By Design

A Journey to Excellence through Science

SEVENTH-DAY ADVENTIST® CHURCH

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Science Classroom and Lab Safety

SAFETY:

It is important to be safe when you perform hands-on investigations. Always look for the safety symbol in your textbook. It tells you how to be safe as you perform your investigations. Below are some important safety rules to follow for most investigations. Remember to be alert and listen to your teacher for any additional safety rules.

Prepare for laboratory work

- Review classroom laboratory procedures with your teacher.
- Never perform unauthorized experiments.
- Keep your lab work area organized and free of clutter.
- Know the location of the safety fire blanket and first aid kit.

Dress for laboratory work

- Tie back long hair.
- Do not wear loose sleeves.
- Wear shoes that completely cover your feet.
- Wear lab apron, goggles, and gloves as required.

Avoid contact with chemicals

- Never taste or sniff chemicals.
- Never draw materials in a pipette with your mouth.
- When heating substances in a test tube, point the mouth away from people.
- Never carry dangerous chemicals or hot equipment near other people.

Avoid hazards

- Keep combustibles away from open flames.
- Use caution when handling hot glassware.
- When diluting acid, always add acid slowly to water. Never add water to acid.
- Turn off burners when not in use.
- Keep lids on reagent containers. Never switch lids.
- Use sharp equipment and objects as they were designed to be used and in a safe manner. For example, always cut away from yourself rather than toward yourself, and be careful to study which edges and points of an object are the sharp ones.

Clean Up

- Consult the teacher for proper disposal of materials.
- Wash hands thoroughly following experiments.
- Leave laboratory work area clean and neat.

In case of accident

- Report all accidents and spills immediately.
- Place broken glass in designated containers.
- Wash all acids and bases from your skin immediately with plenty of running water.
- If chemicals get in your eyes, wash them for at least 15 minutes with an eyewash or clean water.

Scavenger Hunt

Start

Use this Scavenger Hunt to find where things are in your book.

Where will you find the **Essential Question** for each lesson?

What is the first **Inquiry Kick-Off** Engage about?

Write the sentence in which the first **vocabulary** word appears.

What is the first word that appears in the Index in the back of your book?

What is the title of the first **Structured Inquiry**?

What does the first page of the **Inquiry Handbook** talk about?

What is your first **SCIENCE SAFETY** rule?

What are the vocabulary words for Chapter 1, Lesson 1?

What question does the first **Check for Understanding** ask?

What is the scripture reference for the first **Scripture Spotlight**?

What do each of these symbols stand for?

What does the first **Lesson Activity** ask you to think about?

What question does the first **Explore-a-Lab** ask?

What is the solution to the first **Math in Science**?

What is the first question of the first **Concept Check** **Assess/Reflect**?

How many questions are in the first **Chapter Review**?

ByDesign

Table of Contents

Science

How would you define science? Is it all the knowledge accumulated from disciplines such as biology, chemistry, and physics? What other disciplines might it include? Does it include the latest technology? Science includes all of these things, but we usually focus most on science as a process of discovery—a systematic search for understanding of the natural world.

In order to systematically search for the truth, a scientist would have to be true about the natural world. What are some truths about the natural world that a scientist would consider? Can you think of any other assumptions that would need to be true for scientists to proceed with this process?

Scientists make several assumptions that provide the foundation for science:

- Living things and the physical world can be studied and understood.
- The processes of nature follow predictable laws.
- By observation and experimentation, we can learn what these laws are.

Where do you think scientists got the idea that nature follows predictable laws?

Sometimes we distinguish between empirical science and historical science.

Chapter 1

Bacteria, Protists, and Fungi

Chapter Overview

Before you plan your instruction for Chapter 1, take some time to think about **The Big Idea** and how it relates to our faith. Use this page alongside the Bible and other resources at your church to connect the content of this chapter to your spiritual beliefs.

The Big Idea

All living things are classified into groups according to the characteristics they share. Microscopic organisms such as bacteria, protists, and fungi are alike because most cannot be seen without magnification. Each can be either beneficial or harmful.

Chapter Pacing Guide

Chapter 1	Pacing
Unit Opener pp. 12–13	0.5 day
Chapter Opener pp. 14–15	0.5 day
Lesson 1 How Are Living Things Classified? pp. 16–23	3 days
Lesson 2 What Are Bacteria? pp. 24–31	4 days
Lesson 3 What Are Protists? pp. 32–38	3 days
Lesson 4 What Are Fungi? pp. 39–47	3 days
Chapter Features pp. 48–49	0.5 day
Chapter Review pp. 50–51	0.5 day
Chapter Test TE pp. xx–xx	0.5 day

Materials

Hands-on inquiry is an important part of the ***By Design*** series. The tables indicate the materials and quantities needed per individual (or per group) to perform the inquiries that accompany the ***Science Journal.***

Consumable Materials

These materials will be consumed as students perform the inquiry activities. They will need to be replaced each year.

Nonconsumable Materials

These materials should be saved and reused every year. Consider organizing materials in labeled bins or bags, so they can be found easily each year.

Note: Material kits prepared for the ***By Design*** program include most of the items listed here. Live bait will need to be ordered. Some common household materials and food items may not be included either. You may wish to compare this list with the content list from your kit to be sure you have all the necessary materials.

Consumable Materials

Materials	Individual/Group Qty	Activity Page
bags, zip-top plastic	2	41
cereal, variety	small samples	35
container, plastic with lid	1	35
cotton swabs, sterile	at least 5	26
crystal violet stain	1 drop	15
cups, plastic	4	29, 41
dish, small	1	15
foil, aluminum	1 roll	29
fruit, variety	several pieces	35
gloves, disposable	1 pair	26
milk, powdered	15 mL	29
milk, whole	700 mL	29
paper towels	1 roll	35, 41
Petri dishes with nutrient agar	at least 6	26
oatmeal flakes (not instant)	a few flakes	35
slime mold	1 piece	35
soaps, antibacterial	variety	26
spoon, plastic	1	41
sugar, granulated	5 mL	41
sugar, varied types	1 sample of each	41
sweeteners, artificial, varied types	1 sample of each	41
tape	1 roll	26
toothpick	1	15
water	varies	29, 35, 41
water, distilled	10 drops	15
water, distilled, sterile	varies	26
water bottles, plastic	4	29
yeast, active dry	2 packets	41
yogurt	small drop	15
yogurt, plain (active culture)	45 mL	29

Nonconsumable Materials

Materials	Individual/Group Qty	Activity Page
cooler	1	29
cover slip	1	15
goggles, safety	1	26, 41
graduated cylinder (100 mL)	1	29, 41
hand lens	1	18
hot plate	1	29
lab apron	1	26, 41
marker, permanent	1	26, 29, 35, 41
medicine dropper	1	15, 35
microscope	1	15
microscope slide	1	15
microwave oven	1	29
mix of wildflower seeds, beads, foods, or baubles	10 varieties per group	18
pencil, wax	1	26, 35, 41
ruler, metric	1	18, 41
saucepan	1	29
seeds	10 varieties per group	18
thermometer	1	29, 41

Chapter 1

Inquiry Kick-Off Structured Inquiry: Observing Bacteria SE/TE p. 15, ***Science Journal*** p. 7. **Materials:** toothpick, yogurt, distilled water, small dish, medicine dropper, crystal violet stain, microscope slide, cover slip, microscope

Lesson Component	Vocabulary	Lesson Objective(s)	Resources
Lesson 1 **How Are Living Things Classified?** pp. 16–23	common name scientific name species binomial nomenclature taxonomy kingdom domain	• Describe how scientists name and classify living things. • Explain the structure of scientific names. • Describe the classification system used by scientists.	**Science Journal** Structured Inquiry Support pp. 8–9 Guided Inquiry Support pp. 10–11 ***Online Teacher Resource*** Lesson Support, Skill Builder, and Scoring Rubrics
Lesson 2 **What Are Bacteria?** pp. 24–31	microorganism autotroph heterotroph binary fission aerobic bacteria anaerobic bacteria antibiotic	• Identify characteristics and structures of bacteria. • Describe the growth of bacteria. • Describe the types of bacteria. • Describe diseases caused by bacteria. • Summarize the roles of bacteria.	**Science Journal** Structured Inquiry Support pp. 12–13, 16–19 Guided Inquiry Support pp. 14–15 ***Online Teacher Resource*** Lesson Support, Skill Builder, and Scoring Rubrics
Lesson 3 **What Are Protists?** pp. 32–38	protist protozoan phytoplankton pseudopodia flagella cilia	• Identify the characteristics and structures of protists. • Describe the three main groups of protists. • Explain the environmental importance of protists. • Describe helpful and harmful protists.	**Science Journal** Structured Inquiry Support pp. 18–19 Guided Inquiry Support pp. 20–21 ***Online Teacher Resource*** Lesson Support, Skill Builder, and Scoring Rubrics
Lesson 4 **What Are Fungi?** pp. 39–47	hyphae mycelium saprophyte mycology parasite	• Identify the characteristics and structures of fungi. • Explain the role of fungi in decomposition. • Describe the different kinds of fungi. • Describe how fungi are harmful and useful.	**Science Journal** Structured Inquiry Support pp. 22–23 Guided Inquiry Support pp. 24–25 ***Online Teacher Resource*** Lesson Support, Skill Builder, and Scoring Rubrics
End-of-Chapter Features	People in Science: Carolus Linnaeus SE/TE p. 48 Careers in Science: Mycologist SE/TE p. 49		**Assessment Options**

Inquiry and Hands-On Activities

 **Structured Inquiry:** **Classifying Seeds** SE/TE p. 18 **Materials:** seeds, hand lens, metric ruler  **Guided Inquiry:** **Develop a Dichotomous Key** TE p. 18 **Materials:** mix of wildflower seeds, beads, foods, or baubles	**Lesson Activity** SE/TE p. 23 **Materials:** Internet access, poster board
 **Structured Inquiry:** **Bacterial Growth Rates** SE/TE p. 26 **Materials:** safety goggles, lab apron, disposable gloves, Petri dishes with nutrient agar, wax pencil or permanent marker, sterile distilled water, sterile cotton swabs, tape  **Guided Inquiry:** **Antibacterial Soaps** TE p. 26 **Materials:** variety of antibacterial soaps, Petri dishes  **Structured Inquiry:** **Making Yogurt** TE p. 29 **Materials:** graduated cylinder (100 mL), water, plastic cups, marker, whole milk, saucepan, hot plate, thermometer, microwave oven, plain yogurt, powdered milk, aluminum foil, cooler, plastic water bottles	**Lesson Activity** SE/TE p. 29 **Materials:** varied yogurt labels **Lesson Activity** SE/TE p. 31 **Materials:** Internet access, poster board
 **Structured Inquiry:** **Observing Slime Molds** SE/TE p. 35 **Materials:** plastic container with lid, paper towel, wax pencil or permanent marker, water, piece of slime mold, oatmeal flakes (not instant), medicine dropper  **Guided Inquiry:** **Slime Mold Food Preferences** TE p. 35 **Materials:** variety of cereals and pieces of fruit	**Explore-a-Lab** SE/TE p. 34 **Materials:** pond water, small jar, dried grass, wheat seed, medicine dropper, microscope **Lesson Activity** SE/TE p. 37 **Materials:** Internet access, poster board
 **Structured Inquiry:** **Activity of Yeast** SE/TE p. 41 **Materials:** safety goggles, lab apron, large zip-top bags, wax pencil or permanent marker, thermometer, warm water, graduated cylinder (100 mL), plastic cup, active dry yeast, plastic spoon, granulated sugar, paper towels, metric ruler  **Guided Inquiry:** **Sugars and Yeast** TE p. 41 **Materials:** variety of forms of sugar and artificial sweeteners in addition to materials used in the Structured Inquiry	**Explore-a-Lab** SE/TE p. 44 **Materials:** mushrooms from a grocery store, white paper, container, hand lens **Explore-a-Lab** SE/TE p. 46 **Materials:** zip-top bags, white bread, bakery bread, wax pencil or permanent marker, medicine dropper, water, hand lens

Chapter Test TE pp. **xx–xx** and as an ***Online Teacher Resource***
Concept Check SE/TE pp. 23, 31, 38, and 47

Unit 1 Life Science

Introduce the Unit

Have students examine the photo and describe what they see. Then have students read the unit overview and make a list of questions they have. Challenge students to turn their questions into testable scientific questions. For example, the question *Do plants look like their parents?* can be turned into *Will two plants with yellow flowers always produce offspring with yellow flowers?*

God's Design of living things becomes apparent when you study the complexity of life on Earth.

Connect the Content

There are multiple opportunities to connect the photograph to content from this unit:

Ch. 1 Bacteria, Protists, and Fungi Elephants, like people, are relatively complex living things. Their bodies consist of many types of specialized cells, tissues, and organs. The smallest living things are made of just one cell, albeit one very complex cell. Some kinds of multicellular living things do not have tissues or organs.

Ch. 2 Characteristics of Invertebrates An elephant's backbone runs from the back of its head to the middle of its tail. Many animals do not have a backbone. They are called invertebrates.

Ch. 3 Characteristics of Vertebrates Elephants are in a group of vertebrates called mammals. Mammals have hair or fur and feed their young milk.

Ch. 4 How Organisms Inherit Traits Like all organisms, elephants pass on DNA to their offspring. Cells use DNA as instructions to build proteins that give them a certain set of characteristics.

Unit 1 Life Science

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Science and Society

Elephants are the largest land animal living today. African elephants, pictured on this page, have much larger ears than the Asian elephant. Elephant populations declined rapidly in the last two centuries as elephants were killed for their tusks, which are made of ivory. Ivory was used to make billiard balls, piano keys, and ornamental items such as carvings and jewelry.

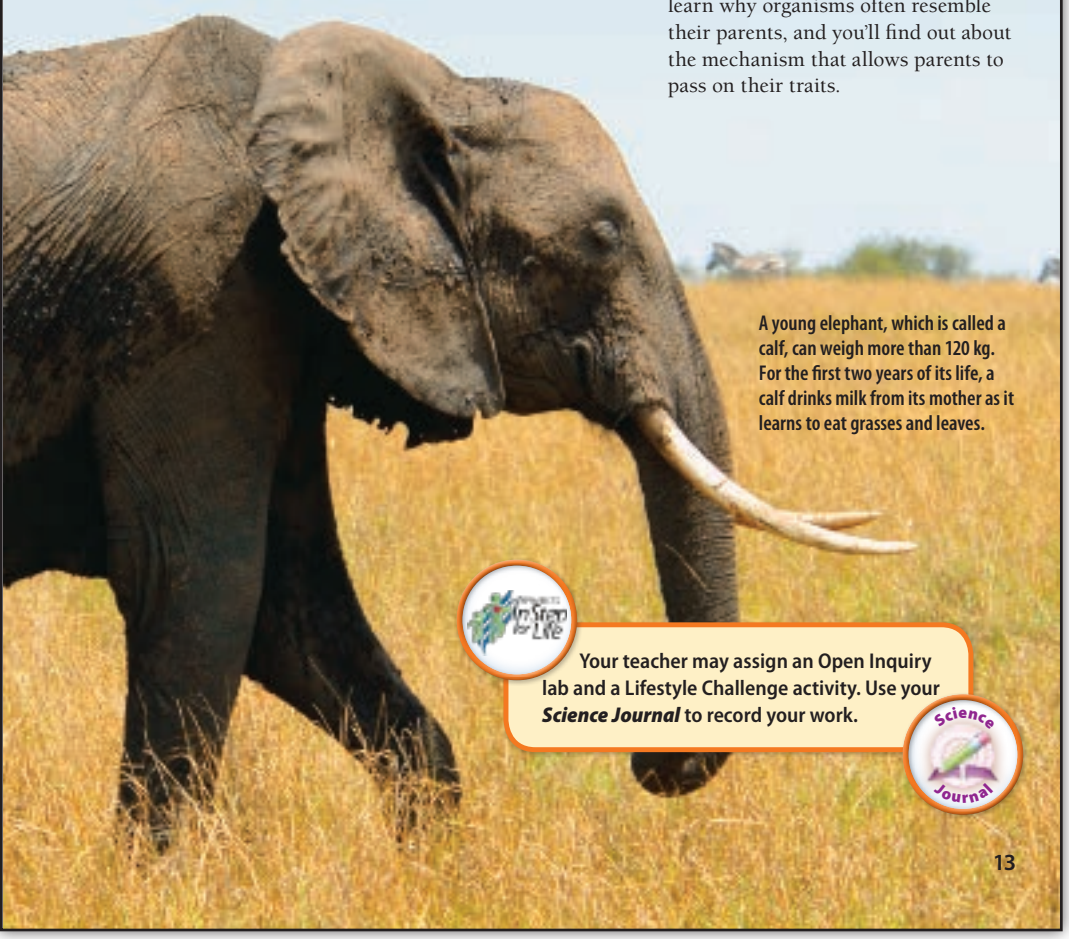
Despite international laws banning the trade of ivory and extensive education campaigns about the plight of elephants, elephant populations in many African countries continue to decline at alarming rates due to habitat loss, climate changes, and continued threats from humans. Asian elephants are classified as endangered due to poaching and the rapid loss of habitat in parts of Asia.

Unit Overview

What living organisms have you encountered today? What do all of these organisms have in common? Living organisms are all around you. They vary in size and shape, but all living things are made of the same small units—cells. In this unit, you will learn more about cells and the cell parts that work together inside the cell. You'll also find out how cells differ in structure and function.

Many living things are made of just one cell. Larger organisms are made of trillions of cells! In this unit, you will take an in-depth look at the variety of organisms God designed during Creation. Why do you think God wanted so much variety? You'll find out about the features of many groups of living things, as well as how the organisms survive in their environments. You will learn how organisms are classified, or grouped, according to their features.

For an organism to survive, it must reproduce. When organisms reproduce, they pass on their traits to their offspring. In this unit, you will learn why organisms often resemble their parents, and you'll find out about the mechanism that allows parents to pass on their traits.



A young elephant, which is called a calf, can weigh more than 120 kg. For the first two years of its life, a calf drinks milk from its mother as it learns to eat grasses and leaves.

Your teacher may assign an Open Inquiry lab and a Lifestyle Challenge activity. Use your ***Science Journal*** to record your work.

Math Link

To help students understand how many cells make up their bodies, give them the following word problem.

Suppose you wanted to write out all the numbers between 1 and 1,000,000. If you wrote one number per second and did nothing but write numbers 24 hours per day, how long would it take you to finish?

1,000,000 numbers ÷ 1 number / second ÷ 60 seconds / minute ÷ 60 minutes / hour ÷ 24 hours / day = 11.57 days

Your body has over 1 trillion cells! A trillion is a million million. When you finished writing numbers, you would have to repeat the process a million more times to reach the number of cells in your body!

Lifestyle Challenge

Healthy living is part of God's plan for all of us. Help students make healthy choices by having students perform the Lifestyle Challenge described in their ***Science Journals.*** Give students about 3 weeks to complete these challenges. Check students' progress throughout the unit, and encourage students to discuss their challenge with their families and friends.

Teach Using Inquiry

Open Inquiry

Life in Pond Water

As students progress through the unit, consider having them design and complete their own investigation with minimal guidance. To get students started, give them the following prompt:

Plan an in-depth investigation of pond life such as how different nutrients affect pond microorganisms, how the organisms found in lakes and streams compare, or what limiting factors affect their growth.

Have students do research, ask questions, and make observations. Students should develop a list of questions about pond water organisms. Have students write one question that could be tested using the process of scientific inquiry.

During the unit, ensure that students record appropriate data, analyze their results, and write a conclusion.

