teacher's Edition

Chapter Resource File
Workbook
Transparency

CD or CD-ROM
* Datasheet or blackline master available

■ Also available in Spanish

All resources listed below are also available on the Teacher's One-Stop Planner.

Why It Matters	Hands-On	Skills Development	Assessment
Build student motivation with resources about high-interest applications.	SE **Inquiry Lab** Mushroom Dissection, p. 519*■	TE **Reading Toolbox** Assessing Prior Knowledge, p. 518 SE **Reading Toolbox,** p. 520	
TE **Fungi and Society,** p. 522 TE **Demonstration** Bread Mold, p. 521	SE **Quick Lab** Mold, p. 523*■	SE **Reading Toolbox** Comparisons, p. 523 TE **Reading Toolbox** Comparisons, p. 523	SE **Section Review** TE **Formative Assessment** **Spanish Assessment*■** **Section Quiz■**
TE **Amphibian Deaths,** p. 524 TE **Ascomycota,** p. 526	**Exploration Lab** Exploring Fungi*	TE **Math Skills** Spore Velocity, p. 525 SE **Reading Toolbox** Process Chart, p. 526 TE **Reading Toolbox** Process Chart, p. 526	SE **Section Review** TE **Formative Assessment** **Spanish Assessment*■** **Section Quiz■**
TE **Career Development,** p. 529 TE **Demonstration** Mushrooms as Food, p. 529 TE **Lichens,** p. 530 SE **Salem Witch Trials,** p. 532	SE **Quick Lab** Fungal Factor, p. 530*■ SE **Inquiry Lab** Yeast and Fermentation, p. 533*■ **Skills Practice Lab** Measuring CO_2 Production*	SE **Reading Toolbox** Word Parts, p. 531 TE **Reading Toolbox** Word Parts, p. 531 TE **Reading Toolbox** Visual Literacy, p. 532	SE **Section Review** TE **Formative Assessment** **Spanish Assessment*■** **Section Quiz■**
	See also Lab Generator		**See also Holt Online Assessment Resources**

Resources for Differentiated Instruction

English Learners

TE Hyphae, p. 525
Directed Reading Worksheets*
Active Reading Worksheets*
Lab Manuals, Level A*
Study Guide*■
Note-taking Workbook*
Multilingual Glossary

Struggling Readers

TE Fungi Phyla, p. 525
TE Sac Fungi, p. 526
Directed Reading Worksheets*
Active Reading Worksheets*
Lab Manuals, Level A*
Study Guide*
Note-taking Workbook*
Special Needs Activities and Modified Tests*

Special Education Students

TE White Button Mushrooms, p. 527
Directed Reading Worksheets*
Active Reading Worksheets*
Lab Manuals, Level A*
Study Guide*■
Note-taking Workbook*
Special Needs Activities and Modified Tests*

Alternative Assessment

TE Process Chart, p. 527
Science Skills Worksheets*
Section Quizzes*■
Chapter Tests A, B, and C*■

Chapter 22

Overview

The purpose of this chapter is to describe how kingdom Fungi is characterized and how fungi obtain nutrients and reproduce. The four groups of fungi differ primarily in their means of sexual reproduction. Fungi play a key role in the environment as partners with plants and algae.

READING TOOLBOX

Assessing Prior Knowledge Students should understand the following concepts:
- sexual and asexual reproduction
- needs of living organisms
- life cycles of organisms

Visual Literacy Tell students that there are many species of *Cordyceps* fungi, but that all species are parasites and most are parasites of insects. One species of *Cordyceps* is used to make a particularly important drug used to suppress the immune system during human organ transplants.

Chapter 22

Fungi

Preview

Why It Matters

When we think of fungi, we usually think of grocery-store mushrooms. But fungi are more than mushrooms. Fungi play several extremely important ecological roles. They can also cause disgusting and sometimes deadly diseases.

Fungi can grow in the most unexpected places. This ant was certainly not expecting to play host to the fungus that ate its body from the inside out.

Chapter Correlations

National Science Education Standards

LSCell 1 Cells have particular structures that underlie their functions.

LSCell 2 Most cell functions involve chemical reaction.

LSCell 3 Cells store and use information to guide their functions.

LSCell 4 Cell functions are regulated.

LSCell 6 Cells can differentiate and form complete multicellular organisms.

LSGene 1 In all organisms, the instructions for specifying the characteristics of the organisms are carried in DNA.

LSEvol 5 Biological classifications are based on how organisms are related.

LSInter 3 Organisms both cooperate and compete in ecosystems.

LSInter 5 Human beings live within the world's ecosystems.

LSMat 4 The complexity and organization of organisms accommodates the need for obtaining, transforming, transporting, releasing, and eliminating the matter and energy used to sustain the organism.

UCP1 Systems, order, and organization

UCP5 Form and function

SI1 Abilities necessary to do scientific inquiry

SI2 Understandings about scientific inquiry

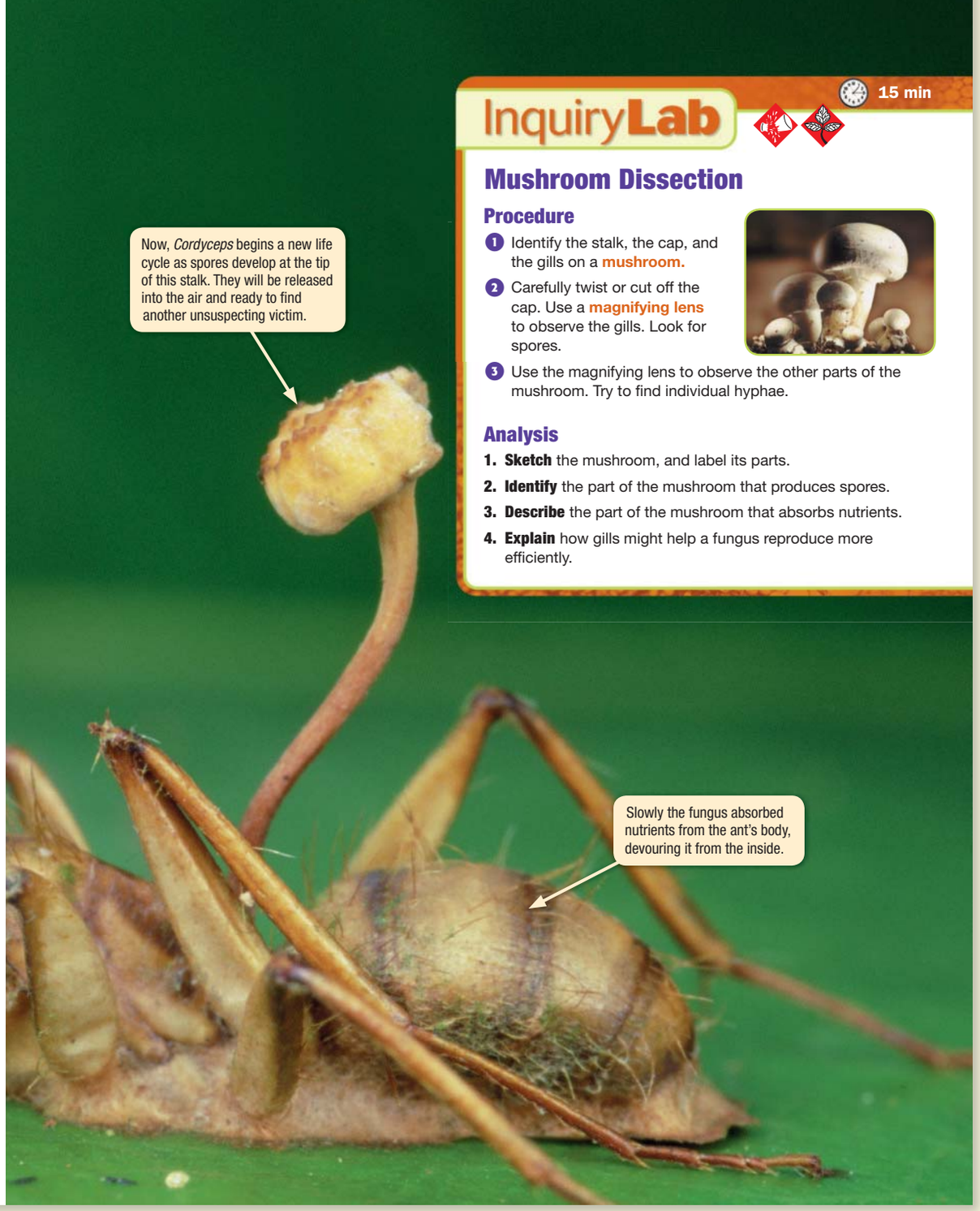
ESS2 Geochemical cycles

ST2 Understandings about science and technology

SPSP1 Personal and community health

SPSP3 Natural resources

SPSP5 Natural and human-induced hazards



15 min

InquiryLab

Mushroom Dissection

Procedure

1. Identify the stalk, the cap, and the gills on a **mushroom.**
2. Carefully twist or cut off the cap. Use a **magnifying lens** to observe the gills. Look for spores.
3. Use the magnifying lens to observe the other parts of the mushroom. Try to find individual hyphae.

Analysis

1. **Sketch** the mushroom, and label its parts.
2. **Identify** the part of the mushroom that produces spores.
3. **Describe** the part of the mushroom that absorbs nutrients.
4. **Explain** how gills might help a fungus reproduce more efficiently.

InquiryLab

Teacher's Notes When selecting mushrooms for students, choose those with exposed gills.

Safety Caution
Students who are allergic to mold should not handle the mushrooms and should wear a facemask.

Materials
- mushroom
- magnifying lens

Answers to Analysis

1. Student sketches should show these labeled parts: cap, stalk, and gills.
2. The gills produce spores.
3. The hyphae that grow underground absorb nutrients.
4. Gills are structured to produce many spores, which can be scattered away from the parent, thus reducing competition for resources.

SPSP6 Science and technology in local, national, and global challenges
HNS1 Science as a human endeavor

READING TOOLBOX

Using Words

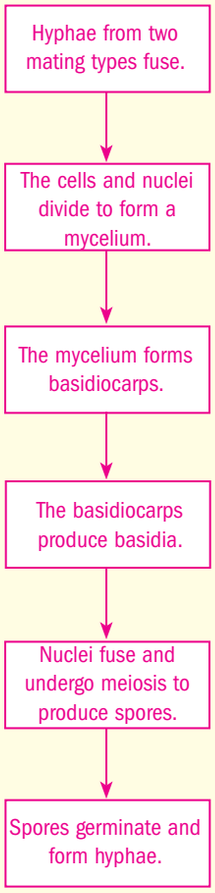
1. A basidiocarp refers to a body that is shaped like a pedestal.
2. An ascocarp refers to a body that is shaped like a bag or sac.
3. A basidiomycete refers to a fungus that is shaped like a pedestal.

Using Language

1. Fungi are being compared to plants.
2. Edible mushrooms are being contrasted with poisonous ones.
3. Unicellular chytrid fungi are being contrasted with other fungi.

Using Graphic Organizers

The following is one possible answer:



READING TOOLBOX

These reading tools can help you learn the material in this chapter. For more information on how to use these and other tools, see **Appendix: Reading and Study Skills.**

Using Words

Word Parts Knowing the meanings of word parts can help you figure out the meanings of words that you do not know.

Your Turn Use the table to write your own definitions for the following terms.

1. *basidiocarp*
2. *ascocarp*
3. *basidiomycete*

Word Parts

Word part	Type	Meaning
basidio-	prefix	pedestal
asco-	prefix	a bag or sac
mycet	root	a fungus
carp	root	body

Using Language

Comparisons Comparing is a way of looking for the similarities between different things. Contrasting is a way of looking for the differences. Certain words and phrases can help you recognize when things are being compared or contrasted. Comparison words include *and, like, just as,* and *in the same way*. Contrast words include *however, unlike, in contrast,* and *on the other hand.*

Your Turn In the following sentences, find the things that are being compared or contrasted.

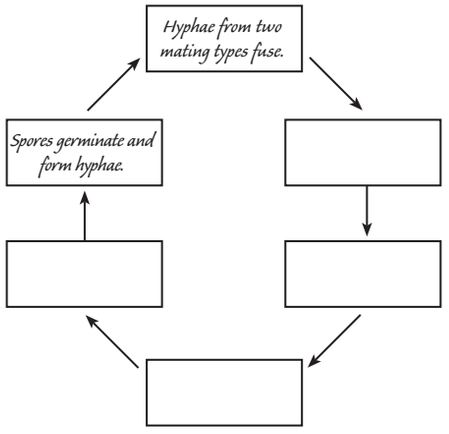
1. Fungi, like plants, have rootlike structures that anchor them.
2. Some mushrooms are edible; however, others are highly poisonous.
3. Unlike most types of fungi, chytrids are unicellular.

Using Graphic Organizers

Process Chart Science is full of processes. Some processes are cycles that repeat the same steps over and over. You can use a circular process chart to help yourself remember what order the steps follow and where the cycle begins again.

Your Turn Create a circular process chart illustrating the life cycle of a club fungus.

1. Draw a box. In the box, write the first step of the cycle.
2. To the right and slightly below the first box, draw a second box. Draw an arrow to connect the two boxes. In the second box, write the next step of the cycle.
3. Continue adding boxes in a circular pattern until each step of the cycle is written in a box. Draw an arrow to connect the last box and the first box.



Section 1

Characteristics of Fungi

Key Ideas	Key Terms	Why It Matters
❯ What are three characteristics that all fungi share? ❯ How is the structure of a fungus related to the way in which a fungus obtains nutrients? ❯ What is the difference between sexual and asexual production of spores in fungi?	chitin hypha mycelium rhizoid saprobe	Fungi are important decomposers, foods, and parasites.

A fungus grows in one place until its food source runs out. Before it dies, it produces millions of spores that float through the air or the water, find more food, and begin the cycle again.

What Are Fungi?

Fungi are a very diverse group of organisms, but all fungi share three characteristics. ❯ **Fungi have threadlike bodies, their cell walls are made of chitin, and they absorb nutrients from their environment.**

- **Fungi have threadlike bodies.** A fungus is made of long, slender filaments. Most of the fungal body is made of loosely woven filaments. The filaments weave more tightly to form reproductive structures, like the colorful mushrooms and brackets in **Figure 1.**
- **Fungal cell walls contain chitin.** The cells of fungi have walls made of chitin. **Chitin** is a tough carbohydrate that is also found in the hard outer covering of insects and other organisms.
- **Fungi are heterotrophic.** Fungi cannot make their own food or move to capture food. Instead, they obtain energy by breaking down organic and inorganic material in their environment and absorbing the nutrients.

chitin (KIE tin) a carbohydrate found in the cell walls of fungi and other organisms

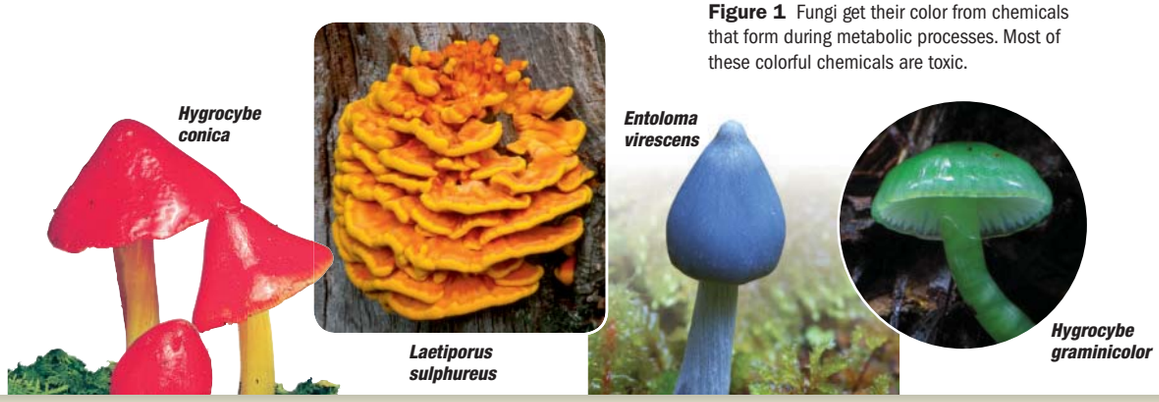


Figure 1 Fungi get their color from chemicals that form during metabolic processes. Most of these colorful chemicals are toxic.

Key Resources

Transparencies
F21 *Penicillium* Mold
F24 Structure of a Mushroom

Visual Concepts
Characteristics of Fungi
Body Structure of Fungi
Parts of a Mushroom
Sexual Reproduction

Section 1

❯Focus

This section introduces structures unique to fungi that facilitate their survival and reproduction.

Bellringer
Use the Bellringer transparency to prepare students for this section.

❯Teach

Demonstration

Bread Mold Place a piece of bakery bread in a labeled, zippered, plastic sandwich bag. (Note: Do not use commercial packaged bread; it contains preservatives.) Sprinkle a second piece of bread with a small amount of water and place it in a second labeled bag. The bags should be sealed with tape and kept in a warm, dark place for a day or two. Students should observe more rapid mold growth on the moist bread than on the dry bread. Ask what conditions promote mold growth. (moist, dark, warm conditions) CAUTION: Some bread molds are health hazards. Do not allow students to open the bags containing the bread. LS Visual

Teach, *continued*

Teaching Key Ideas

Spore Prints Have students take a common mushroom purchased from a grocery store and examine the gills at the underside of the cap. Ask students what gills produce. (spores) Have students remove the stalk and place the cap, with the gills facing downward, on a blank index card or sheet of paper. Have students leave the cap in that position undisturbed overnight. The next day, tell students to remove the cap and observe the card. Ask students to identify what they see. (spores) Tell students that mushrooms leave different types of spore prints and that the prints can be used for identification. CAUTION: Use only mushrooms from a grocery store. Do not allow students to bring in wild mushrooms. LS Visual

Answers to Caption Questions

Figure 2: Sample answer: a tall reproductive structure lifts the spores higher off the ground. This might allow wind to catch the spores better and spread the spores farther.

hypha (HIE fuh) a filament of a fungus

mycelium (mie SEE lee uhm) the mass of fungal filaments that forms the fungal body

rhizoid (RIE ZOYD) a rootlike structure that holds fungi in place and absorbs nutrients

saprobe an organism that absorbs nutrients from dead or decaying organisms

Structure and Function

The mushroom seen above ground is a small part of a fungus. Most of the fungus is hidden in the ground or in the substance that the fungus feeds on. ❯ **A typical fungal body is made of filaments that allow the fungus to have a large surface area and to absorb nutrients efficiently.**

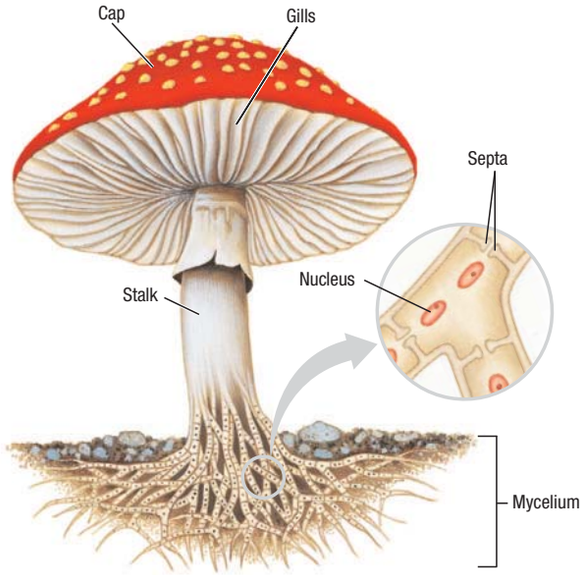
Body Structure Fungi have bodies made of threadlike strands called **hyphae** (singular, *hypha*). The cells of the hyphae are haploid, are almost identical, and generally perform the same functions. In some fungi, these cells do not have walls that separate the cells. In other fungi, the cells have partial walls, called *septa*, which are shown in **Figure 2.** Gaps in the septa allow cytoplasm, nutrients, and some organelles to flow through the hyphae. Hyphae form a tangled mass, often many meters long, called a **mycelium.** In some fungi, hyphae also form rootlike structures called **rhizoids.**

Obtaining Nutrients Fungi release enzymes that break down organic and inorganic matter into nutrients. Fungi absorb the nutrients across their cell walls. Fungi that absorb nutrients from dead organisms are called **saprobes.** Saprobes are a very important part of an ecosystem; they recycle nutrients that otherwise would stay trapped in the bodies of dead organisms. Fungi that absorb nutrients from living hosts are called *parasites*. In humans, fungal parasites sometimes cause diseases, such as athlete's foot and ringworm.