Have students use their ***Science Journals*** to record their work for this inquiry.

Science Projects The Open Inquiry can often lead to Science Fair projects. Have students prepare a final report, oral presentation, or display board to present their findings. Use the Guide to Science Projects in the ***Online Teacher Resource*** for additional support.

Chapter 1

Bacteria, Protists, and Fungi

Introduce the Chapter

The Big Idea

Have a volunteer read the Big Idea statement from the textbook:

All living things are classified into groups according to the characteristics they share. Microscopic organisms such as bacteria, protists, and fungi are alike because most cannot be seen without magnification. Each can be either beneficial or harmful.

Display this statement in the classroom as you cover the material in this chapter. As you review content learned each day, refer to the Big Idea statement and ask how the content relates.

Ask students to describe how the photograph relates to the Big Idea.

How are the bacteria in this picture like you? How are they different from you? Sample answers: We are both alive; we are made of cells; we reproduce. They have only one cell, but we have trillions. They are microscopic, but we are not.

Activite Prior Knowledge

In Grade 5, students learned the basic cell structure. In Grade 6, students learned about two major types of cells.

Essential Questions

Students will be able to answer these essential questions by the end of this chapter.

- **How Are Living Things Classified?**
- **What Are Bacteria?**
- **What Are Protists?**
- **What Are Fungi?**

Practice Consider assigning the practice page found as an ***Online Teacher Resource*** to help students enhance their skills with this chapter. The answer keys are found in the back of this ***Teacher Edition***.

Chapter 1

Bacteria, Protists, and Fungi

Scripture Spotlight

When you think about the things God created, do you think about the things you need a microscope to see? Most bacteria and protists and some fungi are microscopic. By studying these organisms you can better understand God and the world He created for us. You will read the following passages in this chapter.

Isaiah 43:1 (p. 19)
Leviticus 14:33–45 (p. 40)
Numbers 19:15 (p. 27)
Exodus 7:14–25 (p. 37)

Scripture Spotlight

Throughout this chapter, you can strengthen your faith using science.

Students are asked to connect what they are reading to the following Bible passages. Read these passages and their associated teacher tips prior to discussing them with students.

Isaiah 43:1 (p. 19)
Leviticus 14:33–45 (p. 40)
Numbers 19:15 (p. 27)
Exodus 7:14–25 (p. 37)

In addition, you may find it beneficial to review the following readings that apply to content in this chapter:

The Ministry of Healing, Chapters 20 and 21

Listeria, shown growing on an agar plate, is a bacterium found in soil, water, and some animals, such as poultry and cattle. It can be present in raw milk and foods made from raw milk. *Listeria* is one of the harmful bacteria that can cause food poisoning.

The Big Idea

All living things are classified into groups according to the characteristics they share. Microscopic organisms such as bacteria, protists, and fungi are alike because most cannot be seen without magnification. Each can be either beneficial or harmful.

How are the bacteria in this picture like you? How are they different from you?

Inquiry Kick-Off Engage

The live bacteria in yogurt provide many health benefits, such as preventing infections. What do you think bacteria look like? In your ***Science Journal,*** you will investigate what one type of bacteria found in yogurt looks like.

Science Background

Listeria The bacterium *Listeria monocytogenes* is commonly found in hot dogs, deli meats, soft cheese (feta and *queso blanco*), and seafood. *Listeria* causes an infection called listeriosis, which occurs when contaminated food is eaten. Listeriosis symptoms are muscle ache, fever, stomach pain, and diarrhea. Listeriosis is prevented by careful food handling. Produce must be thoroughly washed. Uncooked meat and poultry must be kept separate from other food. Refrigerated foods need to be kept at 4.4˚C or colder. It is important to wash kitchen counters with hot water and soap before and after food preparation. Meat must be cooked thoroughly to kill any *Listeria* present. People with signs of listeriosis should see a doctor immediately.

Engage

Start with an Activity

Inquiry Kick-Off

Use this activity to engage students and determine what they know about bacteria.

Have students use their ***Science Journals*** to record their work for this inquiry.

Help students recognize that organisms such as bacteria are neither "bad" nor "good" but that a select few species of bacteria can sometimes be harmful to humans.

Create Explanations

1. Answers will vary depending on the brand of yogurt used. Common active cultures include *Lactobacillus delbrueckii, L. acidophilus,* or *L. bulgaricus,* which will appear rod-shaped; *Lactococcus lactis* or *Streptococcus thermophilus,* which will appear round; and *Bifidobacterium lactis,* which appears as branched rod-shaped.
2. Sample answer: no, because different kinds of bacteria look different

Set a Goal

Before students begin this chapter, have students begin a K-W-L chart relating to bacteria, protists, and fungi. Have them complete the first column of the chart with what they already **know** about these organisms and the second column with what they **want** to know. As they complete each lesson in the chapter, have them fill in the third column, telling what they have **learned**.

Lesson 1

Essential Question

How Are Living Things Classified?

Preview Lesson Content

Read the objectives with students, and help them pronounce each term in the vocabulary list. Ask students to skim the page and note the table on this page.

Explain

Studying the Living World

Objectives

- Describe how scientists name and classify living things.
- Explain the structure of scientific names.
- Describe the classification system used by scientists.

Set Goals

As they study this lesson, ask students to identify the main ideas and supporting details under each head and subhead.

Understand Visuals

How are these robins different from the common American robin? What could be some reasons these birds have the same common name? Find a picture of an American robin to show the students for comparison with the robins pictured in the text. Have the students research whether there are other robins in the world. Early American settlers saw an American bird that they thought resembled the robins from Great Britain.

Lesson 1

Essential Question

How Are Living Things Classified?

Objectives

- Describe how scientists name and classify living things.
- Explain the structure of scientific names.
- Describe the classification system used by scientists.

Vocabulary

common name
scientific name
species
binomial nomenclature
taxonomy
kingdom
domain

Look out a school window. Make a list of things you see. Which things are living, and which are nonliving? How are the living things—called organisms—alike? How are they different? What characteristics would you use to arrange these organisms into groups? To efficiently study the amazing variety of organisms on the planet, scientists have developed different ways to sort them into similar groups. How would this approach help scientists study and classify organisms? Using the characteristics that you just considered for the organisms outside, how would a lizard fit into the grouping? How would a cactus fit into the grouping? What about a blue whale or a paramecium? In this chapter, you will learn about the different considerations scientists use to group organisms and how science benefits from performing these organizational tasks on the diverse organisms that inhabit the planet.

Studying the Living World Explain

Where in a grocery store would you look for canned corn? Where would you look for fresh carrots? Items in grocery stores are sorted and grouped to make them easy to find. What difficulties would you have shopping in a grocery store where the items weren't sorted and grouped in a way that you understand?

Just as a store arranges similar items together, a system of classification places organisms into groups. These groups are based on similar characteristics. To form these groups, scientists study how organisms are structured and how they function. Scientists look at the following characteristics.

Classifying Organisms

Characteristic	Defining Question
Body type/Cell type	Is the organism single celled or multicellular?
Cell structure	Are the cells of the organism prokaryotic or eukaryotic?
Method of getting energy	Is the organism an autotroph or a heterotroph?

Science Background

The European robin (*Erithacus rubecula*) is a small bird with a red breast. Early American colonists thought that the bird that we now know as the American robin (*Turdus migratorius*) resembled this European bird, so they gave it the common name, robin. The American robin is much larger than the European robin. The American robin is a thrush, while the European robin is a flycatcher. Australian robins (family *Petroicidae*) belong to a third, very different bird family, although some of them, such as the scarlet robin (*Petroica multicolor*), also have red breasts.

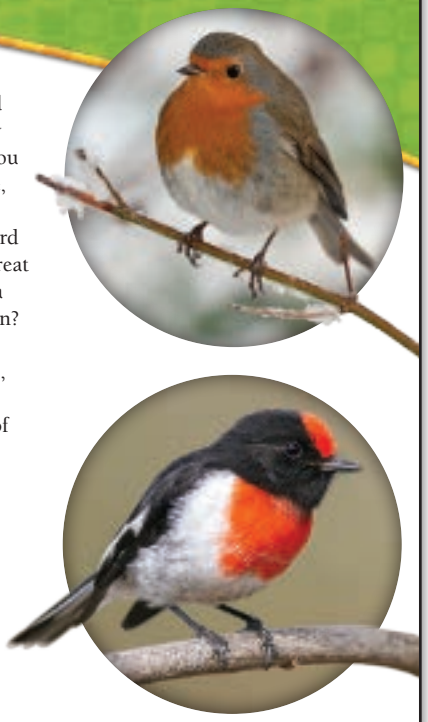
Naming Organisms

The Bible tells us in **Genesis 2:20** that Adam named all the animals at Creation. When speaking, we usually use a **common name** when describing living things. You may use common names to refer to a robin, an oak tree, or a deer. However, the same common name may mean different things to different people. For example, the bird that you call a robin is very different from a robin in Great Britain. In Australia, yet another kind of bird is called a robin. How can three different birds all be called a robin?

To avoid confusion, scientists give each kind of organism a unique, two-word Latin name. For example, the species known as the polar bear is named *Ursus maritimus*. The two-word name assigned to each kind of organism is referred to as its **scientific name**. The first word of a scientific name is the genus name. A *genus* (plural, *genera*) is a group of closely related species. The second word in the scientific name identifies the species. A **species** is a group of organisms that can mate to produce fertile offspring. The genus name of the polar bear is *Ursus,* and the species name is *maritimus*. A genus name is always capitalized, while the species name is always lowercase. Notice that a scientific name is always in italics. Scientific names are underlined if being handwritten. This two-part Latin naming system, called **binomial nomenclature**, is used to name all living things. Do you know the scientific name for humans?

A species is the narrowest category. A genus may contain several species. For example, the genus *Ursus* contains several species of bears. But only polar bears are given the scientific name *Ursus maritimus*.

Swedish naturalist Carolus Linnaeus developed this two-part Latin naming system in the 1750s. Scientists use Latin because it is standardized, consistent, and no longer changing. Why do you think Latin is no longer changing? What issues might occur by using a language that is still changing? People speaking any language can understand Latin scientific names. For example, a Spanish scientist, a French scientist, and a Russian scientist will each use the same Latin name for the same kind of organism. A Latin genus or species name often tells you something about the organism. For example, consider the species name for the polar bear, *maritimus*. What does this name suggest to you? Why do you think *maritimus* is a good species name for the polar bear? The binomial nomenclature for humans is *Homo sapien*. What is the meaning of the word *sapien*?



Each of these birds is called a robin. Yet they are different species.

How are these robins different from the common American robin? What could be some reasons these birds have the same common name?

Science and Technology

When Linnaeus set out to classify animals and determine the original "kinds" from **Genesis 1**, he looked mostly at easily visible characteristics, such as anatomy and behavior. As technology has developed, taxonomists have the tools to study molecular data from DNA to understand similarities and differences between organisms.

The focus of science on evolution has affected the way taxonomists classify organisms. Since the 1960s, they have focused on an evolutionary approach to understand how closely organisms are related to one another. For example, the five Kingdom classifications have resulted from the combined influences of technology and evolutionary theory. More details about these changes are found on page 20.

Develop Key Vocabulary

common name Ask students whether they have ever met someone who shares the same first and last names. **How does it feel to know that your name is not unique?** Sample answer: It is confusing because people mix us up. Explain that with common names for animals, this often occurs. Garden snake, gopher snake, and bull snake are all common names for *Pituophis catenifer*.

scientific name Help students distinguish *scientific name* from *common name*. Remind them that the scientific name always consists of two words. Point out that both parts are italicized, but only the first part is capitalized.

species Point out to students that this word is similar to the word *specific*, which means "one particular thing." A species is the narrowest and most specific taxonomic category. It consists of one particular kind of organism.

binomial nomenclature Tell students that the prefix *bi-* means "two." The word stem *-nomial* is taken from the Latin word for "name." The word *nomenclature* refers to a system of naming and is also based on the Latin word for "name."

Teach Science Concepts

How is it helpful when family members share a last name? It tells everyone that they are related. Provide the name of another bear species, such as *Ursus horribilis* (grizzly bear). Point out that members of the genus *Ursus* are related to one another. **How can you tell that *Ursus horribilis* is closely related to the polar bear?** It has the same genus name as the bear.

It is important to remember that classification can be significantly affected by worldview. Linnaeus did his classification work from a more biblical worldview, but modern taxonomists often interpret scientific data based on evolutionary assumptions.

Today, taxonomists arrange living organisms on a tree- or bush-like diagram that shows what they believe to be evolutionary relationships between animals. An organism and all its descendants are called a clade.

Discover

Use the inquiry activities as an opportunity for students to perform hands-on investigations and think like a scientist.

Structured Inquiry

Classifying Seeds

How do characteristics help you to classify seeds?

Preparation and Tips

Make a seed mix with at least 10 different kinds of seed packets or use a bag of 15-bean soup mix. Students do not have to identify or name the seeds, but they should observe such characteristics as size, shape, color, and mass.

Predict **How many different characteristics could you use to classify the seeds?**

Have students use their ***Science Journals*** to record their work for this inquiry.

Inquiry Practice Tip

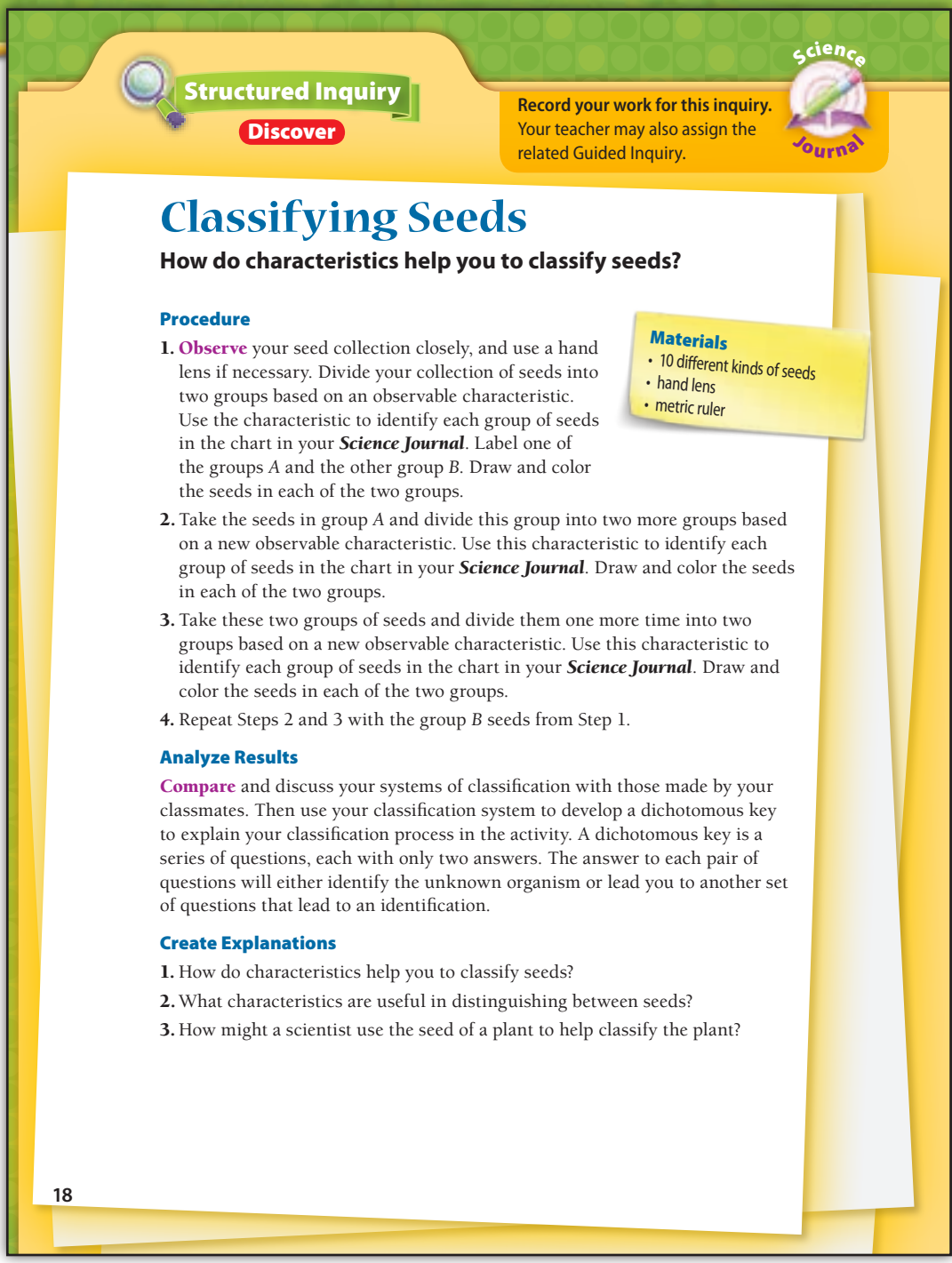
Classify Remind students that when they classify items, they are looking to group items with similar characteristics into a group.

Expected Results

All students should be able to find three different ways to classify seeds. However, some may come up with unexpected or novel ways to classify the seeds a second or third time. There is a sample key in the Grade 6 Unit 3 ***Science Journal*** on page 10.

Create Explanations

1. Answers will vary.
2. Sample answers: structure, size, germination patterns, seed coat, resistance to disease, or type of plant
3. Sample answer: The scientist could compare the seed size, shape, and structure with diagrams in a book to identify the plant.



Structured Inquiry
Discover

Record your work for this inquiry. Your teacher may also assign the related Guided Inquiry.

Science Journal

Classifying Seeds

How do characteristics help you to classify seeds?

Procedure

1. Observe your seed collection closely, and use a hand lens if necessary. Divide your collection of seeds into two groups based on an observable characteristic. Use the characteristic to identify each group of seeds in the chart in your *Science Journal*. Label one of the groups *A* and the other group *B*. Draw and color the seeds in each of the two groups.
2. Take the seeds in group *A* and divide this group into two more groups based on a new observable characteristic. Use this characteristic to identify each group of seeds in the chart in your *Science Journal*. Draw and color the seeds in each of the two groups.
3. Take these two groups of seeds and divide them one more time into two groups based on a new observable characteristic. Use this characteristic to identify each group of seeds in the chart in your *Science Journal*. Draw and color the seeds in each of the two groups.
4. Repeat Steps 2 and 3 with the group *B* seeds from Step 1.

Materials
- 10 different kinds of seeds
- hand lens
- metric ruler

Analyze Results

Compare and discuss your systems of classification with those made by your classmates. Then use your classification system to develop a dichotomous key to explain your classification process in the activity. A dichotomous key is a series of questions, each with only two answers. The answer to each pair of questions will either identify the unknown organism or lead you to another set of questions that lead to an identification.

Create Explanations

1. How do characteristics help you to classify seeds?
2. What characteristics are useful in distinguishing between seeds?
3. How might a scientist use the seed of a plant to help classify the plant?

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Inquiry Extension

Extend

Develop a Dichotomous Key

Guided Inquiry

How can you make a dichotomous key?

Extend the Structured Inquiry by having students develop a dichotomous key for the seeds they classified.

Teaching Tip Let pairs or small groups complete their keys. Then have each group share its keys with the class. Discuss how the questions asked helped students determine the identity of the seeds.

Students may record their work in their ***Science Journals***. A scoring rubric can be found as an ***Online Teacher Resource***.