Reproduction

❯ **In sexual reproduction, spores are produced by meiosis. In asexual reproduction, spores are produced by mitosis.** Sexual reproduction results in genetic diversity. Asexual reproduction allows fungi to spread rapidly. Most fungi reproduce both sexually and asexually.

Figure 2 Hyphae are loosely woven through the soil and tightly packed in the body of the mushroom. ❯ **How might a tall reproductive structure be beneficial?**



Sexual Reproduction Sexual reproduction occurs when hyphae from one fungus fuse with hyphae from a fungus of the opposite mating type. The fused hyphae then form a reproductive structure, such as the mushroom in **Figure 2.** Inside the structure, nuclei from the two mating types fuse. These newly formed diploid nuclei undergo meiosis and produce haploid spores that are released.

Asexual Reproduction Asexual reproduction in fungi is simpler than sexual reproduction is. Specialized hyphae produce long stalks. At the tips of these stalks, haploid spores are produced by mitosis. The fungi that develop from these spores are genetically identical to the parent. Fungi that do not have an observed sexual stage are grouped together and called *imperfect fungi.*

Why It Matters

Fungi and Society While some fungi are harmful, others have beneficial uses. Ask students to use the Internet to make a list of harmful fungi and another list of the beneficial fungi. LS Verbal

Differentiated Instruction

Basic Learners

Comparing Fungi and Plants Have groups of students write the following words on index cards with one word per card: *chitin, cellulose, cell wall, roots, hyphae, spore, seed, autotroph, heterotroph.* Have students label the terms as *plants*, *fungus*, or *both.* Ask students to discuss the differences and similarities between both groups. (Both plants and fungi have cell walls and make spores. Words associated only with plants are *cellulose, roots, seed,* and *autotroph.* Words in the fungus-only group are *chitin, hyphae,* and *heterotroph.*) LS Logical

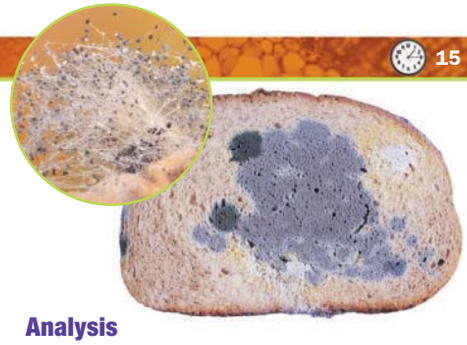
Hands-On

QuickLab

15 min

Mold

You can use a microscope to see the individual threads of cells that make up the body of a fungus.



Procedure

1. Examine a slide of black bread mold under a microscope at low power.
2. Move the slide until you can clearly see threadlike structures and round dark spores.
3. Draw the structures that you have observed.

Analysis

1. **Explain** where you would find each structure on the loaf of bread shown above.
2. CRITICAL THINKING **Recognizing Relationships** Why do you think spores are produced at the tips of stalks?

Yeast and Mold Often, we think of yeasts and molds as distinct classes of fungi. In fact, the words *yeast* and *mold* refer to specific stages of the life cycle that are shared by several types of fungi.

Yeast Some species of fungi exist primarily in a unicellular state. The common name for this unicellular stage is *yeast.* Yeasts usually reproduce asexually by budding, a process in which part of the parent pinches off to form a new organism. Under very specific conditions, yeasts can form multicellular hyphae and may reproduce sexually.

Mold A mold is a rapidly growing, asexually reproducing stage of some types of fungi. The term *mold* refers only to the asexual phase. Some fungi that form molds have no observed sexual stage and are grouped with imperfect fungi. Other fungi that grow as molds also reproduce sexually and are classified according to their sexual reproductive structures.

› **Reading Check** ***What is the difference between spores produced sexually and spores produced asexually in fungi? (See the Appendix for answers to Reading Checks.)***

READING TOOLBOX

Comparisons Write two sentences that compare and two sentences that contrast sexually and asexually produced spores.

SCILINKS
www.scilinks.org
Topic: Fungi
Code: HX80628

Section 1 **Review**

› KEY IDEAS

1. **Identify** three characteristics that fungi share.
2. **Relate** the structure of a fungal body to the way in which a fungus obtains nutrients.
3. **Describe** sexual and asexual production of spores in fungi.

CRITICAL THINKING

4. **Recognizing Relationships** How might the pores in septa be important to fungi?
5. **Relating Concepts** Certain fungi, such as those that form yeasts and molds, grow very rapidly. They reproduce sexually only under harsh conditions. How might this strategy benefit these fungi?

ALTERNATIVE ASSESSMENT

6. Baker's yeast, *Saccharomyces cerevisiae,* is a fungus that is used for making bread, beer, and wine. Research baker's yeast. Find out what conditions will cause baker's yeast to reproduce sexually.

Answers to Section Review

1. All fungi have threadlike bodies, cell walls containing chitin, and are heterotrophic.
2. The body of a fungus is filamentous, which provides a large surface area to absorb nutrients from the environment. The more surface area that contacts the environment, the better fungi will be able to absorb nutrients.
3. During sexual reproduction haploid spores are produced by meiosis. During asexual reproduction, haploid spores are produced by mitosis.
4. Students should recognize that because fungi do not have a vascular system, septa help nutrients flow between cells.
5. Under harsh conditions, sexual reproduction will increase genetic diversity, which may produce offspring that are able to survive in the harsh conditions.
6. Bakers yeast reproduces sexually under conditions of low nutrients.

QuickLab

Teacher's Notes Advise students to observe the mold under low power.

Safety Caution Black bread mold is a carcinogen. Use *only* prepared slides of bread mold. ***Do not*** handle moldy bread for this lab. Remind students to wear goggles. Treat broken slides of mold as a pathogen, and dispose of in a biohazard/glass safety bin. The container should be covered or sealed.

Materials
- compound microscope
- prepared slide of black bread mold

Answers to Analysis

1. Reproductive structures are on the surface. The mycelium made of hyphae is throughout the bread.
2. The spores are able to travel farther when released.

READING TOOLBOX

Comparisons Both types of spores are released from specialized hyphae and develop into new fungi. Asexual spores are produced by mitosis and are genetically identical to the parent. Sexually produced spores are produced by meiosis and are genetically unique.

› Close

Formative Assessment

The body of a fungus is made of threadlike ____.

A. spores (Incorrect. Spores are reproductive cells.)
B. hyphae (Correct! Fungi are made up of groups of hyphae.)
C. rhizoids (Incorrect. Rhizoids are structures that anchor fungi.)

Section 2

Section 2 Groups of Fungi

Key Ideas	Key Terms	Why It Matters
What group of fungi provides clues about the evolution of fungi? Which reproductive structure characterizes the zygote fungi? Which reproductive structure characterizes the sac fungi? What is the name of the structure that produces spores in club fungi? What two symbiotic partnerships do fungi form?	**zygosporangium** **ascus** **basidium** **lichen** **mycorrhiza**	Fungi spread rapidly and destroy harvested citrus because of the efficiency of the fungus life cycle.

Focus

This section introduces the life cycles and reproductive structures that are used to classify fungi. The four phyla of sexually-reproducing fungi are described.

Bellringer

Use the Bellringer transparency to prepare students for this section.

Teach

Why It Matters

Amphibian Deaths Tell students that one species of chytrid fungus, *Batrachochytrium dendrobatidis,* is one of the biggest threats facing amphibian species survival worldwide. Some frog populations are partially affected. Other frog populations can be completely wiped out by the fungus. The mechanism by which the fungus kills frogs is unknown, and there is no known treatment once the fungus is contracted.

Modern fungi are classified into four phyla: Chytridiomycota (chytrids), Zygomycota (zygote fungi), Ascomycota (sac fungi), and Basidiomycota (club fungi). They are classified based on the type of sexual reproductive structures that they form.

Chytrid Fungi

Fungi date back about 500 million years. Fossils show that the earliest fungi produced spores and gametes that had flagella. The ability of ancient fungi to swim suggests that fungi first appeared in water. Today, one group of modern fungi, the chytrids (KIE trids), still retains this ability. **The chytrids are a group of aquatic fungi that provide clues about the evolution of fungi.**

Chytrids, shown in **Figure 3,** were once classified with protists because the two groups share two important characteristics. Like protists, many chytrids are unicellular and produce spores and gametes that have flagella. The similarities between chytrids and protists suggest that fungi may have evolved from protists that had flagella.

Chytrids are like all other fungi in several important ways. They have chitin in their cell walls. They digest food outside their bodies. Most produce hyphae that form rhizoids. These root-like structures hold chytrids in place and absorb nutrients. Finally, the sexual reproductive structures of chytrids contain spores.

zygosporangium (ZIE goh spoh RAN jee uhm) a sexual structure that contains zygotes

Most chytrids are aquatic, although some live in moist places on land. They are mainly saprobes, which feed on dead algae or plants. Some chytrids are parasites that feed on protists, plants, animals, or even other fungi. Chytrids are common parasites of aquarium fish, and they are one of the reasons for the recent and continuing decline of amphibians in the wild.

Reading Check ***Which characteristics do chytrids share with protists, and which do they share with other fungi?***

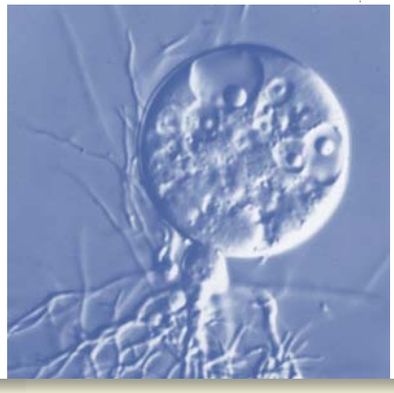


Figure 3 Chytrids are unicellular fungi that provide clues about early fungi and what they may have been like.