Many species's names describe the region where the species lives, its color, size, or shape. The sugar maple, *Acer saccharum*, is the tree from which we get sweet-tasting maple syrup. *Saccharum* is the Latin word for sugar. Sometimes the species name includes the name of the scientist who first described it. In 2012, a new species of hermit crab, *Aeropaguristes tudgei,* was named after Dr. Christopher Tudge, the scientist who discovered it on the barrier reef off the coast of Belize. What does the name of the black bear, *Ursus americanus,* tell you about the species? What are the similarities between a black bear and a polar bear that group them into the same genus?

Scripture Spotlight

Names are important. The Bible says in **Isaiah 43:1** that God has redeemed us and calls us by name.

Classifying Organisms Explain

The science of classifying living things is called **taxonomy**. A *taxonomist* classifies living things by placing organisms into increasingly larger groups based on shared features. The smallest, or narrowest, classification category is a species. Similar species are grouped to form a genus. Similar genera form a family, while similar families make up an order. Taxonomists group similar orders to form a class and similar classes to form a phylum (plural, phyla). Similar phyla form a **kingdom**. Hamsters and other animals form the Animal kingdom. Plants make up the Plant kingdom. Fungi and organisms such as molds and mushrooms are placed in the Fungi kingdom. All living things are classified in the same way. Latin names are used throughout taxonomy. Why do you think taxonomists need to use the same type of classification? What might happen if taxonomists in the United States and Canada classified the groups differently?

Classification of a Dwarf Hamster

Taxonomic Group	Group Name	Group Members
Domain (largest group)	Eukarya	Eukaryotic organisms
Kingdom	Animalia	Animals
Phylum	Chordata	Animals with a nerve cord; many also have a backbone
Class	Mammalia	Animals with fur or hair; also produce milk to feed their young
Order	Rodentia	Mammals that are characterized by a single pair of continuously growing incisors in the upper and lower jaws that must be kept short by gnawing
Family	Cricetidae	Hamsters, including voles, lemmings, and New World rats and mice
Genus	*Phodopus*	A lineage of small hamsters native to central Asia that displays unusual adaptations to extreme temperatures
Species (smallest group)	*P. campbelli*	Hamster named for W.C. Campbell, who collected the first specimen

Scaffold Questions

Help students understand scientific nomenclature.

Approaching Level Write this sentence on the board: Dear King Philip Came Over For Good Spaghetti. **How could remembering this sentence be a useful memory tool?** It is a way to remember the sequence of taxonomic groups.

On Level With which taxonomic group would you place Eukarya, *Phodopus*, and *campbelli*? domain, genus, species

Above Level Have students complete a classification table like the one on this page for a species that is native to your area.

Explain *(cont.)*

Classifying Organisms

Objectives

- Describe how scientists name and classify living things.
- Describe the classification system used by scientists.

Develop Key Vocabulary

taxonomy Tell students that the word *taxonomy* is from the Greek words *taxis* ("arrangement") and *nomos* ("law").

kingdom Ask students what they think of when they hear the word *kingdom*. Have them explain why this is an appropriate word for the second-broadest taxonomic category after domain.

Teach Science Concepts

What is the broadest taxonomic group? domain **What is the narrowest taxonomic group?** species Have students use the Internet to identify an organism of their choice from domain to species.

Understand Visuals

Tell students that the table presents classification information from the largest category (top row) to the smallest category (bottom row). Point out the standard practice of using the first letter of the genus + period + the species when naming a species.

Have students help you draw a table on the board for a similar hierarchical situation in a local setting (for example, USA, state name, county name, city/ town/village name, neighborhood, street name, and so on).

Scripture Spotlight

Ask students whether any of them were named after a family member or someone their parents admired.

Explain *(cont.)*

Develop Key Vocabulary

domain A domain is something large and all-inclusive (for example, a territory ruled by a leader). Tell students that in science, the term refers to the largest classification category.

Teach Science Concepts

Evolutionary scientists try to determine who is most closely related to whom. These conclusions seem definite, but there is a lot of inference involved. For example, when they compare humans with chimps, the results are different depending on what data they look at. All options contain homoplasies (out of sequence characters), and they just pick the option with the fewest homoplasies. Creation scientists view these similarities between species as evidence of a single Designer who reused some elements of a design.

Understand Visuals

In which domain do humans belong? Why? Eukarya Humans are multicellular organisms composed of eukaryotic cells.

Incorporate Inquiry Practice

Practice: Sequence Give eight index cards to each pair of students. Ask them to write the name of one taxonomic group on each card, beginning with domain. Have each partner take turns shuffling the eight cards and putting them in the correct sequence.

Classifications May Change

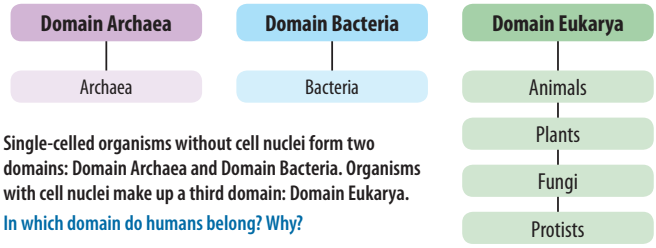
Objective

- Describe the classification system used by scientists.

Domains

A discovery in the 1970s made scientists rethink the use of kingdom as the largest taxonomic category. Research revealed new differences in cell structure and DNA among all of the kingdoms. Scientists found a unique group of organisms called *archaea*. Like bacteria, they are single celled and lack nuclei. However, their cell walls are not made from the same substance as those of bacteria. Also, their DNA structure is similar to that of eukaryotes, not bacteria.

Scientists decided to place the archaea into a new category. They developed a new taxonomic category called a domain. A **domain** is a taxonomic category above the kingdom level. There are three domains: Archaea, Bacteria, and Eukarya.



Single-celled organisms without cell nuclei form two domains: Domain Archaea and Domain Bacteria. Organisms with cell nuclei make up a third domain: Domain Eukarya.

In which domain do humans belong? Why?

Classifications May Change Explain

Compare pictures of a shark and a dolphin. How are they alike? How are they different? How do scientists classify the two animals? Sometimes organisms that look similar are not as alike as they may seem. Can you think of other animals or plants that look similar but aren't classified in the same group?

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Science Background

Classification of living things has changed a lot over the centuries.

1735—two kingdoms: Plants and Animals

1860—three kingdoms: Plants, Animals, and Protists (Protists are all unicellular.)

1938—four kingdoms: Plants, Animals, Protists, and Monera (Monera are all prokaryotes.)

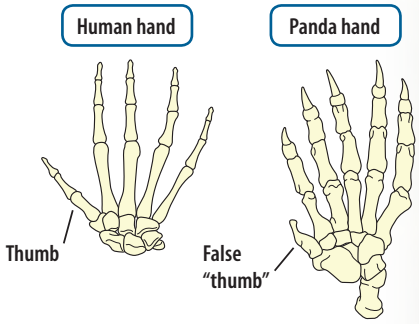
1969—five kingdoms: Plants, Animals, Protists, Monera, Fungi (Fungi were separated from Plants because of how they eat.)

1977—six kingdoms: Plants, Animals, Protists, Bacteria, Archaea, and Fungi (Monera was split into Bacteria and Archaea.)

1990— new three-domain system proposed

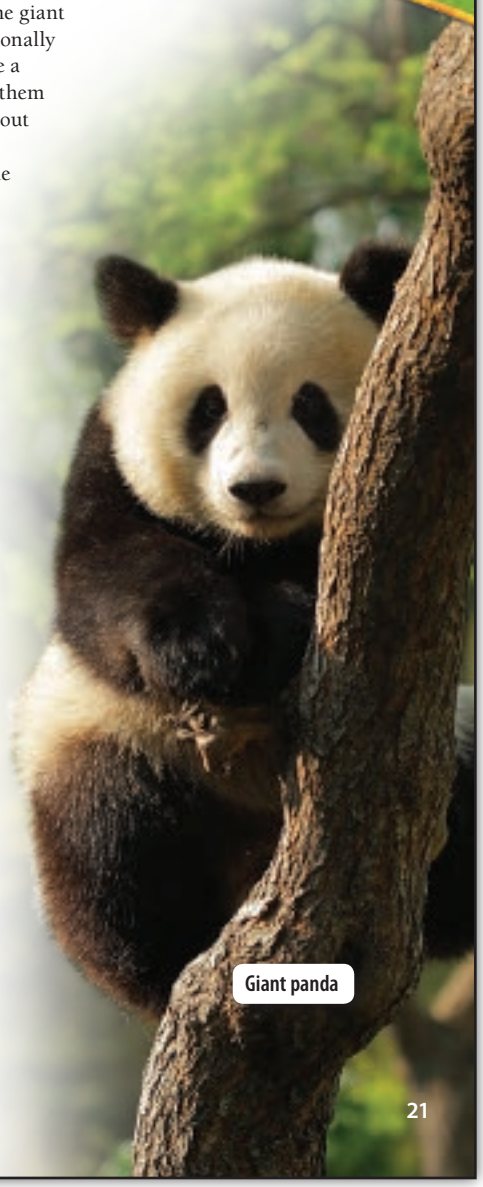
Animals we know as bears are species in the bear family (family Ursidae). The bear family includes the black bear, brown bear, and polar bear. How about pandas? Unlike other bears, the red panda and the giant panda feed primarily on bamboo, but they occasionally eat other plants and even meat. Both species have a small, bony projection on their wrists that helps them grip bamboo stalks. Try to grasp something without using your thumb. Then pick up the same object using your thumb. How does having an opposable thumb help you pick up things?

The giant panda looks more like a bear than the red panda. The red panda shares some characteristics of raccoons. As a result, scientists have debated their classification. After studying the DNA of pandas, scientists learned new information. They discovered that the giant panda is more similar to a bear than to the red panda. Today the giant panda is usually classified as a member of the bear family. What characteristics does the giant panda share with other bears? Many taxonomists classify the red panda, however, in its own family.



The false thumb allows pandas to grip bamboo stalks.

How are the panda's unique wrist bones similar to a human's thumb?



Teach Science Concepts

How are giant pandas and red pandas similar? Both eat bamboo, other plants, and sometimes meat. Both have bony projections on their wrists that work like thumbs.

Ask students to discuss the information on this page and compare and contrast the red panda with other bears and with the giant panda. Would you place the red panda in its own family? Why or why not? Answers will vary but should be based on the evidence presented in this lesson.

Understand Visuals

Can scientists know how to classify an animal just by looking at it? No, they also need to study the animal's DNA.

How are the panda's unique wrist bones similar to a human's thumb? The panda's wrist bone helps the panda grip things like the thumb helps a person hold on to things.

Science Background

Classification Systems Advances in technology as well as the influence of evolution on taxonomy have influenced many of the changes to the system of classification. As they evaluate the scientific data, taxonomists arrange living organisms on clades, tree- or bush-like diagrams that show what they believe to be their evolutionary relationships. In addition to differences discovered between bacteria and archaea, the inference that they belong in different clades (in other words, they have different evolutionary histories) was influential in the decision to separate them into different kingdoms. An important concept to understand is that conclusions about classification can be significantly affected by worldview. Linnaeus did his classification work from a more biblical worldview, but modern taxonomists often interpret scientific data based on evolutionary assumptions.

Explain *(cont.)*

Finding New Species

Objective

- Describe how scientists name and classify living things.

Teach Science Concepts

Do you think a rare species should be protected? Why? Point out to students that every species has an intrinsic right to exist. All species are a vital part of the web of life, and eliminating an organism may have unintended consequences. For example, some species might contain substances that could help researchers produce new, potentially lifesaving drugs for humans. Remind students that once a species is extinct, it is gone forever.

Understand Visuals

Direct student attention to the photo of the recently discovered species.

What are some examples of human activities that could threaten this newly found species? Sample answer: Development by humans can reduce or eliminate habitat for many rare species.

Faith Connection

Scientists continue to find new species of animals in modern times. What does this tell you about God's Creation? Sample answer: God's Creation is so vast that we still continue to learn new things about it.

Math in Science

The percentage of known species that are invertebrates is approximately 87%. Scientists cannot say definitively how many animal species there are because they have not all been discovered.

Finding New Species Explain

Faith Connection

Scientists continue to find new species of animals in modern times. What does this tell you about God's Creation?

Scientists continue to find new species in remote areas that have not been previously explored. Off the coast of Indonesia in 2013, scientists researching the coral reef discovered a new type of shark. This unique species of epaulette shark, now named *Hemiscyllium halmahera*, frequents the shallow waters near large coral reefs and tide pools. Like many epaulette sharks, this shark has small fins on the bottom of its body that it uses to wriggle from side to side to move along the ocean floor. For this reason, it is often called a "walking shark." This new species of shark can grow to be 70 cm long and is covered in large, dark spots or wide, dark stripes. How do you think such a large animal remained hidden for so long?

In 2010, researchers working in Madagascar identified a new species, Durrell's vontsira (*Salanoia durreli*). Scientists think this small, ferret-like animal is the first new meat-eating species seen in more than 25 years. It was first spotted swimming in Madagascar's Lac Alaotra in 2004. Since 2004, scientists have spotted just four Durrell's vontsiras. Two were captured briefly, while another two have only been photographed. Why do you think the two were captured and then released? How do you think new, rare species should be handled? Should they be captured, or should they live in the wild? Why do you think this?

Newly discovered species are often few in number. Many are at risk of extinction because the areas where they live are being threatened by development. Biologists explore these areas, hoping to identify new species before their habitats are destroyed so that they can protect the animal and its habitat.

Epaulette sharks feed on small fish and crustaceans that live on coral reefs.

What are some examples of human activities that could threaten this newly found species?

Math in Science

There are more than 1.5 million identified species of animals. More than 1.3 million of these are known species of invertebrates. What percentage of animals are invertebrates? Why are scientists unable to say definitively how many species of animals there are?

English Language Learners

Language Development Use a listen-and-repeat strategy to help students with the pronunciation of terms in this lesson. Write the following words on the board. Then read aloud each of the words. Have students listen closely as you say each word. They should then repeat each word after you. Then randomly point to words in the list and have students say them. Correct pronunciations as needed and repeat until all students are pronouncing them correctly.

binomial (bī-'nō-mē-əl)

nomenclature ('nō-mən-'klā-chər)

taxonomy (tak-'sä-nə-mē)

genus ('jē-nəs)

genera ('jen-ər-ə)

species ('spē-sēz)

Lesson Activity

Use the Internet or other resources to learn about one of the organisms listed below or another organism discovered since 2000. Create a display that includes a picture of the organism; its scientific name; when, where, and how it was discovered; and who discovered it. Present your poster to the class.

- Cypriot mouse
- Walter's duiker
- walking shark
- Darwin's bark spider
- Olinguito
- red-bearded titi
- Pinocchio frog
- Cambodian tailorbird
- Hero shrew
- legless lizard
- epaulette shark

What organisms have been discovered recently?

Concept Check Assess/Reflect

Summary: How are living things classified? Scientists classify living things by shared characteristics. They name living things using a two-part system developed by Carolus Linnaeus that uses Latin. The first part of an organism's scientific name is the genus to which the organism belongs. The first letter of the genus name is capitalized. The second part of the scientific name identifies the species and is lowercased. An organism's scientific name is italicized in type and underlined when handwritten. The classification system used by taxonomists becomes more precise from the largest to the smallest group. The system progresses from domain to kingdom, to phylum, to class, to order, to family, to genus, and to species.

1. Why is it necessary for scientists to use scientific names rather than common names when describing an organism?
2. Classify the following animals into four groups based on their similarities: gorilla, butterfly, chimpanzee, lobster, mosquito, mouse, wasp, crayfish, lobster, chipmunk, and crab. Describe the characteristics that you used to group the organisms.
3. Life scientists estimate that millions of living species are undiscovered. What might be some reasons so many species are undiscovered?
4. How can new information about DNA help taxonomists?

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Science and Technology

Remote Discovery When wildlife photographer Hock Ping Guek first photographed an insect called a lacewing on May 10, 2011, he had no idea what would follow. He uploaded his photos to an Internet-sharing site. A California entomologist, Shaun Winterton, was examining photos of insects on the same website. He noticed the lacewing had an unfamiliar black-and-blue pattern on its wings. When no colleagues could identify it, he emailed the photographer that it was a new species. However, the photographer did not have an actual specimen. Luckily, Guek found and captured a specimen in January 2012. Guek then contacted Winterton and handed the specimen over to Steve Brooks, another entomologist, at the London Natural History Museum. The men have now been credited with discovering a new species: *Semachrysa jade*, named for Winterton's daughter.

Teach Science Concepts

Why are newly discovered species often few in number? These species are often in remote locations that are infrequently visited. Also, there may be little of their natural habitat remaining for them to live in.

Lesson Activity

What organisms have been discovered recently? Sample answer: legless lizard, walking shark. You may want to allow students a class period to work on this activity, or you may wish to assign it as homework. You may allow students to choose a different type of visual display.

Assess/Reflect

Read the essential question and lesson summary with students. You may work through the concept check as a class or use it as a formal assessment option.

Concept Check

1. Scientists use scientific names to avoid confusion since there is only one scientific name for an organism, but there may be many common names for that same organism in different languages.
2. Sample answers: The gorilla and chimpanzee are both animals that can walk in a semi-upright position. The mouse and chipmunk are animals but can only walk/run on all four feet. The butterfly, mosquito, and wasp are all flying insects. The crayfish, lobster, and crab are all animals that have bodies covered by shells.
3. Sample answers: Many species are still unknown because they live in remote areas of the oceans and land areas. Many species are probably microscopic and are easily overlooked. There probably are too few scientists who are actively searching for new species.
4. New information about DNA can help taxonomists by allowing them to better understand similarities and differences between organisms.

Lesson 2

Essential Question

What Are Bacteria?

Preview Lesson Content

Read the objectives with students, and help them pronounce each term in the vocabulary list. Ask students what they already know about bacteria. Make a list of the facts and ideas to be updated as the lesson continues.

Explain

Characteristics of Bacteria

Objectives

- Identify characteristics and structures of bacteria.
- Describe the growth of bacteria.

Set Goals

As they study this lesson, ask students to identify the main ideas and supporting details.

Develop Key Vocabulary

microorganisms Tell students that the prefix *micro-* means "small." Microorganisms are so small that most cannot be seen without a microscope.

Understand Visuals

What could happen if bacteria got into your food? How can you prevent that from happening? Sample answer: The bacteria could grow and cause you to become sick when you ate the food. To keep that from happening, wash hands well after using the bathroom and before food preparation and keep perishable food well refrigerated.

Lesson 2

Essential Question

What Are Bacteria?

Objectives

- Identify characteristics and structures of bacteria.
- Describe the growth of bacteria.
- Describe the types of bacteria.
- Describe diseases caused by bacteria.
- Summarize the roles of bacteria.

Vocabulary

microorganism
autotroph
heterotroph
binary fission
aerobic bacteria
anaerobic bacteria
antibiotic

Did you know that bacteria (singular bacterium) are the most abundant organisms on Earth? Bacteria are microscopic organisms found in almost every environment on Earth, no matter how extreme. Bacteria have been found on the bottom of the ocean floor, in volcanoes, at the poles, and even in your intestinal tract. Did you know that there are 10 times more bacteria cells living in your body than there are human cells? What other places do you think you could find bacteria if you were looking through a microscope? How can bacteria survive in such diverse environments?