Key Resources

Transparencies
F23 Life Cycle of Zygomycetes
F25 Life Cycle of Basidiomycetes
F26 Life Cycle of Ascomycetes

Visual Concepts
Types of Fungi
Asexual Reproduction in Zygomycetes
Sexual Reproduction in Zygomycetes
Asexual Reproduction in Ascomycetes
Sexual Reproduction in Ascomycetes
Sexual Reproduction in Basidiomycetes

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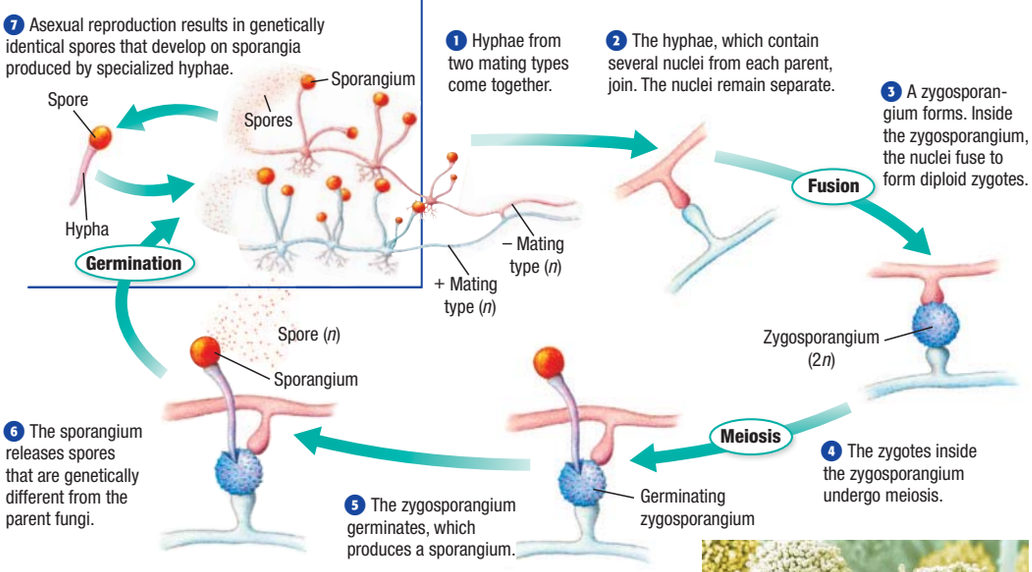
Keyword: HX8FNGF4

Life Cycle of Zygote Fungi



Zygote Fungi

Common black bread mold is a member of the phylum Zygomycota, which contains zygote fungi. **› Zygote fungi are named for sexual reproductive structures that produce zygotes inside a tough capsule.**

Sexual reproduction in zygote fungi begins when hyphae from two mating types come together. In fungi, different mating types are not referred to as male and female, because they are physically identical. Instead, they are called "+" and "−." The hyphae join, but the nuclei remain separate. A tough capsule called a **zygosporangium** forms. Zygosporangia are resistant to hot, cold, and dry conditions. When conditions are right for growth, the nuclei fuse to form diploid ($2n$) zygotes. The zygotes undergo meiosis. The zygosporangium germinates, which produces a *sporangium* that releases haploid (n) spores.

Asexual reproduction is more common than sexual reproduction in zygote fungi. During asexual reproduction, haploid (n) spores are produced in sporangia at the tips of specialized hyphae, as **Figure 4** shows. The haploid spores are produced by mitosis. Spores are carried by the wind to new locations, where they grow into new fungi.

Species of *Rhizopus* and other zygote fungi usually live in the soil and feed on decaying plant and animal matter. However, some species of *Rhizopus,* including the one that grows on bread, have been found to cause cancer in humans.

› Reading Check ***Where does meiosis take place in zygote fungi?***

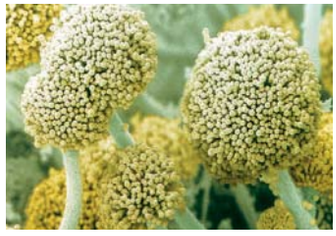


Figure 4 Zygomycetes reproduce both sexually and asexually. Both types of reproduction result in spores produced in sporangia.

ACADEMIC VOCABULARY
identical looking exactly the same

go.hrw.com
interact online

Students can interact with the "Life Cycle of Zygoe Fungi" by going to go.hrw.com and typing in the keyword HX8FNGF4.

Teaching Key Ideas

Zygosporangia Display a series of scanning electron micrographs showing zygospore formation in *Rhizopus.* Ask students why zygosporangia provide an advantage for fungi. (The spores inside the protective zygosporangium can survive until environmental conditions are favorable for germination.) LS Visual

Math Skills

Spore Velocity Tell students that the zygomycete *Pilobolus* grows in animal dung and produces a reproductive structure about 5 to 10 mm high. A clear structure below the spore acts as a lens, focusing sunlight on a photoreceptor inside the fungus. Explain that the reproductive structure bends toward the light and eventually ejects spores to a distance of up to 2 m at a velocity near 50 km/h. Ask students to calculate the time it would take a spore to travel 2 m, based on the velocity of 50 km/h. Use the formula $v = d/t$, where v is 50 km/h, d is 2 m; and t is the time it takes to travel 2 m. ($t = d/v$; 2 m = 0.002 km; 0.002 m/50 km/h = 4×10^5 h; (4×10^5 h)(60 min/h)(60 s/min) = 0.14 s) LS Logical

Differentiated Instruction

English Learners

Hyphae Have students make a drawing of *Rhizopus.* Sporangia and rhizoids should be shown and labeled. Be sure students are using these two terms correctly. LS Visual

Struggling Readers

Fungi Phyla Have students make a table on a sheet of paper. Tell them to write these headings down the left side: *Chytridiomycota, Zygomycota, Ascomycota, and Basidiomycota.* Have them write these headings across the top: *Method of Reproduction, Structures, Habitat, and Example.* As students read the section, have them complete the table. LS Verbal

Teach, *continued*

Teaching Key Ideas

Conidiophores Have students compare the life cycles of sac fungi and zygote fungi, noting that sac fungi produce spores on specialized hyphae called conidiophores. Point out that a single conidiophore often produces thousands of spores. Ask students what the adaptive advantage is of producing so many spores. (Most spores will not survive to germinate into new fungi.) LS Logical

Why It Matters

Ascomycota Tell students that ascomycetes cause many plant diseases. However, ascomycetes are also known for an important contribution to human health. The fungus *Penicillium* is an ascomycete that has given us the antibiotic penicillin.

ascus the microscopic structure that produces spores in sac fungi

basidium the microscopic structure that produces spores in club fungi

READING TOOLBOX

Process Chart Draw a process chart that shows the steps of the life cycle of sac fungi. Draw separate loops for sexual and asexual reproduction.

Sac Fungi

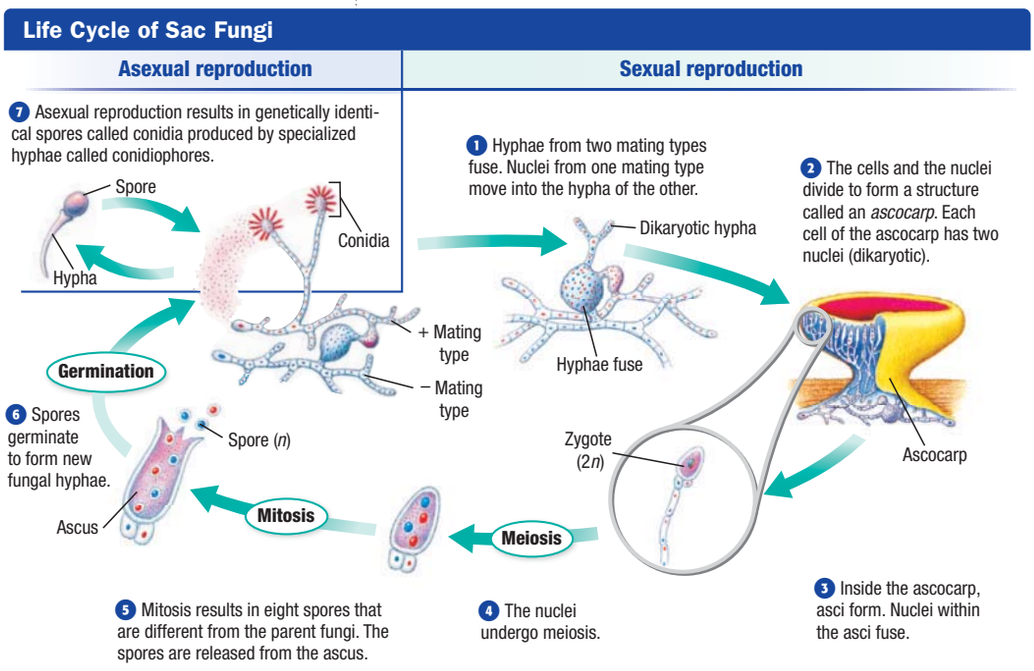
Sac fungi belong to the phylum Ascomycota. **Sac fungi are characterized by an ascus, a saclike sexual reproductive structure that produces spores.** The word *ascus* means "sac," and the plural form is *asci*.

Sexual reproduction of sac fungi, shown in **Figure 5,** is similar to that of zygote fungi in several ways. Hyphae of different mating types grow together. The hyphae fuse to form a bridge that connects them. Haploid nuclei from one mating type move into the tip of a hypha of the other mating type. The nuclei pair up, one "+" with one "−" nucleus. The cells—and the nuclei inside the cells—divide to form a mass of hyphae that contain two nuclei per cell. In most sac fungi, this mass of *dikaryotic* (having two nuclei) hyphae forms a structure called an *ascocarp*. Certain cells within the ascocarp become saclike asci. The nuclei inside the asci fuse and undergo meiosis. Haploid spores are released and grow into new sac fungi.

Sac fungi usually reproduce asexually. Asexual spores called *conidia* form by mitosis on specialized hyphae called *conidiophores*. Conidiophores are slightly different from the sporangia of zygote fungi. Asexual spores of zygote fungi form inside the tip of the sporangium. Conidia usually form in chains and are not covered. The spores are carried by wind and germinate to form new fungi.

Reading Check *In sac fungi, which structure is dikaryotic?*

Figure 5 The life cycle of a typical sac fungus is shown below. Sac fungi can reproduce sexually or asexually.