Characteristics of Bacteria Explain

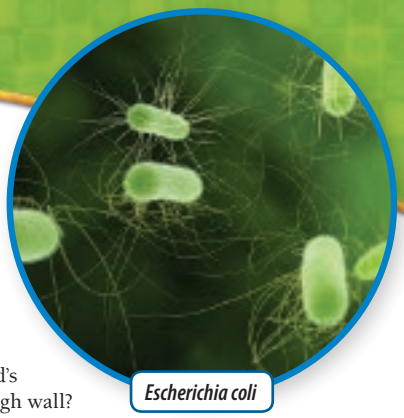
Have you ever gone to the doctor and been told that you have a bacterial infection? Bacteria are **microorganisms**, organisms too small to see without magnification. Bacteria can thrive almost anywhere. What precautions can you take to prevent infections? In what areas of your home are these precautions most important to take? Most of us think of bacteria as tiny, single-celled organisms that cause disease. Because bacteria are small, it is tempting to think of them as simple. Bacteria are more complex and varied than you might think, and not all bacteria are bad for humans. Can you think of any useful bacteria? What are some useful bacteria you have heard of?

What could happen if bacteria got into your food? How can you prevent that from happening?

Science Background

Harmless strains of *E. coli* live in human intestines, where they help our body break down the food we eat as well as assist with waste processing, vitamin K production, and food absorption. However, the presence of other strains of *E. coli* (*Escherichia coli* O157:H7 and others) in food can cause serious gastrointestinal illness. Common food sources include undercooked beef (especially ground beef), unpasteurized milk and fruit juices, dry-cured salami, alfalfa sprouts, contaminated water, and raw fruits and vegetables. Illness begins within 12–72 hours after eating or drinking a contaminated food or beverage. Symptoms of *E. coli* infection include watery or bloody diarrhea, abdominal cramps, and, in some cases, acute kidney failure. Treatment includes fluid replacement, although drugs may also be needed. Proper cooking of meat and washing of produce can reduce the chance of infection.

Bacteria are prokaryotes. Recall that a *prokaryote* is a single-celled microorganism that does not have a nucleus or membrane-bound organelles. As you know, *eukaryotes* have cells that have nuclei surrounded by a nuclear membrane. Bacteria are smaller than many eukaryotic cells. Like plants and fungi, bacteria have cell walls. But how are bacterial cell walls different? They contain *peptidoglycan*, a tough compound made of sugars and protein woven together, which is evidence of its complexity and God's Design. Why do you think a bacteria cell needs a tough wall?



Escherichia coli

The bacterium *Escherichia coli* (better known as *E. coli*) normally lives in the lower intestines of people and other warm-blooded animals.

Why would the presence of *E. coli* in food be a concern?

Food Sources

Recall that organisms that can make their own food are called **autotrophs**, or *producers*. These organisms make their own food using energy from sunlight or from inorganic compounds. Photosynthesis is the process by which autotrophic organisms harvest sunlight to produce energy. Some bacteria, called *cyanobacteria*, are photosynthetic. These bacteria have substances called *pigments* that capture sunlight. Chemosynthesis is the process by which autotrophic organisms harvest energy from chemicals in the environment. The bacteria in the soil that convert nitrogen compounds into a form that plants can use are chemosynthetic bacteria.

Organisms that cannot make their own food must obtain energy from other sources. They are called **heterotrophs**, or *consumers*. Most bacteria are heterotrophs. Heterotrophic bacteria obtain energy in many different ways. Some obtain nourishment from dead organisms. Other bacteria get nutrients from another living organism, called a *host*. These bacteria, called *parasites*, can cause disease as they feed on their hosts. What are examples of parasites? Most strains of *E. coli* bacteria are harmless heterotrophs. However, some strains can cause serious food poisoning in humans.

Reproduction

Bacteria usually reproduce asexually by **binary fission**, a form of reproduction common in single-celled organisms. During binary fission, a single cell first grows in size. Then it divides to form two cells of the same size. Binary fission is considered asexual reproduction because a single parent cell produces offspring that are identical to the parent cell. This type of reproduction allows bacteria to grow quickly in number. Under ideal conditions, a single bacterium can divide roughly every 20 minutes. How long do you think it would take one bacterium to grow to one million? What factors might affect how quickly a bacterium cell grows?

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Science Background

Bacteria Bacteria do not have mouths for eating. They produce food-cutting enzymes that pass through their cell walls. The enzymes break down food into tiny units that need one molecule of water. The water carries the nutrients back into the bacteria through cell walls. We have billions of bacteria in our bodies, and they eat the same things we do. There are 500 types of bacteria living in our mouths. What they really like to eat is candy. Bacteria take in sugar and produce acid waste, which causes cavities in teeth. Bacteria in our intestines eat nutrients from the food we digest. There are millions of different bacteria. Bacteria that live in water may make their own food from sunshine, just like plants. Some may eat iron or sulfur. Other bacteria turn milk into cheese as they eat milk protein.

Teach Science Concepts

As the information on the structure of prokaryotes is review material, an image of an example pointing out the lack of a nucleus and membrane-bound organelles can be helpful for student understanding.

Understand Visuals

About 100 *E. coli* cells lined up end to end span the width of a single human cell.

Why would the presence of *E. coli* in food be a concern? Since *E. coli* normally lives in animal intestines, the presence of *E. coli* in food is a likely sign that it has been contaminated with animal waste.

Develop Key Vocabulary

autotroph The Greek words *auto* and *trophe* mean "self" and "nutrition," respectively. Autotrophs are organisms that make their own food.

heterotroph Tell students that the prefix *hetero-* means "different." The root *troph* means "feeder." Heterotrophs get their food from other organisms.

binary fission Students encountered the prefix *bi-* in the term *binomial nomenclature*, which they learned in Lesson 1. Ask students to recall its meaning ("two"). Remind them that during *binary fission*, one cell makes two cells.

Incorporate Inquiry Practice

Practice: Communicate Have students separate into three groups. Assign each group one of the following photosynthetic pigments: chlorophylls, carotenoids, or phycobilins. Each group should research the chemistry of the pigment and how plants use it during photosynthesis. In addition, the students should list several examples of plants, bacteria, etc. that use the particular pigment. At the end of the activity, gather as a class and have each group share what they learned with the class.

Discover

Use the inquiry activities as an opportunity for students to perform hands-on investigations and think like a scientist.

Structured Inquiry

Bacterial Growth Rates

Where do bacteria grow at school?

Preparation and Tips

Use pre-poured nutrient agar plates. Do not allow students to open the dishes once they are sealed. In Step 6, leave some Petri dishes in a sealed container at room temperature and others in a closed ice chest.

Predict **Which of the test sites will have the most bacteria?**

Have students use their ***Science Journals*** to record their work for this inquiry.

Inquiry Practice Tip

Compare Invite students to devise quantitative ways of comparing bacterial growth.

Expected Results

The amount of bacteria on different school surfaces will vary. Samples from high-traffic areas will often show the most bacterial growth. Students should find that warmer temperatures and longer time produce greater bacterial growth rates.

Create Explanations

1. Answers will vary depending on where swabs were taken.
2. Answers will vary.
3. Sample answer: Longer time and warmer temperatures increased bacterial growth.

Structured Inquiry
Discover

Record your work for this inquiry. Your teacher may also assign the related Guided Inquiry.

Science Journal

Bacterial Growth Rates

Where do bacteria grow at school?

Procedure

1. Working with a partner, obtain four Petri dishes from your teacher. Do not open your dishes until you are told to do so. Use a wax pencil or permanent marker to write your team's name on the top of the dishes.
2. Select three school locations to test for the presence of bacteria. Write the name of each location on one of your Petri dishes. **Record** the locations in your ***Science Journal***. Write *Control* on the remaining Petri dish.
3. Moisten a sterile cotton swab with distilled water. Wipe the swab against the surface of the first location that you are testing. Open the dish and gently rub the swab across the agar on the appropriate side of the dish. Place a piece of tape on each side of the Petri dish to attach the top of the dish to the bottom.
4. Repeat Step 3 using a new cotton swab at a second and third location. Be sure to use a clean cotton swab for each sampling.
5. Store your dishes as directed by your teacher. **Observe** your dishes and those of other groups after 24 hours. **Compare** growth rates for different areas. **Record** what you see in your ***Science Journal***.
6. Return the Petri dish to your teacher. After another 24 hours, observe how the bacterial colonies changed. Record what you see in your ***Science Journal***.

Materials
- safety goggles
- lab apron
- disposable gloves
- 4 Petri dishes with nutrient agar
- wax pencil or permanent marker
- water, sterile distilled
- sterile cotton swabs
- tape

Analyze Results

Bacterial growth will appear as shiny, round dots on the agar. **Display your data** for each location in a table summarizing your findings.

Create Explanations

1. Where do bacteria grow at school?
2. Which of the locations produced the greatest amount of bacteria?
3. How did the growth of bacteria change over time? What factors affected the rate of growth of your samples?

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Inquiry Extension

Extend

Guided Inquiry

Antibacterial Soaps

How do antibacterial soaps affect the growth of bacteria?

Extend this inquiry by asking students to design an experiment to test the effectiveness of one or more antibacterial soaps on bacterial growth.

Teaching Tip Tell students that they will need to determine how to compare and measure the effects of the different soap products. Remind them to include control dishes against which to measure the effect of the soap products on bacterial growth.

Students may record their work in their ***Science Journals***. A scoring rubric can be found as an ***Online Teacher Resource***.

Kinds of Bacteria Explain

Why are bacteria so widespread? Bacteria are adapted to live in many different conditions. **Aerobic bacteria** are bacteria that require oxygen for growth. **Anaerobic bacteria** grow only in the absence of oxygen. Some bacteria live at temperatures just above freezing, while others do well at temperatures near boiling. Other bacteria have adapted for living in the bodies of animals, including humans. These bacteria can thrive only at specific body temperatures.

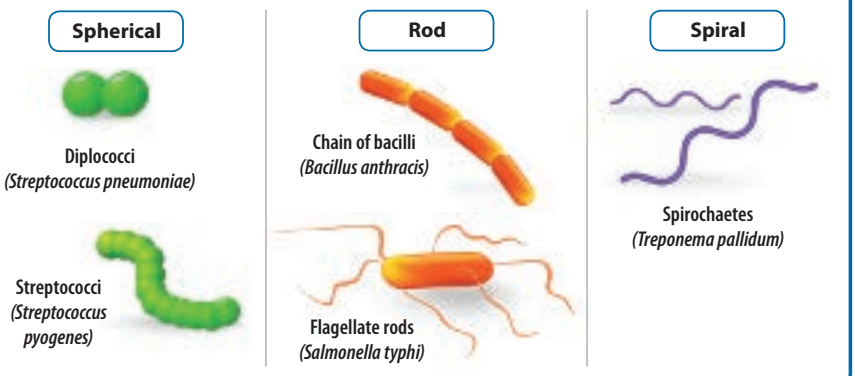
Most bacteria are one of three shapes: spherical, rod, or spiral. Scientists use special stains to make bacteria visible. When a scientist studies an unknown bacterium under the microscope, the shape is the first clue to its identity.

The bacterial cell wall offers a second clue. Scientists classify most bacteria into two groups based on composition of the cell wall. The researchers use a technique called Gram staining, which reveals differences in cell wall structure. How does Gram staining work? The Gram staining procedure distinguishes between Gram-positive and Gram-negative groups by coloring the cells red or violet. Gram-positive bacteria stain violet due to the presence of a thick layer of peptidoglycan in the cell walls. This molecule retains the crystal violet that stains these cells. However, Gram-negative bacteria have a thinner peptidoglycan wall. The thinner wall does not retain the crystal violet stain, producing a red color. What challenges would scientists have if they didn't use Gram staining? How do you think scientists first discovered the unique chemical nature of bacterial cell walls?

Scripture Spotlight

Why do you think that, in **Numbers 19:15**, God said that any open vessel would be unclean?

Different Shapes of Bacteria



English Language Learners

Assist with Comprehension Point out the text features that emphasize comparison, such as the figure comparing the three shapes of bacteria. Have students draw and label a bacterium of each shape (spherical, rod, and spiral). Provide students with pink or red and purple colored pencils. Have them write "Gram-negative" next to a bacterium and color it pink or red. Then ask students to write "Gram-positive" next to a second bacterium and color it purple. Tell students that Gram in "Gram-staining" is capitalized because a Danish physician, Hans Christian Gram, invented it in 1884.

Develop Vocabulary Explain that the singular for *bacteria* is *bacterium*.

Explain *(cont.)*

Kinds of Bacteria

Objective

- Describe the types of bacteria.

Develop Key Vocabulary

aerobic bacteria Ask students what aerobic exercise is. It is exercise that requires oxygen. The word *aerobic* comes from the Greek words *aer*, which means "air," and *bios*, which means "life."

anaerobic bacteria The prefix *an-* means "without," so anaerobic means "without oxygen."

Teach Science Concepts

If possible, obtain slides showing Gram-stained cells. Allow students to observe the two different stains. If slides are not available, images could be found on the Internet.

Understand Visuals

As students study the visual that shows the shapes of bacteria, explain that bacteria can also be in the shapes of triangles, curves, points, tears, or dozens of other forms. Shape relates to a bacterium's function and changes as functions change. The bacterium *Legionella pneumophila* changes its shape eight times through its developmental cycle. For *E. coli* bacteria, shape changes as infection progresses. Scientists think shape is part of bacteria's survival and why antibiotics become less effective.

Scripture Spotlight

Why do you think that, in Numbers 19:15, God said that any open vessel would be unclean? Remind students of the conditions the Israelites were traveling in. Many of the rules given to them were to protect them from disease while they were in the desert. The rules extended to how to deal with the deceased. This passage deals with a tent being unclean because someone has just died in it. Ask students to think about how an open water vessel would be more likely to become contaminated than one with a covering.

Explain *(cont.)*

Develop Key Vocabulary

antibiotic The word comes from two word parts. *Anti-* means "against" as in *antisocial*. The rest of the word comes from the Greek *biotikos*, which means "fit for life." A microbiologist named Selman Waksman first used the term in 1947 for drugs or chemicals such as penicillin and streptomycin that inhibit the growth of bacteria.

Roles of Bacteria

Objectives

- Describe disease caused by bacteria.
- Summarize the roles of bacteria.

Teach Science Concepts

Have students scan the page. **What are three roles of bacteria?** Bacteria can be nutrient recyclers; bacteria have commercial uses; bacteria can cause diseases. Explain that some bacteria are photosynthetic. **What is required for photosynthesis?** light energy, carbon dioxide, and water **What are the products of photosynthesis?** sugars and oxygen

Lesson Activity

To prepare for this activity on page 29, purchase unflavored yogurt. The label should state that it contains live cultures and should identify the name of the culture.

Which brands of yogurt list the scientific names of bacteria? What species of bacteria are listed? Answers will vary depending on the brands of yogurt purchased.

Because of their outer membrane, gram-negative bacteria are often more resistant to host defenses. They are also harder to kill with antibiotics. An **antibiotic** is a drug that can kill bacteria in the body. Different antibiotics kill bacteria in different ways. Many antibiotics, such as penicillin, stop bacteria from dividing. They do this by interfering with the peptidoglycan in the cell wall. Human cells do not contain peptidoglycan, so antibiotics do not stop human cells from dividing. Why is it important for a doctor to know the species of bacteria causing an illness before prescribing an antibiotic? Why might a doctor want to confirm that bacteria cause an illness before prescribing an antibiotic? Antibiotics are not effective on viruses. Why do you think this is so?

Roles of Bacteria Explain

Bacteria are vital organisms in all ecosystems. Did you know that some bacteria in the human body keep our immune systems healthy? Other bacteria produce chemicals that help harness energy in our food. What other vital functions do bacteria perform?

Bacteria as Nutrient Recyclers

Perhaps the most important function of bacteria is to serve as Earth's natural recyclers. Many kinds of bacteria decompose, or break down, dead organisms and waste products. This decomposition releases carbon, nitrogen, and other elements back into the environment. Other living things will use these elements again. Without the actions of decomposers, these elements would remain locked up and unavailable. What other problems would result if there were no decomposers?

Photosynthetic bacteria use light energy to make sugars, releasing oxygen needed by other living things. Some kinds of bacteria capture, or fix, atmospheric nitrogen. These nitrogen-fixing bacteria change nitrogen into forms that plants can use. Bacteria are very important partners in the ecology of all of the places where they live.

Bacteria have been found deep in the ocean. Here, they harness compounds such as hydrogen sulfide to generate energy. This energy supports all of the other organisms in the area. Chemosynthetic bacteria living inside tubeworms get energy from chemicals released in the hot water of hydrothermal vents. The tubeworm protects the bacteria, and the bacteria provide a food source for the tubeworms. Some of these bacteria are decomposers, which provide the same function as they do on land. What would happen if the source of hydrogen sulfide disappeared from a tubeworm community?

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Scaffold Questions

Approaching Level **How do bacterial decomposers benefit the environment?** They release various elements that are needed by living things that would remain locked up in dead bodies or in wastes that would otherwise accumulate in the environment.

On Level **What functions do bacteria perform in ecosystems?** Sample answer: In addition to recycling nutrients, certain bacteria are producers that change sunlight and chemical compounds found in ocean water into food.

Above Level **Why is it important to know the species of bacteria before prescribing treatments?** Certain bacteria are resistant to some drugs. The drug may not be adequate, or effective, on the strain involved and can contribute to antibiotic resistance.

Lesson Activity

Observe the labels of several yogurt brands. Look for the words *live and active cultures*. These words refer to the living bacteria, *Lactobacillus bulgaricus* and *Streptococcus thermophilus,* that form yogurt. These bacteria convert pasteurized milk to yogurt during fermentation. Compare three or more brands of yogurt. Read the yogurt labels. Gather and record data that identifies the names of bacteria.

Which brands of yogurt list the scientific names of bacteria? What species of bacteria are listed?

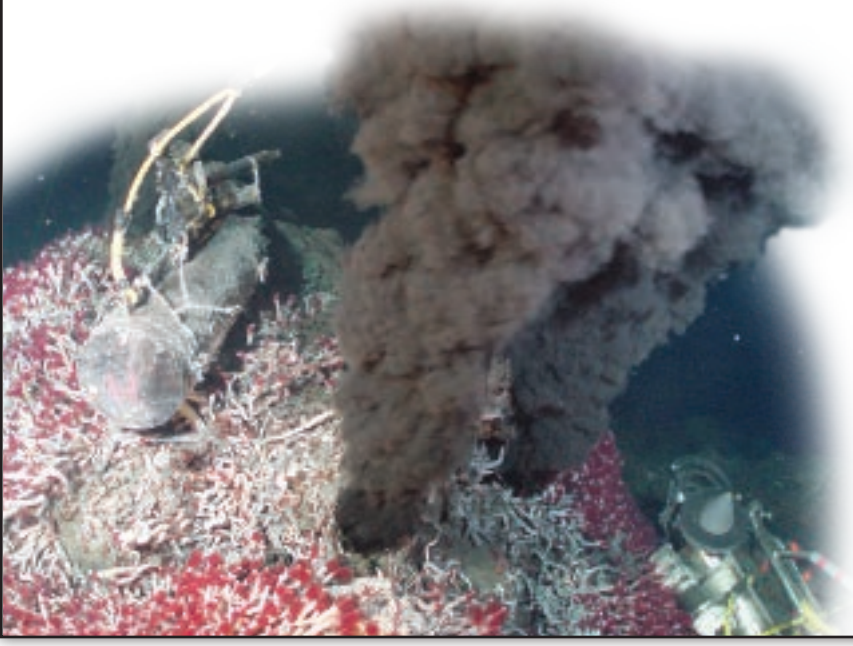
Commercial Uses of Bacteria

Did you eat yogurt, cheese, pickles, buttermilk, or sour cream today? Bacteria contribute to the production of these and many other foods. Dairy foods such as yogurt and many cheeses are made when bacteria break down the lactose in milk, producing lactic acid. Other kinds of bacteria are used in industry to make substances such as acetone or vinegar. Some bacteria can even digest the petroleum released during oil spills.