Differentiated Instruction

Struggling Readers

Sac Fungi Students may struggle with understanding **Figure 5.** Help them with comprehension by asking the following. "What is the meaning of 2*n* shown between steps 2 and 3?" (The zygote has two sets of chromosomes; it's diploid.) "What does dikaryote mean in step 2?" (a cell with 2 nuclei) "Contrast the role of hyphae in sexual and asexual reproduction." (Individual hyphae produce genetically identical spores asexually. Two hyphae fuse in sexual reproduction. The spores produced are not genetically identical to their parents.) LS Visual

Advanced Learners/GATE

Chestnut Blight Tell students that chestnut blight is caused by a type of sac fungus. Have students research and write a report about how chestnut blight wiped out virtually all the chestnut trees in the United States around 1890. Students should note that resistant cultivars of chestnut trees have been developed and are now being planted. LS Verbal

Life Cycle of Club Fungi

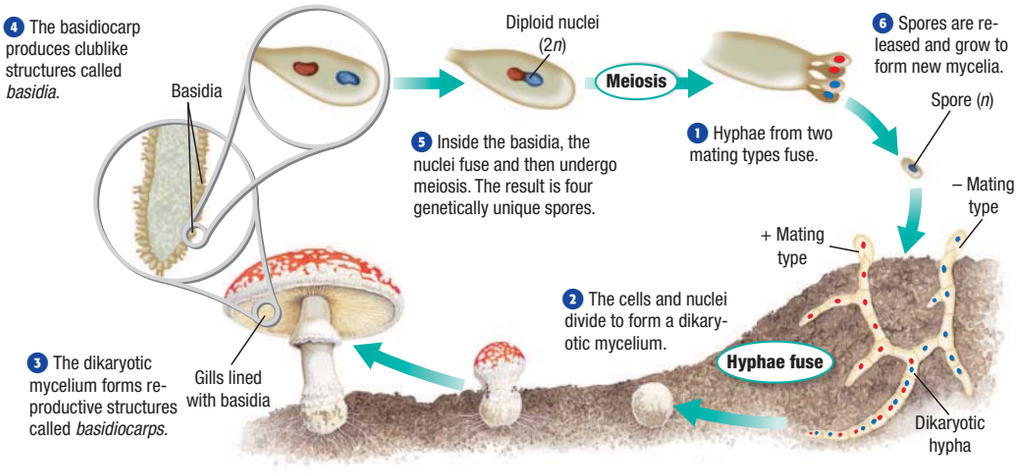


Figure 6 The life cycle of a typical club fungus is shown above. Club fungi usually reproduce sexually.

Club Fungi

Club fungi, which belong to the phylum Basidiomycota, include mushrooms, toadstools, puffballs, jelly fungi, shelf fungi, rusts, and smuts. **› Club fungi are characterized by a basidium, a clublike sexual reproductive structure that produces spores.**

Sexual reproduction of club fungi is shown in **Figure 6.** Specialized hyphae of different mating types grow together. A hypha of one mating type fuses with a hypha of the opposite mating type to form a dikaryotic cell. The nuclei remain separate as the cell grows into a new mycelium in which each cell has two nuclei. The dikaryotic mycelium of a club fungus grows rapidly. When environmental conditions are right, the mycelia form a reproductive structure called a *basidiocarp*. A mushroom, such as the one in **Figure 7,** is an example of a basidiocarp. On the underside of a basidiocarp, club-shaped cells called *basidia* form. The two nuclei inside each basidium fuse. The diploid nucleus undergoes meiosis. Spores are produced and released from the basidium. The spores are carried by the wind and can grow into new club fungi. Asexual reproduction is rare among basidiomycetes but occurs in some rusts and smuts.

Basidiocarps often form at the outer edges of the large mycelial mats that club fungi produce. The mycelia grow out from a central starting point and form an expanding ring of hyphae. When the fungus reproduces sexually, a ring of mushrooms appears. Fungi can grow quite large. In fact, the largest known organism on the planet is a club fungus in Oregon that is 3.5 miles across.

› Reading Check ***Which part of a club fungus is dikaryotic?***

Figure 7 Mushrooms produce spores on structures called gills. **› What might be the reproductive advantage of having gills on the underside of the mushroom?**

Differentiated Instruction

Basic Learners/Special Education Students

White Button Mushrooms Bring in a package of white button mushrooms purchased from a supermarket. Ask students where they encounter these mushrooms (pizzas or salads) Ask students to classify the white button mushroom. (a club fungus) Have students tear apart the mushroom and locate the gills. Ask them where the basidiospores are produced. (on the bottom edge of the gills) This activity is especially helpful for visually impaired students. LS Kinesthetic

Alternative Assessment

Process Chart Have students use **Figure 5** to help them create the chart. In place of the pictures, have them substitute written descriptions of what occurs at each stage. Make sure students include arrows that make it easy to follow the pathway. LS Visual

Teaching Key Ideas

Sac and Club Fungi Have students compare and contrast the structures of sac and club fungi. What difference do they notice in the structures that produce and hold the spores on each type of fungus? (Club fungi produce spores on the outside of a club-like structure, while sac fungi produce spores inside a sac-like structure.) LS Visual

Teaching Key Ideas

Using Field Guides Provide prepared specimens of mushrooms and pictures for students. Have students use field guides to identify which phylum each specimen or picture represents. LS Visual

Teaching Key Ideas

Eating Mushrooms Tell students that contrary to popular belief, poisonous mushrooms cannot be discerned by a quick test such as smearing liquid from a mushroom on white paper or looking for a color change in a broken stalk. Only a trained mycologist should attempt to identify edible mushrooms.

Answers to Caption Questions

Figure 7: Having gills on the underside of the mushroom may protect spores from rain or may make it easier for spores to be dispersed.

Teach, *continued*

Teaching Key Ideas

Lichens Have the students look at the picture of the lichen in **Figure 8.** Ask them to examine the close-up image and identify the part that is the algae and the part that is the fungus. LS Visual

Close

Formative Assessment

Which type of fungi was classified with protists until recently?

A. chytrid fungi (Correct! Chytrids are unicellular like most protists but are now classified as fungi.)

B. club fungi (Incorrect. Club fungi are characterized by basidia that produce spores. Protists do not develop multicellular reproductive structures.)

C. sac fungi (Incorrect. Sac fungi are characterized by an ascus that produces spores. Protists do not develop multicellular reproductive structures.)

D. zygote fungi (Incorrect. Zygote fungi produce zygotes inside a tough capsule. Protists do not develop multicellular reproductive structures.)

Figure 8 Fungal hyphae surround an algal cell (below). Lichens like the British soldier lichen (middle) and wolf lichen (right) get their bright colors from pigments in their fungi.

Fungal Partnerships

Some fungi form important partnerships. **Fungi form mutualistic symbiotic associations to form lichens and mycorrhizae.** In a mutualistic relationship, both members benefit.

lichen (LIE kuhn) a fungus in a symbiotic association with a photosynthetic partner

mycorrhiza (MIE koh RIE zuh) a symbiotic association between fungi and plant roots

A **lichen,** shown in **Figure 8,** is an association between a fungus and a photosynthetic partner, such as a cyanobacterium or a green alga. The photosynthetic partner provides carbohydrates to the fungus. The fungus provides a protected environment as well as vitamins and minerals to the photosynthetic partner. Lichens can survive in extreme environments, such as on volcanic rock and arctic tundra. However, lichens can be damaged by chemical changes in their environment. They can serve as living indicators of air pollution.

A **mycorrhiza** is an association between fungi and the roots of nearly all plants. The fungal hyphae grow inside or around the plant root and out into the soil. The hyphae transfer phosphorus and other minerals from the soil to the roots of the plant. The plant supplies carbohydrates to the fungus.

Section 2 Review

KEY IDEAS

1. **Identify** the characteristics of chytrids that provide clues about the evolution of fungi.
2. **Name** the sexual reproductive structure of zygote fungi.
3. **Identify** the two spore-producing structures in sac fungi.
4. **Describe** the function of the basidium in club fungi.
5. **Name** the two symbiotic partnerships formed by fungi.

CRITICAL THINKING

6. **Relating Concepts** The sexual reproductive structures of some sac fungi, such as truffles, are found underground. Truffles are eaten by animals and people. How might edible reproductive structures affect the spread of spores of these sac fungi?

USING SCIENCE GRAPHICS

7. Use the life cycles of zygote fungi, sac fungi, and club fungi to develop and draw a generalized life cycle of a fungus. Be sure to include both sexual and asexual reproductive stages.

Answers to Section Review

1. Like protists, chytrids are unicellular and produce spores and gametes that have flagella. This suggests that fungi evolved from a unicellular protist similar to chytrids.
2. Zygosporangia are the sexual reproductive structures of zygote fungi.
3. Conidia are asexual spore-producing structures. Asci are sexual spore-producing structures in sac fungi.
4. The basidium is the structure in which nuclei fuse, meiosis takes place, and spores are produced.
5. Fungi form symbiotic partnerships called lichen with photosynthetic cyanobacteria or algae. Fungi form symbiotic partnerships called mycorrhizae with the roots of plants.
6. Students should recognize that because these structures are produced underground, the spores would not be widely distributed if they did not reach the surface. The attractive smell and taste of the fungi helps their spores reach the surface.
7. Students should include a sexual and asexual reproduction phase. Spores are generated by mitosis in the asexual phase and by fusion of nuclei and meiosis in the sexual phase.

Section 3

Fungi and Humans

Key Ideas	Key Terms	Why It Matters
❯ What are some common ways in which humans use fungi? ❯ How are fungi ecologically important? ❯ What are some diseases that fungi cause in humans?	dermatophyte	Fungi have huge effects—both good and bad—on humans and all other living things.

Fungi are in our food and medicines. They are in our labs, in our cars, and in our crops. They can be found on dead organisms and sometimes on living ones. Even though we rarely notice them, fungi play an important role in our world.

Fungi and Industry

Believe it or not, fungi have an enormous effect on industry. ❯ **Fungi are used for food, medicines, research, alternative fuels, and pest control.**

Fungi are probably most familiar as food. White button, shiitake, and portabella mushrooms are common in grocery stores. Fungi provide the flavor and color of blue cheese, shown in **Figure 9.** Yeast is used in baking, brewing, and winemaking. Fungi also produce the citric acid that is used in soft drinks and candies. Some fungi, such as truffles, are delicacies that can sell for $1,000 per pound!

Fungi are an important part of the medical industry. They produce the antibiotics penicillin and cephalosporin. Black bread mold produces cortisone, a drug used to treat skin rashes and to reduce joint swelling. Yeast cells have been genetically engineered to make a vaccine for hepatitis B.

Fungi can also help us improve our environment and reduce pollution. Yeast produces gasohol, a fuel alternative to gasoline. The use of fungal insect parasites to kill crop-destroying insects helps reduce the use of harmful pesticides.

Figure 9 Morels (left) are considered a delicacy by many people. Fungi give blue cheese (middle) its characteristic color and flavor. Yeast is used to make bread rise (right).

Key Resources

Visual Concepts
Symbiosis

Section 3

❯Focus

This section discusses the ways that fungi affect humans in both positive and negative ways.

Bellringer

Use the Bellringer transparency to prepare students for this section.

❯Teach

Demonstration

Mushrooms as Food Have students search the Internet or cookbooks to find recipes that use mushrooms. Also have them find out what kinds of mushrooms are used in the recipes and how the mushrooms are prepared. LS Verbal

Why It Matters

Career Development Invite a speaker from a company that uses fungi in its production process (for example, a representative from a bakery, pharmaceutical company, winery, food-processing plant, or a cheese-making plant). Ask the speaker to discuss the importance of fungi in the industry and how the fungi are cultivated for industrial use. Have students prepare questions for the speaker about careers in that industry. LS Verbal

Teach, *continued*

QuickLab

Teacher's Notes Mycorrhizae increase the uptake of minerals, increase water absorption, and protect tiny rootlets from infection by soil pathogens.

Answers to Analysis

1. group B
2. Sterilizing the soil kills all the mycorrhizal fungi, which provide mineral nutrients to plants.
3. Without the symbiotic fungi, the plants did not have as many nutrients available to them.
4. Inoculate the soil of the stunted plants with mycorrhizal fungi.

Teaching Key Ideas

Composting Explain that compost piles are composed of layers of soil and organic wastes. Eventually, a rich organic material that can be used to supply nutrients for plant growth forms from the materials. Ask students what role fungi play in this process. (Fungi decompose the organic materials so that nutrients can be used.) LS Verbal

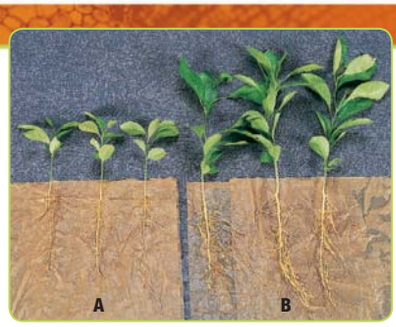
Data

QuickLab

10 min

Fungal Factor

Two groups of plants were planted in similar soils under similar conditions. Group A was grown in sterilized soil, and group B was grown in nonsterilized soil. After 18 weeks of growth, a photograph was taken of the roots of the plants. Use the photograph to answer the questions that follow.



Analysis

1. Compare the growth of the two groups of plants. Which group grew faster?
2. Explain why one group grew better than the other group.
3. CRITICAL THINKING **Inferring Relationships** Suggest a possible cause of slower growth in the smaller plants.
4. Recommend a course of action to restore growth in the stunted plants.

SCILINKS
www.scilinks.org
Topic: Uses of Fungi
Code: HX81585

Fungi and the Ecosystem

Fungi have a large effect on the world around them. **Fungi play important ecological roles by decomposing organic matter and by breaking down and absorbing minerals from rocks and soil.** The main role of fungi in ecosystems is decomposition of dead organisms. Fungi are among the few organisms that can break down wood, as shown in **Figure 10**. By doing this, fungi release nutrients which other organisms can then use. Without fungi, these nutrients might not be available to other organisms ever again. As part of lichens, fungi slowly break down rocks and prepare environments for other organisms. As part of mycorrhizae, fungi absorb minerals from the soil and transfer them to plant roots. Almost all plants have mycorrhizae. Some plants, such as orchids, could not survive without them.

Reading Check *What is the primary role of fungi in ecosystems?*

Figure 10 These mushrooms are decomposing a log. Fungi are one of the few types of organisms that can break down the tough fibers of wood. Fungi can also break down cloth, leather, and even some plastics!

Why It Matters

Lichens Tell students that lichens are particularly susceptible to changes in the environment, as well as an important part of the food chain. Explain that lichens in Finland, Norway, and Sweden absorbed radioactive fallout from the 1986 Chernobyl nuclear power disaster. Reindeer, a major food source for people living in the area, ate the radioactive lichens. More than 70,000 reindeer had to be destroyed because of their exposure to excessive radiation.

Differentiated Instruction

Basic Learners

Fungi in Food Webs Show students a food web that includes fungi. Have students interpret how fungi help transfer matter and energy through the food web. Ask why fungi are especially important. (They are one of the few organisms that can break down and recycle wood material.) LS Logical

Corn smut

Toenail fungus

Ringworm

Figure 11 Smut (left) is a fungus that destroys corn crops. Dermatophytes are a group of fungi that infect skin, hair, and nails, and cause athlete's foot, toenail fungus (middle), and ringworm (right).

Fungi and Disease

Fungi cause may diseases in plants and animals. **Fungi cause disease by absorbing nutrients from host tissues and by producing toxins.**

Fungal Infections Fungi can grow on and inside tissues of the body. **Dermatophytes** are fungi that infect the skin and nails. They cause athlete's foot, toenail fungus, and ringworm. Toenail fungus and ringworm are shown in **Figure 11.** These fungi absorb nutrients and release metabolic wastes that irritate the skin. Yeast is a normal resident of the human body. Antibiotics, hormonal changes, or illness can cause yeast to grow too much. The result is a yeast infection. Yeast infections occur on tissues of the reproductive organs and in the mouth. Histoplasmosis is a lung infection caused by a fungus that grows in bat and bird feces. When its spores are inhaled, this fungus can cause severe respiratory illness in humans. The fungus sometimes spreads from the lungs to other organs. If untreated, it is fatal.

Because fungi grow within the tissues of their host, fungal infections can be difficult to cure. Surface treatments may only relieve the symptoms. Oral medication can cure an infection but can cause damage to the liver or other organs.

Fungal Toxins Many fungi produce dangerous toxins. Toxins in mushrooms can cause vomiting, diarrhea, liver damage, and even death. A type of fungus that contaminates corn, peanuts, and cottonseed produces *aflatoxins,* which can cause liver cancer. Indoor molds can aggravate allergies. Mold toxins may be linked with pulmonary bleeding in infants, but this link has not been proven.

dermatophyte a fungus that infects the skin, hair, or nails

READING TOOLBOX

Word Parts The prefix *histo-* means "a web." Explain why this prefix might be part of an appropriate name for a fungal disease.

Section 3 Review

KEY IDEAS

1. **Describe** ways that fungi are used in industry.
2. **Explain** the roles of fungi in an ecosystem.
3. **Discuss** two ways that fungi can cause disease.

CRITICAL THINKING

4. **Making Predictions** What do you think would happen to an ecosystem if all of the fungi died?
5. **Relating Concepts** How do you think antibiotics and fungal toxins might be related?
6. **Connecting Concepts** What do you think might be the reason that yeast infections cause discomfort?

WRITING FOR SCIENCE

7. Imagine that you work for the health department. You have just been informed that a deadly strain of airborne fungus has been reported your area. Write a public service announcement warning people of precautions they should take.

READING TOOLBOX

Word Parts Sample answer: Fungi have filamentous bodies that grow in a web-like pattern. *Histoplasmosis* probably grows like a web spreading through a person's respiratory system.

LS Visual

Close

Formative Assessment

Which fungus is harmful to plants?

A. smut (Correct! Smut is a fungal pathogen that harms valuable plants.)

B. yeasts (Incorrect. Yeasts help create products such as bread, citric acid, and gasohol.)

C. lichens (Incorrect. Lichens are symbiotic relationships between fungi and algae that help break down rocks to form soil.)

D. mycorrhizae (Incorrect. Mycorrhizae help plants by increasing their ability to obtain minerals.)

Answers to Section Review

1. Fungi are used for food, medicine, research, alternative fuels, and pest control.
2. Fungi decompose organic matter and break down and absorb minerals from rocks and soil.
3. Fungi cause disease by absorbing nutrients from the cells of their host and by producing toxins.
4. Students should recognize that if fungi died, many types of organisms would not decompose. Eventually, an ecosystem would suffer, and other organisms would die. Plants would suffer without mycorrhizae. Lichens would die and animals in arctic tundras that rely on lichens would also die.
5. Students should recognize that fungi compete with bacteria for nutrients, and that releasing a toxin that kills bacteria would help fungi conserve nutrients.
6. Sample answer: Yeasts are a normal resident of humans, but an overgrowth could cause irritation because of the increase in metabolic wastes.
7. Announcements should include cautions to people to wear facemasks when going outside, and to see a doctor if symptoms such as coughing or breathing difficulties develop.

Why It Matters

Teacher's Notes Ergot is a fungal disease that affects about 60 genera in the grass family. Scientists have theorized that ergotism occurred at many points in history, including the Black Death plague. Some studies show that population numbers have frequently declined in rye-eating communities after periods when the weather favors ergot. Witch hunts hardly ever occurred in communities that did not eat rye as part of their diet.

READING TOOLBOX

Visual Literacy Direct students' attention to the picture of wheat at the top of the page. Point out that the purplish-black growths are sclerotia that have replaced grains. Explain that sclerotia are fruiting bodies that fall to the ground and germinate to produce tiny mushroom-like bodies. Spores in those bodies are released and carried by wind currents to other plants, which they then infect.

Answer to Research

Students should find that ergotamine is a drug that is often used to treat migraine headaches. Lysergic acid, commonly known as LSD, is a drug that causes hallucinations, and was popularized in the 1960s.

Why It Matters

Salem Witch Trials

It all began in December 1691 when a few young girls were suddenly afflicted with unusual symptoms. The girls claimed that they were possessed and began accusing townspeople of witchcraft. Soon, witchcraft hysteria had spread throughout the colony of Salem, Massachusetts. Over the next six months, 19 "witches" were hanged, one was pressed to death, several died in jail, and more than 150 townspeople were imprisoned.

Witches or Fungi?

Evidence now suggests that a small fungus may have started the madness that erupted in Salem. Ergot poisoning, or ergotism, results from eating grain infected with the fungus *Claviceps purpurea.* Warm, wet weather favors the growth of *C. purpurea.* Early rains, a warm spring, and a hot, stormy summer were the perfect conditions for ergot in Salem in 1691. The rye was harvested in August, stored in barns, and then processed in November. Bread baked from this rye was beginning to hit the tables in December. The children's first symptoms appeared in late December. Luckily for the people of Salem, 1692 turned out to be a dry year, so the rye was not contaminated. By late fall of 1692, the witchcraft crisis had come to an abrupt end.

A Mysterious Affliction Ergotism is characterized by seizures, crawling sensations in the skin, tingling in the fingers, vomiting, diarrhea, delirium, and hallucinations. All of these symptoms are described in the Salem court records and eyewitness accounts. The victims claimed that they were being tortured by witches.