Science Journal

Check out your ***Science Journal*** for a Guided Inquiry that explores how to test homemade yogurt for live bacteria.

Extend



Tubeworms, the red and white structures in the picture, live near hydrothermal vents deep in the ocean. They contain chemosynthetic bacteria that support these unique ecosystems.

Science Background

Chemosynthetic Bacteria Chemosynthesis is the conversion of chemical energy to produce food. Although photosynthesis depends on light, chemosynthesis can take place in total darkness. It is the way organisms living beside hydrothermal vents on ocean floors survive. Most organisms cannot survive being close to such toxic, acidic liquid, but some bacteria thrive in this environment. The bacteria are the primary food source for snails, clams, mussels, and tube worms. Millions of bacteria live within a single tube worm, converting chemicals to food and excreting nutrients that help tube worms grow up to ten meters a year.

Extend

Use the inquiry activities as an opportunity for students to perform hands-on investigations and think like a scientist.

Structured Inquiry

Making Yogurt

How can you prove that homemade yogurt contains live bacteria?

Preparation and Tips

Use cultures from different yogurt flavors or brands to see whether differences occur. The yogurt should have the *Live and Active Cultures* seal to indicate it contains living bacteria. Milk substitutes, such as heavy cream, infant formula, or lactose-free milk, may be used.

Predict **How does yogurt bacteria change milk?**

Science Journal

Have students use their ***Science Journals*** to record their work for this inquiry.

Inquiry Practice Tip

Control Variables A steady temperature should be maintained in the coolers.

Expected Results

The milk cup will look and smell like rotten milk over time. The other cups won't smell rotten; they will appear yogurty. The powdered milk mix will have a thicker consistency than the cup with milk and yogurt.

Create Explanations

1. Sample answer: Bacteria create lactic acid, keeping the milk from smelling rotten.
2. The warmth helps the bacteria work at their peak performance.
3. Sample answer: Skim milk will also work because bacteria act on lactose, not fat.

Explain *(cont.)*

Teach Science Concepts

Many students will have heard stories about bacterial diseases on a local, national, or global level. Others may have personal experiences involving friends or families. **How can people reduce their chances of becoming ill with a bacterial disease?** Answers will vary. Sample answers: frequent hand washing; choosing foods carefully; washing produce well; avoiding foods that have been improperly stored; maintaining a healthy immune system; taking care to avoid ticks if you live in an area where Lyme disease is prevalent

Incorporate Inquiry Practice

Practice: Compare Explain that a table makes it easy to compare data at a glance. **What kinds of data are shown in this table?** name of disease, area of the body affected, mode of transmission **How many of these diseases affect the intestines?** three **Which bacterial disease does an animal transmit?** Lyme disease **Which disease do bacteria in air droplets transmit?** tuberculosis

Focus on Health

Since the 1980s, a multidrug therapy approach has been used to treat leprosy successfully. Modern medicine has also greatly reduced tuberculosis, cholera, and botulism.

Lifestyle Challenge

Encourage students to continue their Lifestyle Challenge. Remind them to record their progress and think about how a healthful lifestyle honors God.

Reminder

Focus on Health

Leprosy is a bacterial disease that was common in Bible times. Why is leprosy not a huge concern in most parts of the world today? What other bacterial infections has modern medicine all but eliminated?

Harmful Bacteria

Bacteria can sometimes cause disease in humans and other organisms. Recall that a disease-causing organism is called a pathogen. Bacterial diseases can be transmitted in the air, in water, or in food. Each kind of pathogenic bacteria is transmitted in a characteristic way. Some pathogenic bacteria invade food or water supplies. These bacteria can grow in food and cause food poisoning if the contaminated food is eaten. What are examples of illness or disease caused by bacteria?

Pathogenic bacteria harm a host because they damage the host's cells. Some pathogenic bacteria destroy cells directly. Others release harmful substances called toxins, which damage the cells. Each species of disease-causing bacterium affects a specific area of the body. Tooth decay, for example, is caused by a bacterium that lives on teeth. Another species of bacteria lives in the stomach and can cause stomach ulcers. What other harmful bacteria have you heard of?

Refer to the table on bacterial diseases. Botulism is a dangerous foodborne illness that can occur when food is not canned properly. Botulism is the illness that occurs when a person is exposed to the toxins produced by the bacterium *Clostridium botulinum*. How do you think companies prevent botulism from affecting products bought by consumers? What are the symptoms of botulism poisoning? What can you do if you believe you have been exposed to botulism?

The deer tick, which carries the bacterium that causes Lyme disease, is very small and can be easily overlooked.

Bacterial Diseases

Disease	Bacterium Shape	Area Affected	How Transmitted
Botulism	Rod	Nervous system	Improperly canned foods
Cholera	Rod	Intestines	Contaminated water
E. coli 0157:H7	Rod	Intestines	Contaminated vegetables or raw or undercooked beef
Lyme disease	Spiral	Joints, heart, nervous system	Infected tick
Salmonella food poisoning	Rod	Intestines	Contaminated food or water
Methicillin-resistant *Staphylococcus aureus* (MRSA) infection	Spherical	Skin, lungs, blood	Touching contaminated object or the skin of infected person
Tuberculosis	Rod	Lungs	Breathing in air droplets from an infected person's cough or sneeze

Science and Technology

The search for antibiotics began in the late 1800s with growing acceptance of the "germ theory of disease" that Louis Pasteur helped develop, which linked microbes with the cause of many diseases. Pasteur and Robert Koch were studying anthrax when they discovered that certain airborne strains inhibited the growth of bacterial cultures. Pasteur first coined the terms *aerobic* and *anaerobic* to describe organisms that live in the presence or absence of oxygen, respectively. Many substances first tried as antibiotics not only killed bacteria but also harmed people. In 1928 Alexander Fleming first discovered penicillin in a fungus in his lab. The wonder drug was mass-produced only during World War II by a team of Oxford scientists led by Sir Howard Florey and Ernest Chain, who received the Nobel Prize for this work. Since that time, a wide menu of antibiotics have been developed.

Lesson Activity

Separate into groups. Each group should select one of the diseases (except botulism) from the Bacterial Diseases table. Using the Internet, each group should answer at least the following questions: What causes the disease? What are the symptoms of the disease? How is the disease spread? What are the precautionary measures to prevent people from becoming sick? Prepare a three-minute presentation with accompanying poster-board illustrations to present to the class. After all of the presentations, regroup as a class and discuss whether more can be done by society to prevent these illnesses.

How can you help prevent illnesses?

Concept Check Assess/Reflect

Summary: What are bacteria? Bacteria are prokaryotic microorganisms. Some bacteria are heterotrophs, while others are autotrophs. Bacteria usually reproduce asexually by binary fission, often very quickly. Aerobic bacteria require oxygen, while anaerobic bacteria grow only in the absence of oxygen. Bacteria can be round, rod, or spiral shaped. Some bacteria recycle nutrients in ecosystems. Other bacteria are used to produce foods, make chemicals, or clean up pollution. Some bacteria cause diseases. Antibiotics are used to treat bacterial diseases.

1. Explain the difference between a heterotroph and an autotroph. Describe one type of beneficial autotrophic bacteria and one type of beneficial heterotrophic bacteria.
2. How do bacteria differ from plants and animals?
3. Explain the connection between bacterial growth rates and the ability of bacteria to cause disease.
4. Predict some of the negative consequences if all bacteria disappeared.

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Science Background

MRSA The acronym "MRSA" stands for "methicillin-resistant *Staphylococcus aureus*." Bacteria in the genus *Staphylococcus* are a common cause of infections called "staph" infections. MRSA, however, is sometimes called a "superbug," because it is resistant to methicillin and several other antibiotics, such as penicillin and amoxicillin. MRSA is spread by persons coming into contact with the bacteria, either by touching another person or a contaminated object. Persons who share close quarters are especially at risk. MRSA often begins as a pimple or a boil. If left untreated, the infection can become a serious skin infection and can spread to the bloodstream, the lungs, or the urinary tract. To treat MRSA, medical personnel perform lab tests that reveal which antibitotics can successfully kill the bacteria.

Lesson Activity

How can you help prevent illnesses?
Students should address the questions posed in the activity. For example, botulism is caused by the toxin produced by the bacterium *Clostridium botulinum*. The symptoms include disrupting voluntary muscles, dry mouth, decreased blood pressure, constipation, nausea, and vomiting. Botulism is primarily spread to humans by improperly preserved food. Botulism can be avoided by carefully cleaning and properly canning and preserving food. From their research and presentations, students should realize that hand washing, cleaning food, cooking food properly, and avoiding contaminated items can help them stay healthy.

Assess/Reflect

Concept Check

1. Sample answer: An autotroph is an organism that makes its own food using sunlight or chemical compounds. Photosynthetic cyanobacteria produce food from sunlight. Photosynthetic cyanobacteria provide the benefit of producing oxygen. Nitrogen-fixing bacteria are heterotrophs that provide the benefit of changing nitrogen into a form that plants can use.
2. The cells of bacteria are much smaller than those of plants and animals, and their cells lack nuclei. They also have cell walls made of peptidoglycan.
3. Sample answer: Because bacteria grow quickly, they can multiply in large numbers fast enough to cause illness or a disease.
4. Sample answer: If all bacteria disappeared, much of Earth's decomposition would stop and nutrients would not be recycled. Photosynthetic bacteria would no longer produce oxygen. Plants would no longer have nitrogen from nitrogen-fixing bacteria.

Lesson 3

Essential Question

What Are Protists?

Preview Lesson Content

Read the objectives with students, and help them pronounce each term in the vocabulary list. Ask students to read the heads and subheads and tell what the lesson is about in their own words.

Explain

Characteristics of Protists

Objective

- Identify the characteristics and structures of protists.

Set Goals

As they study this lesson, ask students to identify the main idea of each paragraph.

Develop Key Vocabulary

protist Explain that a protist is an organism belonging to the kingdom Protista. Protists are so varied that they are divided into three unofficial categories based on how they obtain nutrition.

protozoans Explain that protozoans are a group of tiny animals, such as amoebas, that are single-celled protists. Protozoans often have complicated life cycles.

Understand Visuals

How do you think these diatoms obtain energy? They use sunlight to make sugars.

Lesson 3

Essential Question

What Are Protists?

Objectives

- Identify the characteristics and structures of protists.
- Describe the three main groups of protists.
- Explain the environmental importance of protists.
- Describe helpful and harmful protists.

Vocabulary

protist
protozoan
phytoplankton
pseudopodia
flagella
cilia

Imagine an amoeba, a paramecium, and an alga on the table in front of you. How would you classify these organisms? They have different life cycles, trophic levels, forms of locomotion, and cell structure. Which characteristic would you use to classify these organisms? Are they like plants? Are they like animals? What if other classmates disagreed with your classification? How would you classify the organisms then? Would it help to know that these organisms do not fit into any of the other kingdoms? Scientists are often faced with this same dilemma. They resolved this conflict by creating a brand new kingdom. Meet the protists!

Characteristics of Protists Explain

A **protist** is a eukaryotic organism that cannot be classified as a fungus, a plant, or an animal. If you think this is a broad definition, you are correct. Protists include an astonishingly wide variety of organisms. Some protists resemble plants or fungi. Others look and act more like animals. These single-celled eukaryotes that move and eat food were once called **protozoans** and classified in the Animal kingdom.

Protists have different ways of obtaining nutrition. Some protists are autotrophs. Autotrophic protists include algae, seaweeds, and diatoms, for example. What characteristic do these organisms share? How do these protists get the energy they need? Other protists are heterotrophs. Heterotrophic protists include amoebas, paramecia, and the organisms that cause the disease malaria. Some heterotrophic protists are parasites, while others are decomposers and live on decaying organisms.

Marine diatoms, as viewed with a microscope, float in the surface water of marine environments.

How do you think these diatoms obtain energy?

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Science Background

Another example of how evolutionary theory has affected classification involves protists. Scientists have learned a lot about protist structure and organization recently. They have discovered increasingly tiny protists (some as small as prokaryotes). Interpreting their DNA research data from an evolutionary perspective, scientists infer that protists are not all from the same clade (in other words, they have different evolutionary histories). Since ancestors by definition belong with all their descendants in the same clade, scientists no longer believe a separate kingdom for protists is accurate. Biologists still use the term *protist* but simply as an easy way to refer to eukaryotes that are not plants, fungi, or animals.

Protists include organisms of many different sizes. Many are single celled. But some, such as brown seaweed, are more than 60 m in length. Many protists can move, sometimes extremely fast. Other kinds of protists stay in one place.

As scientists learn more about the structure and function of protists, they continue to find new ways to classify them. Many of these classifications are based on scientists' understandings of their similarities and differences. Scientists are also still discovering new species of protists. Why do you think the scientific classification of protists is frequently updated? Do you think protists will ever have a clear and concise classification? Explain.

Faith Connection

As scientists study and discover more data, they may change their thinking.

How might your life change the more you study God's Word?

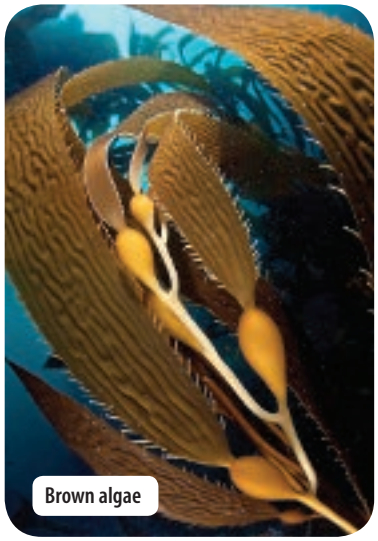
Protist Diversity Explain

The easiest way to learn about protists is to study them in three general groups that are based on the shared characteristics of the members of each group. The three groups are plant-like protists, animal-like protists, and fungi-like protists.

Plant-Like Protists

These protists are autotrophs that need sunlight energy to perform photosynthesis. What other living thing uses sunlight for photosynthesis? Algae are primarily aquatic protists. Some algae resemble plants. But, unlike plants, algae lack roots, stems, and leaves. Red algae and brown algae live in the oceans. Brown algae are commonly called *seaweeds* and can be many meters in length. Green algae include both single-celled and multicellular varieties. Green algae are found in marine water, in freshwater, and living on land.

Phytoplankton are small photosynthetic organisms that float and drift near the ocean's surface. These organisms, which include photosynthetic bacteria as well as algae and other protists, produce oxygen through photosynthesis. They also provide food for other organisms, such as heterotrophic protists, animals such as fish, and ultimately consumers who eat the fish. Why do you think phytoplankton aren't classified as plants? How much oxygen do these tiny organisms contribute to the planet?



Giant kelp is a brown alga that grows abundantly off the Pacific coast of North America. It can be as much as 100 m long.

How do other organisms and humans use giant kelp?

Protist Diversity

Objective

- Describe the three main groups of protists.

Develop Key Vocabulary

phytoplankton Point out the root word *phyte-*, which is from the Greek word meaning "plant." This root word is the source of *phyto-* in *phytoplankton*.

Teach Science Concepts

Even though protists are a varied group, why do scientists try to separate them only into three groups? Do you think this is a good way to study protists? Why or why not? Because there are so many protists to study, it is easier to discuss them in as few groups as possible. Let students share their thoughts on this strategy.

Understand Visuals

How do other organisms and humans use giant kelp? Other organisms and humans use giant kelp as a source of food.

Incorporate Inquiry Practice

Practice: Communicate Divide the class into teams. Each team will have six students divided into three pairs. Within each team, assign a different protist group (photosynthetic, animal-like, or fungus-like) to each pair of students. Pairs of students will then present three-minute summaries about their protist group.

Faith Connection

How might your life change the more you study God's Word? Sample answer: As we study the Bible, our relationship with God deepens and we want to be more like Him. This affects how we treat others and ourselves.

Scaffold Questions

Have students explain a protist's role in energy relationships in ecosystems.

Approaching Level **Why do some organisms not need to eat other organisms?** because they make their own food using sunlight or from chemicals

On Level **How do the protists obtain energy?** Some protists use sunlight to make sugars, others use chemosynthesis, while an ever larger percentage eat other living things.

Above Level **What is a possible ocean food chain that would show feeding relationships between autotrophic protists, heterotrophic protists, animals, and humans?** Answers will vary but should be logical and in agreement with the content in this lesson.

Explain *(cont.)*

Develop Key Vocabulary

pseudopodia Tell students that the prefix *pseudo-* is from the Greek word for "false." The word root *–podia* is from the Greek word for "foot."

flagella A flagellum resembles a whip. Point out to students that the word *flagellum* is from the Latin word for "whip."

cilia Explain to students that the word *cilium* comes from the Latin word for "eyelash."

Understand Visuals

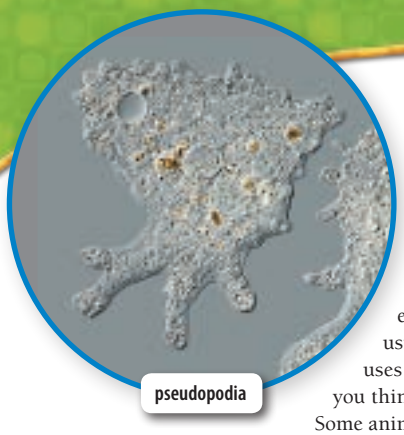
Discuss how an amoeba uses the pseudopodia to move and eat.

How is this amoeba plant-like? How is it animal-like? Sample answer: An amoeba is not plant-like, but it is animal-like because it captures its own food, hunting like an animal.

Explore-a-Lab Structured Inquiry

To make a protozoan culture for students, get a sample of pond water (or water from a puddle that has been standing for a couple of days), including some of the bottom "scum," and place it in a small jar. Add a pinch or two of dried grass that has been cut into small pieces. Add a boiled wheat seed as a food source for bacteria that the protozoa will eat. Wheat seeds are available from the grocery store or some health-food stores. Students should take a drop of the water (especially near the rice or wheat grain) and some of the sediment or debris at the bottom of the jar and examine it with a microscope each day for a week or more. Within two or three days, protozoan should be able to be seen moving about in the water. To make this even more interesting and engaging to students, have them make their own protozoan cultures following the procedure above.

How do the protists in a drop of water move about? Some use flagella to swim around. Others beat tiny hairlike structures called cilia. There are others that use pseudopods.


pseudopodia

How is this amoeba plant-like? How is it animal-like?

Animal-Like Protists

Early scientists used the simple microscope to study water droplets. They identified some protists as animals. Why do you think they thought these protists were animals? The cells of most protists have adaptations enabling them to move through water. For example, an amoeba, a single-celled protist, moves by using extensions of its cell called **pseudopodia**. It also uses its pseudopodia to capture and engulf food. How do you think an amoeba determines the location of food?

Some animal-like protists, such as the euglena, have whiplike structures called **flagella**. Euglena are single-celled photosynthetic protists. They swim, using a flagellum to move toward light. Flagella rapidly move back and forth, causing the cell to move forward. Other protists, such as paramecium, have cells covered with short, hairlike structures called **cilia**. These protists move and search for food by beating their cilia. Can organisms control the speed and direction of their movement with cilia or flagella? The discovery of Euglena and similar organisms in the mid-1800s created the need for the addition of the third kingdom Protista to the existing two kingdoms, Animalia and Plantae.

Fungi-Like Protists

Fungi-like protists absorb food from their environments and release spores to reproduce, much like fungi do (which will be studied in the next lesson). Organisms called slime molds are not molds at all, but protists. Slime molds can form large, colorful masses. They often live on the damp forest floor, where they absorb nutrients from decaying vegetation. Did you know that a slime mold could negotiate a maze to find food? What do you think happens to a slime mold when conditions become unfavorable? When food is scarce, slime molds produce spores that can travel through the air.