Research The toxic chemicals that cause ergotism include lysergic acid and ergotamine. Use library or Internet resources to find out more about these chemicals and their current uses.

Inquiry

Chapter 22 Lab

MULTI-DAY 45 min

Lab

Objectives

- Observe the process of fermentation by yeast.
- Investigate various energy sources and their effects on fermentation.
- Measure energy released by fermentation in the form of heat.

Materials

- vacuum flask, 500 mL
- rubber stopper, one-hole
- beaker, 250 mL
- sucrose (75 g)
- glucose (75 g)
- milk (50 mL)
- potato flakes (50 mL)
- packets of artificial sweetener (5)
- package of dry baker's yeast
- thermometer
- rubber tubing, 50 cm long

Safety

Yeast and Fermentation

Yeast releases energy stored in carbohydrates in a process called *fermentation*. In this investigation, you will measure energy released in the form of heat, observe CO_2 release during fermentation, and figure out which carbohydrate best supports yeast growth.

Preparation

1. SCIENTIFIC METHODS **State the Problem** Which carbohydrate does yeast use most efficiently as food for fermentation?
2. SCIENTIFIC METHODS **Form a Hypothesis** Form a testable hypothesis about which carbohydrate will promote yeast fermentation the best.

Procedure

1. Put on safety goggles, gloves, and a lab apron.
2. Mix 75 g or 50 mL of a carbohydrate of your choice in 400 mL of water.
3. **CAUTION: Do not touch your face when working with active yeast.** When your carbohydrate is thoroughly mixed, add one package of dry yeast and stir. Pour the yeast solution into a vacuum flask.
4. **CAUTION: Use extreme caution when working with glass.** Insert a thermometer into a one-hole rubber stopper. Place the stopper into the mouth of the bottle. Adjust the thermometer so that it extends into the yeast solution.
5. Attach a piece of rubber tubing to the side arm of your vacuum flask. Place the end of the tubing into a beaker of water so that you can observe bubbles of CO_2 produced during fermentation.
6. Record the temperature of the solution. Continue to record the temperature at regular intervals during the next two days.
7. Clean up your lab materials according to your teacher's instructions. Wash your hands before leaving the lab.

Analyze and Conclude

1. **Summarizing Data** Prepare a line graph of your data to illustrate the temperature of your solution over time.
2. SCIENTIFIC METHODS **Analyzing Data** Compare your graph to your classmates' graphs. Which carbohydrate best supported yeast growth?
3. SCIENTIFIC METHODS **Analyzing Methods** Design an experiment in which you measure CO_2 production in a different way.

Time Required

One 45-minute class period is required for day 1, and about 10 minutes are required on each of the next two days.

Ratings

Teacher Prep	
Concept Level	
Student Setup	
Cleanup	

Tips and Tricks

Remind students to use caution when inserting the thermometer into the rubber stopper. Have students lubricate the thermometer with soapy water.

Indicator Solutions You can replace the 75 mL of water in the beaker with 75 mL of an indicator such as limewater or bromthymol blue.

Preparing Limewater To prepare a saturated limewater solution, combine 700 mg of calcium carbonate per 500 mL of distilled water. Allow the solution to sit overnight. Filter before using.

Preparing Bromthymol Blue To prepare a bromthymol blue indicator solution, dissolve 0.25 g of bromthymol blue powder per 50 mL of distilled water. If the solution is green or yellow, titrate to blue with a 0.1% sodium hydroxide solution. The limewater will turn cloudy and the bromthymol blue solution will turn yellow as the CO_2 gas produced by the yeast flows into the beaker.

Answers to Analyze and Conclude

1. Graphs will vary. They should show that as fermentation progresses, the temperature in the yeast solution increases.
2. Graphs will vary. Students should notice that glucose worked best and that artificial sweetener was the least effective for growing yeast.
3. Students may propose using an indicator solution to measure CO_2 production by measuring the change in cloudiness or color of the liquid through which the gas passed as it was released from the yeast solution. They may also suggest trapping the gas in a balloon and measuring the

Key Resources

- Holt Lab Generator
- Lab Datasheet (Levels A, B, C)
- Holt Science Biology Video Labs
- Virtual Investigations

Chapter 22

SUPER SUMMARY

Have students connect the major concepts in this chapter through an interactive Super Summary. Visit **go.hrw.com** and type in the keyword **HX8FNGS** to access the Super Summary for this chapter.

Reteaching Key Ideas

Characteristics of Fungi Have each student find a picture or make a drawing of a fungus. Tell students to label parts and to use callouts to show the characteristics it has in common with all fungi. LS Visual

Fungi Classification Provide pictures and prepared specimens of fungi from each of the four phyla students have studied. Have students classify each fungus by phylum. LS Logical

Roles of Fungi Have students make a list of ways that fungi are helpful and ways they are harmful. LS Logical

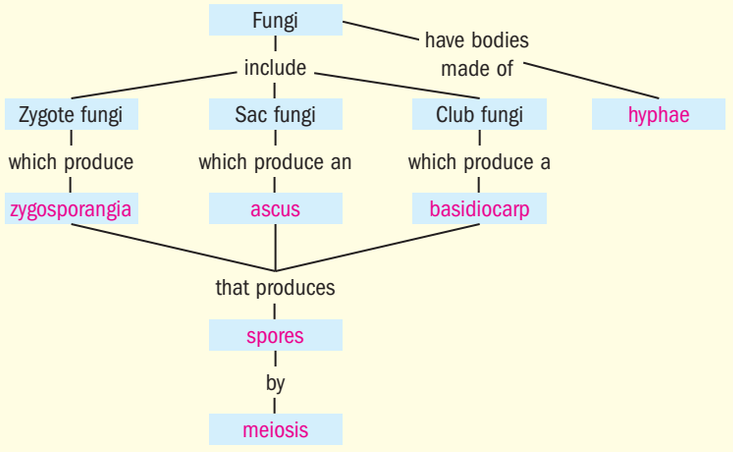
Chapter 22 Summary

go.hrw.com
SUPER SUMMARY
Keyword: HX8FNGS

Key Ideas	Key Terms
1 Characteristics of Fungi › Fungi have threadlike bodies, their cell walls are made of chitin, and they absorb nutrients from their environment. › A typical fungal body is made of filaments that allow the fungus to have a large surface area and to absorb nutrients efficiently. › In sexual reproduction in fungi, spores are produced by meiosis. In asexual reproduction in fungi, spores are produced by mitosis.	**chitin** (521) **hypha** (522) **mycelium** (522) **rhizoid** (522) **saprobe** (522)
2 Groups of Fungi › The chytrids are a group of aquatic fungi that provide clues about the evolution of fungi. › Zygote fungi are named for sexual reproductive structures that produce zygotes inside a tough capsule. › Sac fungi are characterized by an ascus, a saclike sexual reproductive structure that produces spores. › Club fungi are characterized by a basidium, a clublike sexual reproductive structure that produces spores. › Fungi form mutualistic symbiotic associations to form lichens and mycorrhizae.	**zygosporangium** (525) **ascus** (526) **basidium** (527) **lichen** (528) **mycorrhiza** (528)
3 Fungi and Humans › Fungi are used for food, medicines, research, alternative fuels, and pest control. › Fungi play important ecological roles by decomposing organic matter and by breaking down and absorbing minerals from rocks and soil. › Fungi cause disease by absorbing nutrients from host tissues and by producing toxins.	**dermatophyte** (531)

Answer to Concept Map

The following is one possible answer to Chapter Review question 2.



Chapter 22 Review

READING TOOLBOX

1. **Comparisons** Find the paragraphs in your text that discuss chytrids. Write down the sentences that compare protists, chytrids, and other fungi. Then, write down the sentences that contrast protists, chytrids, and other fungi.
2. **Concept Map** Construct a concept map that describes the structure and reproductive methods of zygote, sac, and club fungi. Use the following terms in your concept map: *zygosporangia, hyphae, ascus, spore, basidiocarp,* and *meiosis.*

Using Key Terms

For each pair of terms, explain how the meanings of the terms differ.

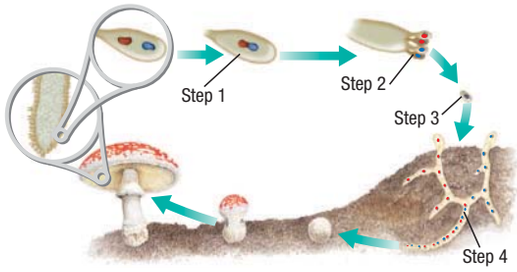
3. *hypha* and *mycelium*
4. *ascus* and *basidium*
5. *mycorrhiza* and *lichen*

Use each of the following terms in a separate sentence:

6. *saprobe*
7. *dermatophyte*

Understanding Key Ideas

8. The cell walls of fungi are made out of
   a. asci. **c.** rhizoids.
   b. chitin. **d.** cellulose.
9. What is a hypha?
   a. a small, lightweight reproductive cell
   b. a single filament that is part of a fungus body
   c. a toxin produced by poisonous mushrooms
   d. a group of filaments that make up a fungus body
10. A rapidly growing, asexually reproducing stage of a fungus is called a
    a. mold. **c.** parasite.
    b. yeast. **d.** zygote fungus.
11. Which fungi produce cells that have flagella?
    a. chytrids **c.** club fungi
    b. sac fungi **d.** zygote fungi
12. Zygote fungi usually reproduce
    a. sexually by spores. **c.** by budding.
    b. asexually by spores. **d.** by fragmentation.
13. The reproductive body of a sac fungus is a(n)
    a. zygospore. **c.** basidiocarp.
    b. ascocarp. **d.** zygocarp.
14. In the life cycle shown here, which step results in a diploid cell?



    a. Step 1 **c.** Step 3
    b. Step 2 **d.** Step 4
15. The association between a fungus and an alga in lichen is an example of
    a. predation. **c.** mutualism.
    b. parasitism. **d.** commensalism.
16. What is the main ecological role of fungi?
    a. parasites
    b. producers
    c. consumers
    d. decomposers
17. Which two fungal infections are caused by the same type of fungus?
    a. smut and thrush
    b. athlete's foot and thrush
    c. athlete's foot and ringworm
    d. yeast infections and liver cancer

Explaining Key Ideas

18. Name three ways that fungi are used in industry.
19. Describe the similarities and differences between protists, chytrid fungi, and other fungi.
20. Explain why people should not eat mushrooms found growing in the wild?

Assignment Guide

Section	Questions
1	3, 6, 8, 9, 10, 20, 21, 22, 25
2	1, 2, 4, 5, 11, 12, 13, 14, 15, 19, 26
3	5, 7, 15, 16, 17, 18, 20, 23, 24, 27, 28

Review

Reading Toolbox

1. Like protists, many chytrids are unicellular and produce spores and gametes that have flagella. Chytrids are like all other fungi in several important ways: They have chitin in their cell walls, they digest food outside their bodies, and most produce hyphae that form rootlike structures called rhizoids.
2. See previous page for answer to concept map.

Using Key Terms

3. A *hypha* is a threadlike structure. A *mycelium* is a fungal body composed of hyphae.
4. An *ascus* is the structure that produces spores in sac fungi. A *basidium* is the structure that produces spores in club fungi.
5. *Mycorrhizae* are partnerships between fungi and plants, and *lichens* are partnerships between fungi and algae or cyanobacteria.
6. A *saprobe* obtains its nutrition from dead organisms.
7. A *dermatophyte* is a kind of fungus that infects skin and nails.

Understanding Key Ideas

8. b 9. b 10. a 11. a
12. b 13. b 14. a 15. c
16. d 17. c

Explaining Key Ideas

18. Accept any three of the following: as foods, in medicine, in research, as alternative fuels, and in pest control.
19. Chytrid fungi and protists are unicellular, and produce spores and gametes with flagella. Unlike protists, chytrids and other fungi have cell walls made of chitin, digest food outside of their bodies, and produce hyphae.
20. Many mushrooms are highly toxic, and it is almost impossible to distinguish some varieties of edible mushrooms from varieties of toxic ones.

Critical Thinking

21. Recognizing Relationships In what way is the mycelium of a fungus a good adaptation for absorbing nutrients from the environment?

22. Applying Information Yeast cells break down simple sugars into carbon dioxide and ethanol in a process called *fermentation*. Explain how this process is used in bread making.

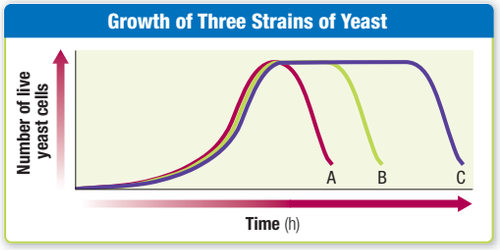
23. Predicting Outcomes If all fungi suddenly disappeared from Earth, what kinds of changes would you notice immediately? What kinds of changes would you notice over several years?

Methods of Science

24. Recognizing Relationships Imagine that you are a doctor in an emergency room. A patient comes in with a severe cough and difficulty breathing. A chest X ray reveals cloudy lungs, indicating a respiratory infection. How might you determine whether the infection is bacterial, viral, or fungal?

Using Science Graphics

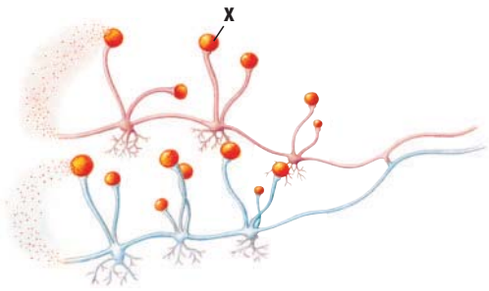
The graph shows the growth rate of three types of yeast. Each type was grown in a separate container on the same variety of grapes. Use the graph to answer the question that follows.



25. Which of the following statements might explain the data in the graph?

- **a.** Strains B and C reproduced rapidly and ran out of food quickly.
- **b.** Strains A and B reproduced more slowly than strain C and therefore survived longer.
- **c.** Strain A produced more yeast cells than strains B and C did.
- **d.** Strain C was more tolerant of high alcohol concentrations than strains A and B were and survived longer.

The diagram shows the reproductive structures of a type of fungus. Use the graphic to answer the question that follows.



26. What is the structure labeled "X" called?

- **a.** a hypha
- **b.** a zygote
- **c.** a sporangium
- **d.** a zygosporangiospore

Writing for Science

27. Communicating Results In 1882, Pierre Millardet, a professor in France, made an important discovery. A mixture of copper sulfate, calcium oxide (lime), and water was used in France to make wine grapes unappetizing and to keep thieves from stealing them. Millardet noticed that this chemical also killed downy mildew, a fungus that destroys wine grape crops. Imagine that you are Pierre Millardet. Write a week of daily journal entries chronicling your observations and discovery.

Math Skills

28. Using Percentages An estimated 10% of the U.S. population is allergic to inhaled mold spores. In a population of 1,000, how many people will be allergic to mold? This can be calculated by multiplying 1,000 by 0.10, which gives you 100.

If 25% of the population were allergic to mold, how many individuals in a population of 1,000 would be allergic to mold?

If 25% of the population were allergic to mold, how many individuals in a population of 165,000 would be allergic to mold?

Critical Thinking

21. Students should recognize the advantage that the large surface area afforded by mycelia provides to absorb nutrients from the environment.

22. Students should understand that the yeast metabolizes carbohydrates in bread dough and produces bubbles of carbon dioxide, which causes the dough to rise.

23. Students would immediately notice that certain kinds of foods, beverages, and medicines could not be produced. After a period, dead material would accumulate because fungi would not be available to decompose it.

Methods of Science

24. Students should understand that bacterial or fungal pathogens could be cultured from the patient. A bacterial infection would respond to antibiotics, and some fungal infections would respond to antifungal medications, while a viral infection would not respond to these medications. Fungal infections could also be detected by identifying the toxins they release.

Using Science Graphics

25. d **26.** c

Writing for Science

27. Accept well written journals that discuss the discovery of this mixture as a plant antibiotic.

Math Skills

28. To calculate the number of people affected, multiply the total population by the decimal equivalent of the given percentage.

$1{,}000 \times 0.10 = 100$

In a population of 1,000, if 10% are allergic, then 100 people will be allergic.

$1{,}000 \times 0.25 = 250$

In a population of 1000, if 25% are allergic then 250 people will be allergic.

$165{,}000 \times 0.25 = 41{,}250$

In a population of 165,000, if 25% are allergic then 41,250 people will be allergic to mold.

Chapter 22 Standardized Test Prep

TEST TIP When studying for a test on the life cycles of fungi, organize the information into a table. It can be easier to recall information from a table than from a paragraph.

Science Concepts

Choose the letter of the answer choice that best answers the question.

1. The body of a fungus is called a
- **A** stolon.
- **B** mycelium.
- **C** mycorrhiza.
- **D** zygosporangium.

2. Fungi that absorb nutrients from dead organisms are called
- **F** parasites.
- **G** saprobes.
- **H** mutualists.
- **J** autotrophs.

3. During sexual reproduction in club fungi, which of the following steps happens first?
- **A** Nuclei in the basidia fuse.
- **B** Fused hyphae form a mushroom.
- **C** Opposite mating types grow together.
- **D** The zygote undergoes meiosis, which forms spores.

4. What does the word *basidiocarp* mean?
- **F** zygote
- **G** hyphae
- **H** mushroom
- **J** haploid nuclei

5. Which of the following is an association between a fungus and a plant?
- **A** a lichen
- **B** a rhizoid
- **C** a mycorrhiza
- **D** a microrhizoid

6. Which fungi generally reproduce only sexually?
- **F** chytrids
- **G** zygote fungi
- **H** sac fungi
- **J** club fungi

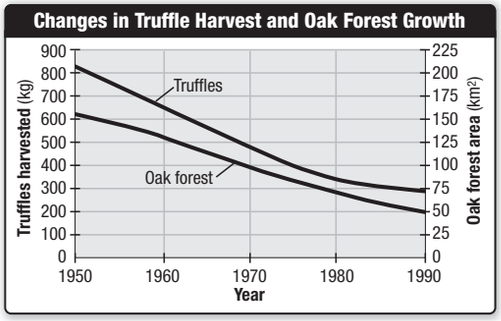
7. Which disease is caused by inhaled spores?
- **A** thrush
- **B** aflatoxins
- **C** histoplasmosis
- **D** dermatophytes

Writing Skills

8. Short Response Describe the general process of sexual reproduction in fungi.

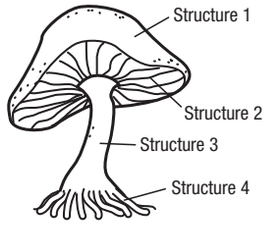
Using Science Graphics

The graph below shows changes in truffle harvest in a certain oak forest over a 40-year period. Use the graph to answer the following question(s).



9. Which of the following statements is supported by the data in the graph?
- **F** The oak forest covered 125 km² in 1970.
- **G** The truffle harvest decreased most rapidly between 1980 and 1990.
- **H** The oak forest area decreased by 50 percent between 1955 and 1970.
- **J** The truffle harvest decreased at a constant rate between 1950 and 1975.

The diagram below shows the reproductive structure of a club fungus. Use the diagram to answer the following question(s).



10. Which structure obtains nutrients for the fungus?
- **A** Structure 1
- **B** Structure 2
- **C** Structure 3
- **D** Structure 4

11. Which structure is the stalk?
- **F** Structure 1
- **G** Structure 2
- **H** Structure 3
- **J** Structure 4

State Resources

For specific resources for your state, visit go.hrw.com and type in the keyword **HSHSTR**.

Test Practice with Guided Reading Development

Answers

1. B **2.** G **3.** C
4. H **5.** C **6.** J
7. C
8. Students should include the idea that opposite mating types grow together. Hyphae fuse. A reproductive structure forms. Nuclei fuse to form a diploid zygote. The zygote undergoes meiosis to produce haploid spores. Spores are released.
9. J **10.** D **11.** H

TEST DOCTOR

Question 1 **A** is incorrect, because stolons are the creeping hyphae of some fungi. **B** is correct! Hyphae form tangled masses called mycelia. **C** is incorrect, because a mycorriza is a symbiotic relationship between a fungus and plant roots. **D** is incorrect, because a zygosporangium is a sexual structure that contains zygotes.

Question 4 **F** is incorrect, because a zygote is a cell that results when nuclei fuse. **G** is incorrect, because hyphae are the filaments of a fungus. **H** is correct! A mushroom is an example of a basidiocarp. **J** is incorrect, because haploid nuclei are the nuclei of cells formed by meiosis.

Question 10 **A** is incorrect, because this is the cap which contains the gills. **B** is incorrect, because this is a gill. **C** is incorrect, because this structure is the stalk. **D** is correct! The mycelium obtains nutrients.