Explore-a-Lab Structured Inquiry

How do the protists in a drop of water move about?

Observe, under a microscope, a drop of pond water or a culture your teacher provides. Look for the three different methods protists use to move—cilia, flagella, or pseudopods. Can you find amoebas, euglenas, and paramecia? Did you find any that look like they are colonies made from many cells? Do any appear to have green coloring matter within their cells as plants do? Make detailed, labeled diagrams of each organism you see at low power and at medium or high power. Identify each as an autotroph or a heterotroph.

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English Language Learners

Develop Vocabulary Students may need help recognizing the plural forms of *pseudopodium* (*pseudopodia*), *flagellum* (*flagella*), and *cilium* (*cilia*) on this page. Explain that the *-a* ending creates a plural for these words.

Structured Inquiry

Discover

Record your work for this inquiry. Your teacher may also assign the related Guided Inquiry.

Science Journal

Observing Slime Molds

How does a slime mold change as it grows?

Materials
- plastic container with lid
- paper towel
- wax pencil or permanent marker
- water
- piece of slime mold
- oatmeal flakes (not instant)
- medicine dropper

Procedure

1. Line a plastic container with a moist (not wet) paper towel. Label the container with your name.
2. Your teacher will give you a piece of the slime mold *Physarum polycephalum*. Place the slime mold on the paper towel. Drop in a few flakes of oatmeal that have been moistened with a drop or two of water. Observe the slime mold for 5 minutes.
3. Put the lid on the container and place it in a cool, dark place.
4. **Observe** the slime mold each day for three days. **Record** your observations and make drawings of the slime mold in your ***Science Journal***. Add a few more oatmeal flakes to the container each time you make observations. Return the container to a cool, dark place after each observation.
5. On days 4–7, **observe** but do not feed the slime mold. Make sure the paper towel is kept moist. Use the medicine dropper to add water, if needed. **Record** your observations and make drawings of what you see. Return the container to a cool, dark place after each observation.

Analyze Results

Compare your drawings and observations with those of other class members.

Create Explanations

1. How does a slime mold change as it grows?
2. What conditions are necessary for the slime mold to grow?
3. Where do you think you would find slime molds in the natural environment?

Inquiry Extension

Extend

Slime Mold Food Preferences

Guided Inquiry

How does a slime mold react to different food sources?

Extend the Structured Inquiry activity by having students design their own procedures to identify what, if any, food preferences slime mold has.

Teaching Tip Provide a variety of cereals and pieces of fruit (berries, orange, apple, banana) so groups can choose three test foods, or assign each group three foods to test. Students might design a simple maze to test the slime mold's ability to find the foods.

Students may record their work in their ***Science Journals***. A scoring rubric can be found as an ***Online Teacher Resource***.

Discover

Use the inquiry activities as an opportunity for students to perform hands-on investigations and think like a scientist.

Structured Inquiry

Observing Slime Molds

How does a slime mold change as it grows?

Preparation and Tips

Each group will need a tiny cube cut from the slime mold, which you will need to obtain ahead of time along with oatmeal flakes. Be sure to use oatmeal flakes, not instant oatmeal.

Predict **How will the slime mold change over time?**

Science Journal

Have students use their ***Science Journals*** to record their work for this inquiry.

Inquiry Practice Tip

Observe Remind students to watch the slime mold carefully for five minutes after each time they add oatmeal flakes.

Expected Results

When the slime mold is in a moist environment, it will become blob-like and begin to flow toward food and engulf it. Over time, the *P. polycephalum* will grow. When food is no longer available, it will begin to transform. It will produce fruiting bodies that release spores into the air.

Create Explanations

1. It gets larger and spreads out. Finally, it will produce fruiting bodies.
2. The slime mold needs a cool, dark, moist environment and food.
3. Sample answer: in leaf litter on a forest floor

Explain *(cont.)*

Importance of Protists

Objective

- Explain the environmental importance of protists.
- Describe helpful and harmful protists.

Understand Visuals

Have students look at the photo showing the red tide. **What is a sign that something unusual is happening?** There are dead fish floating in the water.

Why do clams and other shellfish, which are not part of a red tide, pose a danger to humans? Sample answer: Clams are filter feeders. They eat the dinoflagellates. The toxins accumulate in the clam tissue and can sicken people who eat them.

Incorporate Inquiry Practice

Practice: Draw a Conclusion Assign students to work with a partner. The first team member will assume the (secret) identity of "Unknown Protist." The second team member will interview "Unknown Protist" and attempt to determine the protist's identity. Questions must elicit information about the protist's habitat, lifestyle, and diet. The interviewee must provide logical, accurate answers and may also provide creative clues. Interviewer and interviewee will switch roles after the correct identity is determined.

Teach Science Concepts

From the written information on the next page, have students draw a cause-and-effect diagram showing the cause of each disease and its effects.

Importance of Protists Explain

You may not know it, but protists can be found in many of the products people use every day. Some of these products are agar, medicines, soaps, and food products. Protists affect people and other living organisms in another way—they can cause diseases.

Environmental Roles

Protists play a vital role in global photosynthesis. Scientists believe that phytoplankton contribute between 50 to 85 percent of the oxygen in Earth's atmosphere. They aren't sure because it's a tough thing to calculate. In the lab, scientists can determine how much oxygen is produced by a single phytoplankton cell. The hard part is figuring out the total number of these microscopic organisms throughout Earth's oceans. Phytoplankton populations increase and decrease with the seasons. Phytoplankton bloom in spring when there is more available light and nutrients. The sugars and other carbon compounds made by the phytoplankton provide food for many organisms. Phytoplankton form the base of the food chains in the ocean. What do you think would happen to ocean ecosystems if phytoplankton didn't exist?

The toxin given off by dinoflagellates often causes a red tide's characteristic fish kill.

Why do clams and other shellfish, which are not part of a red tide, pose a danger to humans?

Science Background

Phytoplankton are the keystone organism of the oceans. They are at the base of the ocean's food web. Through photosynthesis, they produce the food that feeds all marine life and a billion or more people. Phytoplankton also help remove carbon dioxide (CO_2) from the atmosphere and move it into the deep ocean. They achieve this through what is called a "biological pump." During photosynthesis, phytoplankton remove dissolved CO_2 from the surface ocean and lock it into the organic carbon of their bodies. When they die, they sink to the bottom of the ocean, preventing the carbon from returning to the atmosphere. It is estimated that each year the biological pump moves about 10 billion tons of carbon into the intermediate and deep ocean depths, counteracting about 25% of the carbon dioxide humans add to the atmosphere each year from fossil fuels and deforestation.

Some kinds of algae have a major impact when they suddenly increase in number. A large, rapid growth in the population of algae is called an *algal bloom*. When the algae die, they decompose. In freshwater lakes and ponds and even in the ocean, the decomposition of large algal blooms reduces the oxygen level in the water. How might this drop in oxygen levels change the relationships of other living things in the ecosystem?

In coastal areas, large populations of photosynthetic protists called *dinoflagellates* can cause harmful algal blooms known as *red tides*. Some species of dinoflagellates produce a toxin that kills fish. The toxin affects the fish's nervous system so that it is paralyzed and cannot breathe. When humans eat seafood affected by the organisms living in these waters, they can become very sick. The toxin can damage the human nervous system, causing illness and even death. Red tides can reduce fishing in affected areas and harm tourism.

Diseases Caused by Protists

Protists that are parasites can sometimes cause diseases. For example, *Phytophthora infestans* causes potato blight, a disease that has had great economic and historic impact. Soon after *P. infestans* infects potato plants, the stalks and the stems become a slimy, black mass. Entire potato crops are ruined. When potato blight swept through Ireland in the late 1840s, it created widespread famine. During the great potato famine, about one million people died of famine and related diseases. As a result, many thousands of Irish citizens immigrated to the United States.

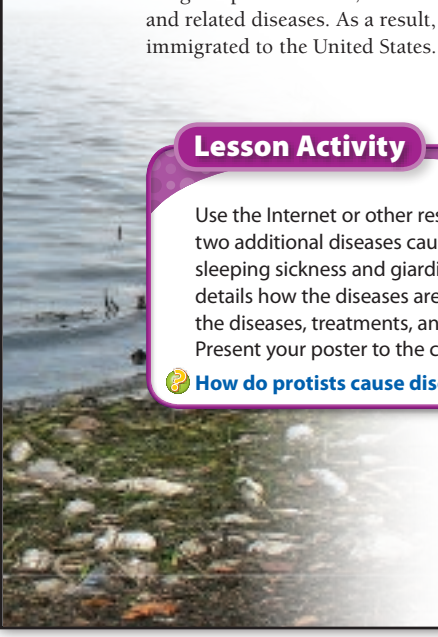
Scripture Spotlight

Read **Exodus 7:14–25**. Some people think the Nile turning to blood was God using a phenomenon similar to red tides. What protist creates conditions such as those described in this text?

Lesson Activity

Use the Internet or other resources to learn about two additional diseases caused by protists—African sleeping sickness and giardiasis. Make a poster that details how the diseases are spread, symptoms of the diseases, treatments, and methods of prevention. Present your poster to the class.

How do protists cause disease?



Social Studies Link

Between 1845 and 1860, the potato blight, caused by the fungus-like protist *Phytophthora infestans*, infected Ireland's potato crop. It destroyed several consecutive crops of potatoes, which were the main food source for one-third of Ireland's population. This caused a large percentage of Ireland's population to die from starvation, and millions of others were forced to leave Ireland to avoid starvation. Nearly a million of these people immigrated to the United States. This reduced Ireland's population by an estimated 20% to 25%.

Have students research what hardships the Irish immigrants faced when they arrived.

Lesson Activity

How do protists cause disease? Students should provide clear and accurate information obtained from reliable sources. Encourage students to use websites that are .gov, .edu, or .org. Avoid sites that end in .com.

Scripture Spotlight

Discuss with students some of the similarities between the Bible description in this passage and the description of red tides. Dinoflagellates are one type of protist that causes red tides.

In the Enlightenment of the 1700s, people's attitudes toward authority, religion, and God's role in nature changed. Reacting against a tendency to answer scientific questions with the response "God did it," scientists began a trend toward naturalism (explaining everything using natural causes). Naturalism's claim that all things can be explained that way goes beyond what science can demonstrate. Science's inability to test supernatural interventions does not mean that miracles are outside the scope of reality. Some questions to think about: Might God use a natural cause to intervene in human history? If so, does understanding the natural cause make it any less miraculous? (It depends on your definition of miracle. If a miracle is defined as something beyond the natural, then technically, God's intervention through natural means would not be a miracle, but it would still be an intervention. If a miracle is defined as something done by God, then knowing the natural process He used does not make it any less an act of God). Is God limited to using only natural causes to intervene in human history? (As the creator of natural laws, God is not bound by them.) Can God intervene supernaturally without tampering with His own natural laws? (Because of gravity, a book will fall when dropped. If someone catches it, no law was tampered with, but someone intervened.) Why do we want to find a natural explanation for this or any other miracle? Are we interested in figuring out whether God used some method of intervention we can understand, or are we trying to replace divine intervention in human history?

Explain *(cont.)*

Understanding Visuals

What are some reasons that malaria is so difficult to eradicate? The protist infects mosquitoes, which multiply rapidly. A vaccine has been hard to develop. Mosquitoes are hard to control without harming other organisms.

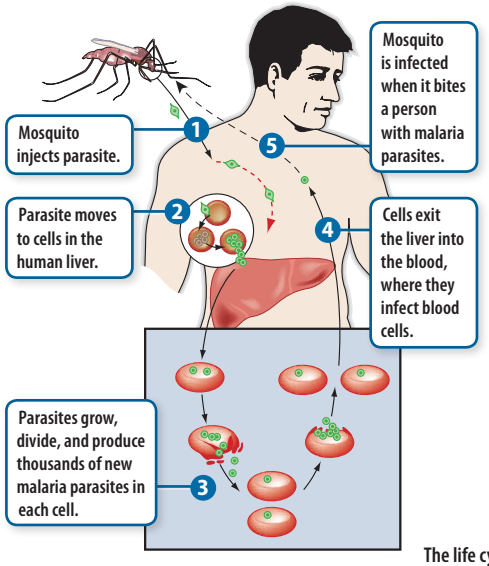
Assess/Reflect

Read the essential question and lesson summary with students. You may work through the concept check as a class, or use it as a formal assessment option.

Concept Check

1. Sample answer: Protists are an extremely diverse group. Some perform photosynthesis and provide food and oxygen for other organisms. Others release toxins or cause devastating diseases, such as malaria and potato blight.
2. Photosynthetic protists and heterotrophic protists are both eukaryotes. Photosynthetic protists use sunlight energy to make sugars. Heterotrophic protists must get food from other organisms.
3. Sample answer: If most of the world's ocean phytoplankton died, the organisms that eat phytoplankton would also die, resulting in the subsequent death of the organisms that prey upon them, ultimately causing food chains in the world's oceans to collapse. A significant amount of the world's oxygen would no longer be produced.
4. Sample answer: Drain wetlands, use mosquito nets, and spray chemicals to kill mosquitoes. Many of these approaches cost money. Many regions are rural and are difficult to get to.

Cycle of Malaria



Malaria is a life-threatening human disease caused by parasitic protists that are transmitted through the bites of infected *Anopheles* mosquitoes. Each year, malaria causes nearly one million deaths, mostly among African children. Malaria causes fever, headache, chills, and vomiting. These symptoms can become severe and may result in death. The disease can usually be treated and often cured, but no vaccine yet exists. Vaccines are in the testing stage. By the time you read this, there may be a vaccine that is effective against malaria.

The most effective way to prevent people from getting malaria is protection against mosquito bites, which usually occur at night when the *Anopheles* mosquito is active. Insecticide-treated mosquito nets protect people from mosquito bites while asleep, reducing the chance of developing malaria. What other ways can humans protect themselves against mosquito bites?

The life cycle of the parasitic protist that causes malaria involves the host *Anopheles* mosquito before it infects a human or animal host.

What are some reasons why malaria is so difficult to eradicate?

Concept Check Assess/Reflect

Summary: What are protists? Protists are eukaryotic organisms that are not classified as fungi, plants, or animals. Many protists are single celled, while others are multicellular. The three main groups of protists are plant-like protists, animal-like protists, and fungi-like protists. Scientists continue to debate the classification of protists based on new research. Autotrophic protists form the basis of many food chains. Algal blooms reduce oxygen in water, causing other organisms to die. Protists also cause diseases, such as potato blight and malaria.

1. Why are protists considered both helpful and harmful organisms?
2. How are photosynthetic protists and heterotrophic protists alike? How are they different?
3. What would happen if most of the world's ocean phytoplankton died?
4. What three steps would you recommend to reduce the cycle of malaria? Why might communities be slow to adopt these changes?

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Science and Society

The U.S. Centers for Disease Control and Prevention (CDC) maintains a set of online resources about malaria, including data about ongoing efforts to find an effective malaria vaccine. The challenges facing vaccine development are daunting. The protist that causes malaria, *Plasmodium*, has a complex life cycle that involves both humans and mosquitoes. During much of its life cycle, *Plasmodium* lives inside cells, shielded from the host's immune system. Finally, *Plasmodium* continues to constantly change its surface proteins that serve as antigens, resulting in a "moving target" for vaccine researchers. A person may be infected with malaria for months without symptoms, making it hard to track the spread of the disease. Unlike many other diseases, infection with malaria does not confer lifelong immunity, so those persons who get malaria are not protected from future infection. Malaria vaccine trials are undergoing clinical testing.

Lesson 4

Essential Question

What Are Fungi?

Did you know that one gram of forest soil can contain more than one million microscopic fungi? In forest soils, other than plant roots, fungi are the dominant life forms. How can fungi be so prevalent but seemingly invisible to us?

In Oregon's Blue Mountains, a gigantic fungus occupies about 965 hectares of soil. This fungus would cover 1665 football fields, or nearly 10 square kilometers. But you cannot really see this fungus because, except for the mushrooms it forms on the surface, it is entirely underground! It is one of the world's largest organisms. What is the purpose of mushrooms in the life cycle of a fungus?

Objectives

- Identify the characteristics and structures of fungi.
- Explain the role of fungi in decomposition.
- Describe the different kinds of fungi.
- Describe how fungi are harmful and useful.

Vocabulary

hyphae
mycelium
saprophyte
mycology
parasite

Omphalotus olearius **is more commonly called the jack-o'-lantern mushroom. It is orange in color and glows at night due to bioluminescence.**

Why shouldn't people eat the wild mushrooms they find in the forest?

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Science Background

Puffballs Puffballs are a type of mushroom that grows out of rotten wood or other decaying matter. Puffballs are round or pear-shaped fruiting bodies that range in size from as small as a golf ball to as large as a watermelon. In fact, the *Calvatia gigantean* is almost two feet long. The puffball contains the spores that are released into the environment for reproduction. *C. gigantean* contains 7,000,000,000,000 (7 trillion) spores. **How much is 7 trillion?** For comparison, there are about 31.6 million seconds in a year. If you held your breath for 7 trillion seconds, you would not take your next breath for 221,817 years. Each spore is 3.5 to 5.5 microns (0.00035 to 0.00048 cm) in diameter. *C. gigantean* grows in the central and eastern United States and Canada.

Lesson 4

Essential Question

What Are Fungi?

Preview Lesson Content

Read the objectives with students, and help them pronounce each term in the vocabulary list. Ask students to read the heads and subheads in the lesson and predict what the lesson is about.

Understand Visuals

Why shouldn't people eat the wild mushrooms they find in the forest? Many mushrooms are poisonous. It is important to know what type of mushroom you are picking before eating it.

Teach Science Concepts

Poisonous mushrooms, often called toadstools, are basidiomycetes that contain toxic alkaloids. Approximately 70 to 80 species of mushrooms are poisonous to humans. Well-known mushrooms that cause poisoning include several species in the genus *Amanita*. *Amanita phalloides*, the Death Cap, is the most deadly, causing coma followed by death in more than 50% of cases. When not lethal, ingestion can cause permanent liver and kidney damage. There are no antidotes for mushroom poisoning. Some poisonous mushrooms closely resemble wild, edible varieties. Wild mushrooms should not be eaten unless an experienced professional has identified them.

Life in Pond Water

Encourage students to complete the analysis of the data gathered in the Open Inquiry activity. Remind them that they should think like scientists and use the scientific process when creating explanations.

Reminder

Explain *(cont.)*

Characteristics of Fungi

Objectives

- Identify the characteristics and structures of fungi.
- Explain the role of fungi in decomposition.

Set Goals

As they study this lesson, ask students to make a table for comparing and contrasting the various groups of fungi.

Develop Key Vocabulary

hyphae Tell students that the word *hyphae* is from the Greek word for "web." Fungal hyphae are made of thin filaments, just as a spider's web is made of thin filaments.

mycelium The word *mycelium* comes from the Greek word *mukes,* which means "fungus."

Teach Science Concepts

Explain to students that fungi release digestive enzymes and digest their food externally. Ask students to imagine what it would be like if humans did this. **What would it look like if you went into the school cafeteria and ate your lunch in this way?** Answers will vary.

Understand Visuals

How are the spores dispersed? Once released, wind, water, and animals disperse spores.

Scripture Spotlight

What were these instructions? In **Leviticus 14:33–45**, God says to empty the house of all its belongs then lock the doors for seven days. If the plague still spreads, clean the house and replace the stones. If the plague returns, tear down the house. **What health problems may result from inhabiting a building infested with mold?** People exposed to toxic mold may experience headaches, nausea, and asthmatic symptoms.

Characteristics of Fungi Explain

Scripture Spotlight

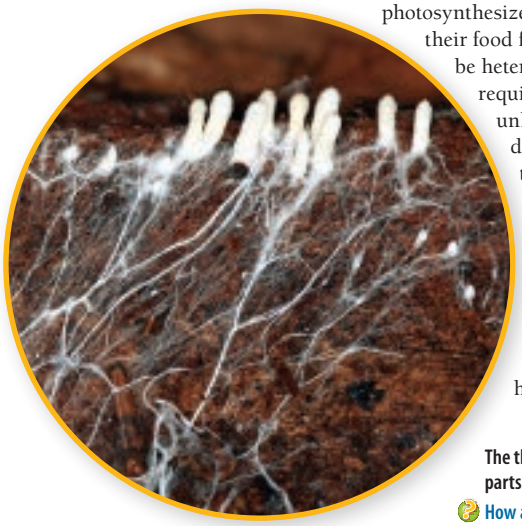
God gave the Israelites very specific instructions for dealing with mold in a building in **Leviticus 14:33–45**. What were these instructions? What health problems may result from inhabiting a building infested with mold?

The organisms known as fungi (singular, fungus) are so unique that they are placed in their own kingdom. The Kingdom Fungi includes mushrooms, molds, mildews, and yeasts. A mold is a fungus that appears as a fuzzy film growing on surfaces and foods, such as fruits and bread. Where are some places you have seen a fungus growing? Do fungi always look alike?

Many strange and beautiful life forms populate the Kingdom Fungi. Like protists, plants, and animals, fungi are eukaryotes and have cells with a nucleus surrounded by a membrane.

Have you ever opened a bag of bread and found green, white, or black mold growing on the bread? How did it get on the bread? What did the mold look like? Fungi may be single celled or multicellular. Multicellular fungi, such as mushrooms and molds, have threadlike bodies made of thin filaments. These filaments are called **hyphae** (singular, hypha). The hyphae may be tightly packed, as in the familiar mushroom. In other species, the hyphae are single strands, like the moldy fungal threads that reach deep into bread or overripe fruit. The hyphae together form a tangled mass called a **mycelium**. However, not all fungi produce mycelium. Yeasts are single-celled sac fungi. Unlike other fungi, yeasts do not have a mycelium.

Because mushrooms do not move, they once were thought to be plants. However, unlike plants, they are not able to photosynthesize and are not autotrophs. Fungi must get their food from other sources and are considered to be heterotrophs, like animals. Like animals, fungi require oxygen and release carbon dioxide. But unlike animals, mushrooms and other fungi do not ingest, or eat, their food. Instead, they release digestive enzymes outside their bodies. These enzymes break down the food into smaller molecules, which are then absorbed by the fungus. The fungal mycelium gives a fungus a very large surface area with which to absorb nutrients. However, fungi dry out easily because of this large surface area. What happens to a fungus when it dries out?



The thick, white structures are the spore-producing parts of this mold.

How are the spores dispersed?

Health Link

Mushrooms are low in protein but are a good food source of Vitamin B12. This vitamin is essential for creating red blood cells and helps protect against anxiety, stress, and depression. For over 2 000 years, mushrooms have been an important part of traditional Chinese medicine. They have been used mainly to stimulate immune system responses rather than to treat specific illnesses. Several varieties of mushroom species that are regarded as valuable can work wonders for the body. For example, *Ganoderma lucidum* has important antiallergic and anti-inflammatory properties. It has been shown to inhibit histamine release and is useful for treating cases of allergic asthma and insomnia. *Coriolus versicolor* is useful for lung disorders, tiredness, and chronic diseases.

Structured Inquiry

Discover

Record your work for this inquiry. Your teacher may also assign the related Guided Inquiry.

Science Journal

Activity of Yeast

How does sugar affect the growth of yeast?

Materials
- safety goggles
- lab apron
- 2 large, zip-top bags
- wax pencil or permanent marker
- thermometer
- warm water (40°C to 45°C)
- 100 mL graduated cylinder
- 2 packets active dry yeast
- plastic spoon
- granulated sugar
- 3 paper towels
- metric ruler

Procedure

1. Use a wax pencil or permanent marker to write your name on each bag. Label the first bag *A*. Label the second bag *B*.
2. Use a thermometer to measure the water temperature. **Record** the temperature in your ***Science Journal***.
3. **Measure** and pour 100 mL of warm water into the plastic cup. Add one packet of yeast to the cup and stir gently until the yeast is mixed thoroughly in the water. Add the water and yeast mixture to bag *A*. Squeeze most of the air out of the bag and seal it. Place the bag flat on top of three layers of paper towels. Do not move or touch the bag for 30 minutes.
4. Rinse out the plastic cup and dry it.
5. Repeat Step 3 with bag *B* but add one spoonful of sugar to the water and yeast mixture. Note: Make sure that all of the sugar has dissolved in the cup before adding the mixture to the bag.
6. **Observe** the bags at the end of 30 minutes. **Record** your observations.

Analyze Results

Measure the height that each bag has risen above the tabletop.

Create Explanations

1. How does sugar affect the growth of yeast?
2. How can you explain the difference in the appearance of the bags?
3. Why is yeast useful in baking?
4. What cell process is going on inside the yeast cells that produces the gas that filled the bag?

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Inquiry Extension

Extend

Guided Inquiry

Sugars and Yeast

Can yeast use sugars other than table sugar?

Extend the Structured Inquiry by having students determine whether yeasts can use different sugars and artificial sweeteners.

Teaching Tip Provide fructose, lactose, maltose, or other forms of sugar, such as honey, corn syrup, or pancake syrup. Also provide artificial sweeteners, such as aspartame, saccharin, neotame, and sucralose. Have different groups use different sugars and compare their results.

Students may record their work in their ***Science Journals***. A scoring rubric can be found as an ***Online Teacher Resource***.

Discover

Use the inquiry activities as an opportunity for students to perform hands-on investigations and think like a scientist.

Structured Inquiry

Activity of Yeast

How does sugar affect the growth of yeast?

Preparation and Tips

Allow tap water to sit overnight, allowing chlorine to dissipate. During the experiment, place bags on several layers of newspaper as insulation to prevent heat loss.

Predict **How do you think the two bags will differ?**

Science Journal

Have students use their ***Science Journals*** to record their work for this inquiry.

Inquiry Practice Tip

Measure Help students understand why they need to measure material amounts accurately.

Expected Results

Students should find that the bag with sugar shows yeast activity seen as foaming, bubbling, swelling up or inflating, and gas production.

Create Explanations

1. The bag with sugar expanded because carbon dioxide was produced, showing evidence of yeast growth.
2. In Bag *B* yeast cells began to metabolize the sugar (cell respiration), producing CO_2 gas. This makes the bag appear to inflate.
3. Yeast is useful in baking because the carbon dioxide it releases causes bread to rise, making the bread light in texture.
4. As they use the sugar, yeast cells release carbon dioxide, which causes the bag to swell. This is called cell respiration.

Explain *(cont.)*

Develop Key Vocabulary

saprophytes Tell students that the root word *–phyte* is frequently used in life sciences. It is from the Greek word *phuton,* which means "plant." The prefix *sapro-* is from the Greek word *sapros,* which means "rotten."

mycology Ask students whether they have seen a similar word earlier in this lesson. Like *mycelium,* introduced on page 40, the word *mycology* comes from the Greek word *mukes,* which means "fungus."

Understand Visuals

What characteristics do fungi and animals have in common? What characteristics do fungi share with plants? Both fungi and animal cells contain chemicals called *sterols*. Both fungi and plants have cell walls.

Fungi have characteristics similar to both plants and animals. Recall that a plant cell is surrounded by a cell wall made of cellulose, a tough, rigid material made of carbohydrates. What is the function of the cell wall in plants? Like plants, fungi have cell walls. The cell walls of fungi are made of chitin, a tough carbohydrate similar to cellulose. Chitin is the same substance that forms the hard, outer coating of insects. Why might fungi require a tough exterior? Do fungi cell walls serve the same function as plant cell walls? Fungal proteins are also more like the proteins found in animals than those found in plants. Both animal and fungal cells contain chemicals called *sterols*. These compounds play an important role in biological messenger systems. Human bodies contain the sterol cholesterol, while fungi contain the sterol ergosterol. However, both animals and fungi contain lanosterol. None of these chemicals are found in plants. How might fungi use ergosterol?

Along with bacteria, fungi are important decomposers, breaking down the bodies of dead organisms. Such decomposers are called **saprophytes**, organisms that absorb carbon and other nutrients from dead organisms. Saprophytes recycle nutrients that would otherwise remain unavailable to the living world. How would the forest floor be different without saprophytes, such as fungi?

Studying Fungi

The study of fungi is called **mycology**. Scientists who study fungi examine fungal cell structure and reproduction. They use these characteristics to classify the Kingdom Fungi into several distinct groups. What characteristics might scientists use to group fungi?

Like all members of the Kingdom Fungi, *Amanita muscaria* mushrooms share these parts.

What characteristics do fungi and animals have in common? What characteristics do fungi share with plants?

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English Language Learners

Language Development Students may need help pronouncing some of the science words in this lesson. Model the pronunciation for the following words: *zygote* (ZEYE goht), *chytrid* (KEYE trihd), *lichen* (LY kuhn), *cyanobacterium* (SY uh nuh bak TIHR ee um), and *mycorrhizae* (my kuh RY zee). Point out that the *ch* in *chytrid* and *lichen* is spoken with a hard *k* sound.

Develop Vocabulary Remind students that the prefix *myco-* in the word *mycorrhizae* comes from the Greek word *mukes*, which means "fungus." This same Greek word is found in *mycology* and *mycelium*.

Kinds of Fungi Explain

Many people think of fungi as nothing more than molds and mushrooms. But fungi are far more diverse. The major groups that make up the Kingdom Fungi include an astonishing variety of organisms.

Fungi reproduce both asexually and sexually. All fungi produce spores. A *spore* is a thick-walled, asexual reproductive cell that is very effective for reproduction. Spores are lightweight so that they can be carried great distances by the wind, and they are resistant to drying. Why do you think resistance to drying is an advantage to the spore?

The sexual stage of fungi reproduction generally occurs underground. Fungi are placed into taxonomic groups according to the type of spore and spore-bearing structures they have. Study the table to learn about different fungi and their characteristics.

Black bread mold *(Rhizopus stolonifer)*

How should you handle foods with molds on them?

Fungi

Type	Characteristics	Examples
Club fungi	• Organisms are primarily an underground network of hyphae. • Mushrooms are reproductive organs. • Mushroom has umbrella-like cap lined with gills that release asexual spores.	• Mushroom
Sac fungi	• Asexual reproduction is primarily through budding. • Spores are located in microscopic, saclike structures. • Some sac fungi are parasites, organisms that feed on other organisms.	• Yeast • Chestnut blight • Dutch elm disease
Zygote fungi	• Asexual reproduction is by producing spores in spore cases atop stalks. • Spore cases give molds their fuzzy, dusty appearance. • Sexual reproduction is by producing reproductive structures that form zygotes (fertilized eggs) inside a tough capsule.	• Black bread mold
Aquatic fungi	• Organisms live in water. • They produce spores that swim during sexual reproduction. • They can be parasitic. • They can cause disease in fish.	• Frog fungus

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Science Background

Frog Fungus One of the most devastating diseases known to biodiversity is a fungal infection in amphibians caused by *Batrachochytrium dendrobatidis*, an aquatic fungi commonly called the frog fungus. More than 350 species of amphibians have been affected by it, and over 200 of these species are being driven into decline or extinction. The earliest signs of frog fungus infections coincide with the increase in frog use in research and pregancy testing in the 1930s. Further transporting of frogs and salamanders in the pet trade, food trade, and other human activities has contributed to the spread. Once introduced, the fungus spreads quickly to other amphibians. A rapid skin infection occurs, interferring with gas exchange, nutrient acquistion, and electrolyte balance. Eventually death occurs by cardiac arrest.

Kinds of Fungi

Objective

- Describe the different kinds of fungi.

Understand Visuals

Direct students' attention to the photo of the moldy bread. Remind them that cleanliness is vital in controlling the growth of mold.

How should you handle foods with molds on them? Sample answers: Do not sniff them as they could cause respiratory problems. Discard any food that is covered with mold in the trash. Check nearby items that the moldy food may have touched as it spreads very easily. Clean surfaces where the food was stored. Explain that many cheese varieties are designed to have visible molds.

Incorporate Inquiry Practice

Practice: Experiment Provide each student with pencil shavings, flour, quinoa, lentils, couscous, and oats. Each student should lay white paper across his or her desk. Standing in the same place at desk level, students should place one pinch of one substance on their palm. Have them blow across their palm and mark where the material lands on the white paper. Then have them label the farthest point on the white paper. Have students repeat this process with each substance. **Which substance traveled the farthest? Why?** Sample answer: Answers may vary, but substances will travel farther based on size and shape.

Understand Visuals

Have students study the information in the table. Have each student compose a question on a note card that he or she would like to learn based on the information provided in the table. Collect the note cards and mix them up. Have students select a note card at random. Have students use the Internet or library resources to explore the question. Return as a class and have students share their answers.

Explain *(cont.)*

Explore-a-Lab Structured Inquiry

⚠ For safety reasons, do not use wild mushrooms or any mushroom that has not been purchased at a grocery store.

Remind students that when you observe, you carefully examine details to see what they can reveal. Obtain mushrooms from a grocery store and let them age until the undersides look brown. Have students follow the instructions. Have a class discussion on how to estimate the number of spores a single mushroom can produce.

For best results, light-colored mushrooms generally have light-colored spores that show up best on black or dark paper. Portobello mushrooms make good spore prints on white or light colored paper.

What can you learn from a spore print or fungi? You can tell what part of the mushroom produces spores, how small the spores are, and that one mushroom can produce a huge number of spores.

Understand Visuals

Why are lichens not classified as plants? Lichen is an association between a fungus and a partner, such as a photosynthetic green algae and blue-green algae. Lichens are combinations of two distinct organisms.

Faith Connection

When the Jews celebrated Passover, why did they prepare unleavened bread? Eating unleavened bread symbolized removing sin from our lives.

Faith Connection

Yeast often symbolizes evil or corruption in the Bible. When the Jews celebrated Passover, why did they prepare unleavened bread?

Explore-a-Lab Structured Inquiry

What can you learn from a spore print?

Carefully remove the stems from two mushrooms and lay the mushroom caps with the gills down on an unlined sheet of white paper. Cover the mushrooms and paper with a container to keep them moist. Let the mushrooms sit undisturbed overnight and remove them from the paper the next day. Observe the paper with a hand lens. Draw and label a sketch of what you see on the white paper. Describe the marks on the paper and what made them. With classmates, discuss ways you could estimate the number of new mushrooms that could be produced from one mushroom cap.

Lichens come in a multitude of colors: green, gray, black, white, yellow, orange, and even red.

Why are lichens not classified as plants or fungi?

Fungal Partnerships

Remarkably, some fungi form lifelong symbiotic partnerships with other organisms. Lichen is an association between a fungus and a partner, such as a photosynthetic cyanobacterium or a green alga. The photosynthetic partner produces sugars, which are shared with the fungus. The fungus, on the other hand, protects the photosynthetic partner and keeps it from drying out. Both organisms benefit from the partnership. Other fungi, called mychorrihizae, form an association with plant roots. These fungi help the plant roots absorb minerals and aid in the uptake of water. In return, the fungus receives nutrients from the plant. Why do you think some plants have a symbiotic relationship with mycorrhizae while others do not? What kinds of plants do you think are most dependent on a relationship with these fungi?

Science and Society

The World's Most Expensive Fungus Truffles have been found in Europe, Asia, North Africa, and North America. The most commercially important species are black truffles (*Tuber melanosporum*) and white truffles (*Tuber magnatum*). Truffles live in close mycorrhizal association with the roots of specific trees. Their fruiting bodies grow underground. Truffles are round, warty, and irregular in shape and vary in size from a walnut to a man's fist. The season for most truffles falls between September and May. Truffles are harvested in Europe with the aid of female pigs or truffle dogs, which are able to detect the strong smell of mature truffles under the surface of the ground. Since the times of the Greeks and Romans, these fungi have been used in Europe as delicacies and as medicines. They are among the most expensive natural foods, often costing $500 or more per kilogram.

Economic Impact of Fungi Explain

Fungi are versatile and seem to grow everywhere. What benefits come from being able to grow almost anywhere? What disadvantages come from this capability? Fungi are important in the building of soil. Would you be surprised to learn that fungi have been used for centuries to produce dye, especially brown, yellow, and gray colors for fabrics? Fungi have even been used to enhance the color of food!

Plant Diseases

Why don't people like fungi? Many fungi produce plant diseases that cause millions of dollars of crop damage every year. Besides this being a problem for farmers, what other problems come with a loss of crops? How do agricultural scientists try to combat plant pathogens that can destroy crops? Most economically important plants have one or more fungal parasites. A **parasite** is an organism that feeds on another organism. Fungal hyphae burrow into plant tissues, damaging leaves, stems, and roots, resulting in plant death and reduced harvests. Rusts, so named because they cause powdery, orange spots on infected leaves, destroy wheat and many other grasses. How do you think these fungi spread from plant to plant? Powdery mildews infect the leaves of grasses, vegetables, trees, and shrubs. Chestnut blight and Dutch elm disease have destroyed these once-common North American trees. Why would a cool, wet summer be of concern to farmers? Are plant diseases only a concern when plants are alive, or can they also affect plants, such as grains, after harvest? If so, how?

Fungal diseases can affect crops around the world, especially in regions where dews are frequent and temperatures are warm, between 18°C and 30°C.

Scaffold Questions

Approaching Level **What information would scientists need to classify a fungus into one of the groups on these pages?** Scientists would need to know the type of sexual reproductive structure produced by the fungus.

On Level **Why do you think fungi cause many plant diseases?** Many fungi are parasites. Because fungi produce lightweight spores, a pathogenic plant fungus can spread quickly from plant to plant and infect many new plants.

Above Level **Some parasitic organisms kill their hosts; others do not. Why might it benefit a parasite if its host does not die?** If the host lives, the parasite keeps its source of nutrition. **How have parasitic fungi adapted to hosts that die?** Fungi produce large numbers of spores that can travel great distances, enabling a fungus to infect new hosts.

Economic Impact of Fungi

Objective

- Describe how fungi are harmful and useful.

Develop Key Vocabulary

parasite Ask students to name an example of a parasite. Tell students that the term comes from the Greek words meaning "one who eats at another's table." The prefix *para-* means "alongside" or "near," as in the words *paralegal* or *paramedic*.

Teach Science Concepts

You might explain that the spores of mold and other fungi cause serious health problems in buildings that are damaged by water from floods, broken pipes, or sewage backups. Spores are introduced along with floodwaters and dust or dirt entering buildings and may grow or spread because of leaks behind walls. **What impact do you think a fungus could have if it infected a large region that grows fresh produce or grains, such as wheat?** Answers will vary, but students should recognize a possible food shortage and higher food costs.

Incorporate Inquiry Practice

Practice: Communicate Have students break into groups and select one of the diseases caused by fungi: aspergillosis, coccidioidomycosis, histoplasmosis, white-nose syndrome, and candidiasis. Students should use the Internet or library resources to learn more about what causes the illness, the symptoms that manifest, and the group affected. Each group should prepare a poster to display the information group members just researched. At the end of the activity, each group should present the information to the class. After the presentations, the class should gather together to discuss the different diseases.

Explain *(cont.)*

Explore-a-Lab Structured Inquiry

Leaving the bread slices out on a counter uncovered for a day can help speed up the molding process.

Practice: Draw Conclusions Remind students that you draw conclusions by examining data collected in your experiment. Ask students to describe their results. What was the difference between the two kinds of bread? Guide students to consider the ingredients listed on each bread package. What can you conclude based on your observations? Encourage students to focus on the key ingredient(s) present or absent in each kind of bread.

Which type of bread molds fastest?
Students will most likely find the bakery bread samples contain more mold than the regular white bread. Regular grocery store bread contains one or more preservatives, such as calcium propionate, which will inhibit fungal growth. Bakery breads may lack these ingredients.

Understand Visuals

How could someone avoid the fungus athlete's foot? Sample answers: Keep feet clean and dry, wear shoes that allow your feet to breathe, wear clean socks to absorb sweat and change them if they get wet or sweaty, use foot powder, allow shoes to air out between uses, and wear shower sandals in public showers, locker rooms, and around pools.

Explore-a-Lab Structured Inquiry

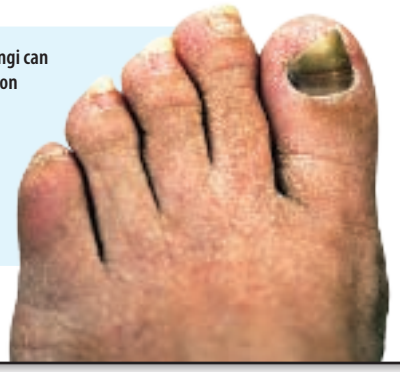
Which type of bread molds fastest?

Obtain two zip-top bags from your teacher. Into one bag, place a slice of white bread from a commercial grocery store. Into the other bag, place a slice of bakery white bread or homemade bread of equal size. Label each bag with the type of bread and your name. Moisten the bread in each bag with five drops of water. Seal the bags and place them in a warm, dark place. Do NOT open the bags! After several days, observe the bread through the bags using a hand lens. Compare the two slices of bread.

Human Diseases

In humans, some fungi are parasites that infect body tissues. Athlete's foot and ringworm are common skin diseases caused by fungi. Although the name *ringworm* suggests that a worm is the cause, it is actually a fungus that leaves round, itchy, red, raised, scaly patches on the skin. If ringworm occurs on the scalp, round bald patches may form. Athlete's foot is a fungal infection that develops in the moist areas between the toes. What are the symptoms of athlete's foot? Similar fungal infections can affect other regions of the body. Why do you think both of these fungi grow best in warm, moist environments?

The yeast-like fungus *Candida* causes the infection candidiasis, known as thrush when it affects the mouth. This fungus is a normal internal resident of the body, but when the body is weakened, *Candida* can grow in large numbers, causing an infectious disease. Patients with undeveloped or weakened immune systems, such as babies, people with AIDS, or those undergoing cancer treatment, are at higher risk of such infections.



Athlete's foot and other fungi can damage the skin and nails on feet. Most athlete's foot infections can be treated with over-the-counter creams.

How could someone avoid the fungus athlete's foot?

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Science and Society

Ergot Ergot is a group of fungi that grows on rye and related plants. When a person eats ergot-infected food, they develop ergotism. The disorder is characterized at first by convulsions, painful seizures, diarrhea, and vomiting. As the disorder progresses, it manifests with severe pathological syndromes, which include hallucinations, irrational behavior, and even death. Although it is a controversial explanation, some historians have proposed that the accusers in the Salem Witch Trial suffered from ergotism. However, ergot poisoning has additional symptoms not associated with the events in Salem. This hypothesis provides a unique way to approach and explore the historical record.

Commercial Uses of Fungi

Fungi have many commercial uses. Some sac fungi can actually feed on paint and jet fuel and are used to clean up contaminated waste sites. Another species of sac fungus produces citric acid that is used to add flavor to candy and soft drinks. Mushrooms are grown as a source of food. The bluish-green mold *Penicillium* is the original source of the antibiotic penicillin. Yeasts are vital for baking. What other commercial uses of fungi can you think of?

These molds belong to the genus *Penicillium*. They are used to make the antibiotic penicillin.

Concept Check Assess/Reflect

Summary: What are fungi? Fungi are eukaryotic organisms that can be single celled or multicellular. Yeasts are single celled, and mushrooms are multicellular. Fungi are heterotrophic and have cell walls made of chitin. Multicellular fungi have bodies made of hyphae, which together form a mass called a mycelium. Fungi can be both helpful and harmful. Types of fungi include club, sac, zygote, and aquatic. Fungi can reproduce by asexual and sexual reproduction.

1. Why have scientists placed fungi in their own kingdom?
2. How are fungi important to the environment?
3. How are fungi both helpful and harmful to other living things?
4. List some animal-like and plant-like characteristics of fungi. Do fungi appear to be more like an animal or more like a plant? Explain.

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Science Background

Lichen Caribou moss, which is actually a type of lichen, grows in Arctic and northern regions around the world. It grows on the ground and on rocks. It looks like a foamy, gray-green, spongy mass and grows to be 2.5 to 10 cm high. The lichens can survive for long periods of time without water. They just dry out and go dormant when there is little water or light. They can begin to grow again even after very long periods of dormancy. Caribou feed on lichens during the coldest periods of the season. They do this because there is little other vegetation left when the weather is cold. Lichens form about 90% of their winter diet. Lichens are high in carbohydrates that give the caribou energy to make body heat.

Teach Science Concepts

Which of the fungi described on this page and the previous two pages are parasites? Which are saprophytes? Ask students to name the fungi on the pages that they think are parasites (rusts, powdery mildews, chestnut blight, Dutch elm disease, athlete's foot, ringworm, Candida). Ask them to also point out some examples of those that are saprophytes (mushrooms, yeasts).

Assess/Reflect

Read the essential question and lesson summary with students. You may work through the concept check as a class, or use it as a formal assessment option.

Concept Check

1. Scientists have placed fungi in their own kingdom because they have unique characteristics that do not match any of the characteristics found in other kingdoms.
2. Many fungi are important decomposers and recyclers of many important compounds, including carbon and many minerals.
3. Sample answer: Some fungi are helpful because they can be eaten or used to produce food products or medicines. Other fungi can help to clean up contaminated waste sites. Some fungi are harmful because they cause diseases in plants and animals, including humans. Other fungi cause foods to spoil.
4. Students opinions of fungi being more like animals or plants will vary, but their reasoning should be supported by facts. Like animals, fungi are heterotrophs and eukaryotes. They need oxygen and release carbon dioxide like animals. Like plants, fungi, absorb their food. Like both plants and animals, fungi have cells with a nucleus surrounded by a membrane.

People in Science

Extend

Set Goals

As students study this page, ask them to think about how classification helps organize large groups to synthesize information easier.

Carolus Linnaeus Teach Science Concepts

Long before binomial nomenclature, scientists struggled to develop a method to classify living organisms that was easy to remember and navigate. Linnaeus established such a classification scheme that was based on three kingdoms—animal, vegetable, and mineral. This scheme is the basis of the popular *20 Questions* game. The first question is often "Is it animal, vegetable, or mineral?"

Linnaeus shared his knowledge with his students. His students traveled far and wide to collect samples and in doing so spread his approach to other scientific groups. In time, his system was accepted as the standard system to classify biology. **How do scientists share information widely today?** Today scientists share their work in peer-reviewed journals and at scientific conferences. At the latter, they can debate and talk in person to advance the science and make it more widely available to the public.

Concept Check

1. Sample answer: Linnaeus's classification system provides a way to group like organisms together. Today's classification system is similar but more refined in how it groups organisms. Both the Linnaean system and the modern system of classification use binomial nomenclature.
2. Sample answer: He used his study of classification to understand God's Divine order of Creation.

People in Science

Extend

Get to Know Carolus Linnaeus

Carolus Linnaeus was born Carl von Linné in 1707 in Sweden, but he is more often known by the Latinized version of his name. He is recognized as the father of modern taxonomy. Linnaeus's system for classification, naming, and ranking of organisms is still widely used today.

Although Linnaeus entered the University of Lund to study medicine in 1727, he fell in love with botany instead. He collected and studied plants as part of his medical training. Doctors at that time needed to learn to prepare and prescribe medicinal plants.

Linnaeus is particularly known for his work *Systema Naturae* ("The System of Nature") which was originally only pages long and described a taxonomy of three kingdoms of nature: stones, plants, and animals. Each kingdom was then subdivided into classes, orders, genera, species, and varieties. Linnaeus continued to revise his *Systema Naturae* throughout his life from his 11-page pamphlet to a multivolume system. Although today's biologists have added additional rankings, such as family, this system is largely unchanged.

Called to Serve

Carolus Linnaeus was filled with wonder over nature's beauty and intricacies. He spent his life devoted to learning God's order of living things.

Linnaeus was a deeply devout man, and this was reflected in his love of living things. Linnaeus felt that only by studying and classifying nature could humanity understand God's Divine order of Creation. It was humanity's task, and perhaps duty, to reveal this natural order.

Concept Check

1. In what ways does Linnaeus's *Systema Naturae* resemble today's classification of organisms?
2. How did Linnaeus express his belief in God and love of nature?

History of Science

Fishy Classification Peter Artedi, commonly called the father of ichthyology, was a friend and contemporary of Carolus Linnaeus. Although he began studying theology, he turned his attention to medicine and natural history. He was particularly intrigued by fish. He followed his passion cataloging the collection of fish owned by a wealthy Dutchman. His work was published after his death, which lead to the modern classification of fish.

Mycologist

Just as botanists study plants, mycologists study the mysteries of fungi. Mycologists begin their education by getting a four-year college degree in certain areas of biology, such as microbiology. Then most continue their college education for two or more years. There are more mycology-related jobs than there are qualified mycologists to fill them. Careers in mycology can range from applied agriculture to academic research and laboratory work.

Fungi have many uses in numerous industries. The most obvious positive application is as a food source. Most of us are familiar with mushrooms, such as the button, portobello, and morel varieties in our local markets. Identifying new species that are safe to eat is an important field. David Arora is an American mycologist. He has authored several books on amateur mushroom hunting and conservation to arm mushroom hunters with information on which species are safe to eat. Identifying poisonous mushrooms and treatments for eating toxic mushrooms are two of the tasks a mycologist might undertake. Fungi are also a constant concern in agriculture. Fungal infections can destroy crop plants, and plants tainted with even a small amount of certain fungi can poison people who unwittingly consume them. We know that 25 percent of the human population is sensitive to fungal molds, so this is an important area of research.

How fungi relate to human health is the main focus of mycology. Fungal molds in particular can affect many aspects of human health, whether they are ingested in tainted food or inhaled. Mold in homes is well known for creating respiratory illnesses for the people who live there. However, some molds heal. The fungal mold *Penicillium* has saved millions of lives. This common bread mold is now an antibiotic. Certain strains are also used to produce cheese, including blue cheeses, Gorgonzola, Brie, and Camembert.

Concept Check

1. In what ways may mycologists contribute to human health?
2. Fungi can be harmful or beneficial. Create a two-column chart to compare ways fungi can have a positive or negative effect on humans. Then identify how mycologists use their knowledge of fungi to help people.

Science Background

Dangerous Fungi The most deadly fungi is *Amanita phalloides,* commonly called the Death Cap. It is responsible for 90% of the deaths attributable to fungal poisoning in the world. Symptoms often begin 12 hours after eating the Death Cap. The symptoms include violent stomach pain, vomiting, and diarrhea. Although the effects may pass after a few days, the toxin can damage a person's liver and kidneys. Many people who eat the Death Cap have to undergo a liver transplant due to the damage from the toxins.

Set Goals

After students study this page, ask them to consider how a mycologist gathers data.

Mycologist
Teach Science Concepts

Collecting mushrooms in the field is not an expensive endeavor. Mycologists have rather simple tools in their collection kits. They use a pocket knife to dig up the base of the mushroom. They place their samples in wax paper or brown paper bags. They do not use plastic bags, because mushrooms "sweat," especially in hot weather. In a plastic bag, the mushroom will start to degrade. Finally, mycologists rely on a permanent marker to make notes and label the sample bags. This is especially important when sorting through notes and samples back in the lab. **What kind of research do you think a mycologist uses these sample mushrooms for?** Sample answer: A mycologist might try to develop treatments for people who are sickened by the mushrooms or figure out other uses for the mushrooms, such as medicine. **What else might be beneficial to a mycologist collecting samples?** Sample answer: insect spray, sunscreen, a hat, gloves, sturdy boots

Concept Check

1. Sample answer: Mycologists can help people who suffer from illnesses resulting from inhaled or ingested mold. They also help identify safe and unsafe wild mushrooms.
2. Sample answer: Fungi can have a positive effect on humans when used as a source of food and medicine. Fungi can have a negative effect on humans becuase they are a source of illnesses and toxicity when ingested. Mycologists help people by providing information on what mushrooms are safe to eat and developing treatments for people who have eaten toxic mushrooms.

Chapter 1

Assess/Reflect

Study Guide

Use the study guide to review important chapter concepts with students. Ask students what important information they would add to the lesson summaries.

Family Link

Consider assigning the following activity as a school-home connection.

Grocery Store Explore Visit the grocery store with a family member. Look for foods that contain or are processed with commercial bacteria, fungi, or protists. Keep track of the kinds of foods you see. How many of these foods have you tried?

More Fun with Science

Consider assigning the following activity as a project for students to complete.

Protist Pond Set up a small pond (a submerged dishpan will do) in a quiet, shaded area near your home. Fill the pond with non-chlorinated water. Look for evidence of lichens or algae in the area. Keep the pond full of water. Revisit the pond regularly to check on growth of fungi and protists. Collect samples to examine under the microscope. How many organisms can you identify?

Answer Key

Have students answer the questions in a notebook or on a separate sheet of paper.

1. Sample answer: Scientific names consist of two parts: a genus name followed by a species name.
2. Domain is the largest taxonomic group, and kingdom is the second-largest group.
3. An autotroph makes its own food using energy from sunlight or from chemical compounds. A heterotroph cannot make its own food but must eat other living things or products obtained from them.

Chapter 1

Review Assess/Reflect

Study Guide

Lesson 1

1. Scientists classify living organisms based on their characteristics. The organisms are placed into increasingly smaller and smaller groups until the organism is given its unique scientific name.
2. Scientists use a naming format called *binomial nomenclature* to give each organism a scientific name. Scientific names consist of two Latin names—genus and species.
3. Organisms are organized into eight levels of classification. The order of the levels used in classification is domain, kingdom, phylum, class, order, family, genus, and species.

Lesson 2

1. Bacteria are microscopic, single-celled, prokaryotic organisms. Bacteria belong to the Domain Bacteria and can be autotrophic or heterotrophic.
2. Bacteria can grow in aerobic and anaerobic environments. Most bacteria reproduce.
3. Bacteria are described by shape, spherical, rod, and spiral, and Gram-staining, negative or positive.
4. Bacteria cause many diseases, including botulism, cholera, *E. coli*, lyme disease, salmonella, and tuberculosis.
5. Bacteria decompose material at Earth's surface and are used by industry.

Lesson 3

1. Protists are eukaryotes that cannot be classified as fungi, plants, or animals. They can be autotrophic or heterotrophic. They can be very small or very large.
2. There are three main types of protists. Plant-like protists are autotrophs that photosynthesize. Animal-like protists move using cilia, flagella, or pseudopods. Fungus-like protists absorb food from their environment.
3. Photosynthetic protists form the base of freshwater and marine food chains and produce much of Earth's oxygen.
4. Helpful protists are important in making products such as agar, soaps, and certain medicines. Harmful protists cause many diseases, including malaria, African sleeping sickness, and giardiasis.

Lesson 4

1. Fungi are eukaryotic heterotrophs with cell walls composed of chitin. They are made up of thread-like structures called hyphae. The hyphae form a mass of tangled threads called a mycelium.
2. Fungi are decomposers. They release digestive enzymes outside their bodies that digest organic material that is then absorbed by the fungi.
3. There are four types of fungi: club fungi, which include mushrooms that reproduce by releasing spores; sac fungi, including yeast and morels, which reproduce by budding and by releasing spores; zygote fungi, such as bread mold, which reproduce sexually by producing zygotes and asexually by releasing spores; and aquatic fungi, such as frog fungus, which reproduce sexually using spores.
4. Fungi are both helpful and harmful. Helpful fungi break down paints and other contaminants and are also used in food and medicine production. Harmful fungi cause spoilage of food, contamination in homes and businesses, and many diseases, including chestnut blight and athlete's foot.

Assessment Options

Informal Assessment Use the questions and features provided at point-of-use in the teacher wrap.

Formal Assessment Consider assigning the chapter review in the ***Student Edition*** or the lesson support page found as an ***Online Teacher Resource***. The chapter test in the ***Teacher Edition*** may be used for formal assessment.

Performance Assessment Ask students to perform the task described below. Use the rubric on the next page to assess students.

> **Task:** Use paper squares to show taxonomic groups for an organism. Make a hierarchical stack of labeled squares (nested on top of each other) to show the organism's complete classification with your organism at the top.

Vocabulary Check

Explain how each pair of items is related.

1. scientific name—species
2. domain—kingdom
3. autotroph—heterotroph
4. hyphae—mycelium

Multiple Choice

Choose the best answer.

5. Which is the largest category of classification?
   A. domain
   B. family
   C. kingdom
   D. phylum
6. Which is the correct way to write the scientific name for a dwarf hamster?
   A. *phodopus campbelli*
   B. *Phodopus Campbelli*
   C. *Phodopus campbelli*
   D. *phodopus Campbelli*
7. How are bacteria and fungi alike?
   A. Both have cell walls.
   B. Both are autotrophic.
   C. Both are multicellular.
   D. Both are eukaryotic.
8. Which disease is caused by a protist?
   A. botulism
   B. malaria
   C. Dutch elm disease
   D. ringworm
9. What two characteristics do all fungi share?
   A. pigments that capture sunlight, flagella
   B. cells without nuclei, spores
   C. cell walls of chitin, absorb food
   D. binary fission, cilia

Check Point

Answer the following questions.

10. What characteristics do scientists use when classifying organisms?
11. Why do scientists rely on scientific names rather than common names to classify organisms?
12. Antibiotics kill certain bacteria but do not harm human cells. Explain.
13. A student discovers that fungi usually grow only in damp places. Why might fungi thrive in moist environments? Explain.
14. **Develop a hypothesis** about the effect of temperature on the growth of yeast, and **design an experiment** to test your hypothesis.

4. Multicellular fungi have threadlike bodies made of thin filaments called hyphae. All hyphae together form a tangled mass called a mycelium.
5. A
6. C
7. A
8. B
9. C
10. Scientists use body type, cell type, cell structure, and method of getting energy when classifying organisms.
11. Scientific names can be used and understood by people around the world so scientists can communicate easily with their counterparts in other countries.
12. Antibiotics prevent bacteria from reproducing by interfering with their making of cell walls but do not harm human cells, which lack cell walls.
13. Fungi usually grow in damp places because fungal mycelia have a very large surface area, which allows moisture to evaporate from fungi.
14. Sample answer: If yeast is placed in a warm area, it will grow faster than at room temperature. Prepare two identical containers containing the same amounts of water, sugar, and yeast. Place one container at each temperature.

Performance Assessment Rubric: Use the following rubric for evaluation.

3—Students list all taxonomic categories. Category names are accurate and in the correct order.

2—Students list a few taxonomic categories. Some categories are missing, out of order, or incorrectly labeled.

1—Students list one or two taxonomic categories that may not be entirely accurate.

0—Students do not list any accurate taxonomic categories.