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.

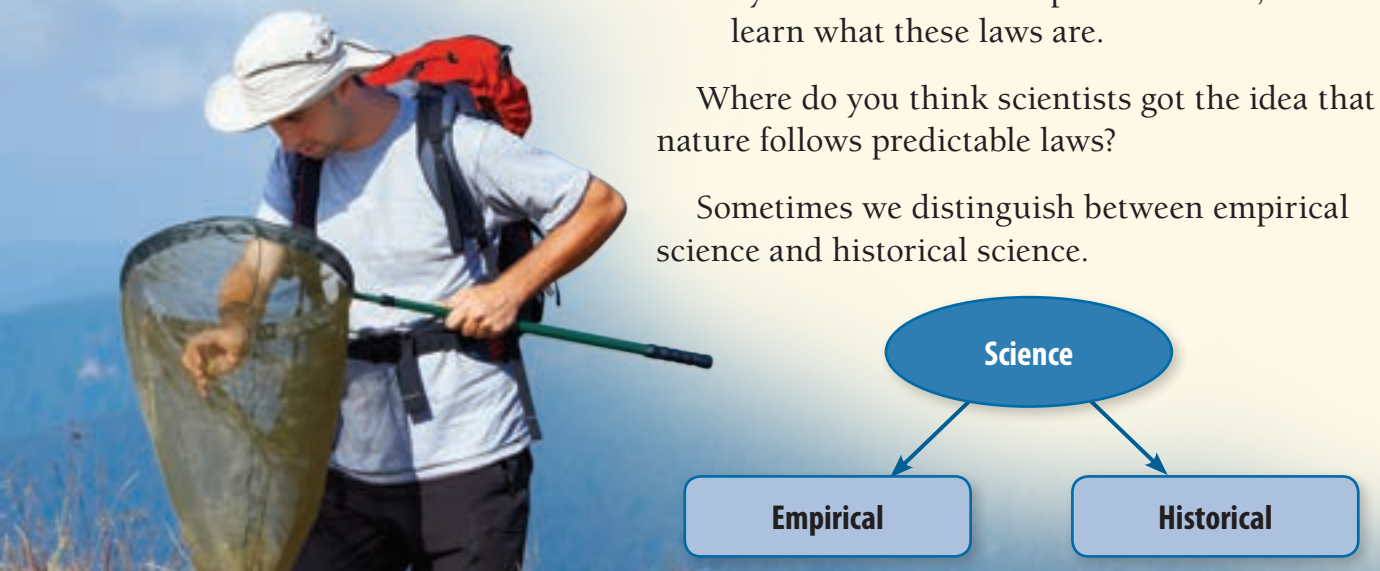
In order to systematically search for the truth, a scientist would have to be true about the natural world. What are some truths about the natural world that a scientist would consider? Can you think of any other assumptions that would need to be true for scientists to proceed with this process?

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

How Life on Earth Has Changed

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

There are many ideas about the origins of life. Several kinds of scientific evidence are consistent with the biblical story of Creation by God.

Chapter Pacing Guide

Chapter 1	Pacing
Unit Opener pp. 12–13	0.5 day
Chapter Opener pp. 14–15	0.5 day
Lesson 1 What Are Theories of Origins? pp. 16–27	4 days
Lesson 2 What Does the Evidence Show? pp. 28–35	3 days
Lesson 3 What Is Phylogenetics? pp. 36–43	3 days
Chapter Features pp. 44–45	0.5 day
Chapter Review pp. 46–47	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**
candy, assortment of popular and unpopular	2 per student plus many unpopular candies	15
crickets	10	22
cup, paper	1	20, 38
leaves from the same tree	10	22
paper (black, white, graph, newspaper)	assortment	20, 22
targets (black, white, black and white newspaper)	variety	20

Nonconsumable Materials		
Materials	**Individual/Group Qty**	**Activity Page**
beads	assortment	20
beans	assortment	20
bowl, large	1	15
car magazines	assortment	33
cars, variety in school parking lot	3 different cars	33
container, plastic, medium with lid	1	22
field key	1	38
Internet access	1	33
meterstick	1	20
paper punch	1	20
paperclips, colored	assortment	20
ruler, metric	1	22
soup mix, bean	1 bag	38
stopwatch	1	20
straw or hay	fistful	20
straws, drinking	assortment of colors	20

Chapter 1

Inquiry Kick-Off Structured Inquiry: Candy Survival SE/TE p. 15, ***Science Journal*** p. 7. **Materials:** candy

Lesson Component	Vocabulary	Lesson Objective(s)	Resources
Lesson 1 **What Are Theories of Origins?** pp. 16–27	origins creationism Informed Interventionism abiogenesis macroevolution spontaneous generation primordial soup exogenesis panspermia fixity of species artificial selection natural selection microevolution mutation Intelligent Design	• Compare and contrast the theories of origins that are consistent with the biblical worldview and those that are consistent with the naturalistic worldview. • Describe the Miller-Urey experiment. • Explain Darwin's contribution to the theory of evolution. • Compare and contrast microevolution with macroevolution.	**Science Journal** Structured Inquiry Support pp. 8–9 Guided Inquiry Support pp. 10–11 Structured Inquiry Support pp. 12–15 ***Online Teacher Resource*** Lesson Support, Skill Builder, and Scoring Rubrics
Lesson 2 **What Does the Evidence Show?** pp. 28–35	vestigial structures homologous structures analogous structures conservation of design	• Assess the evidence that scientists use to support theories of origins. • Compare and contrast creationist and naturalistic interpretations of observable data. • Define vestigial structure. • Compare homologous structures with analogous structures.	**Science Journal** Structured Inquiry Support pp. 16–17 Guided Inquiry Support pp. 18–19 ***Online Teacher Resource*** Lesson Support, Skill Builder, and Scoring Rubrics
Lesson 3 **What Is Phylogenetics?** pp. 36–43	systematics phylogenetic analysis phylogenetic tree cladogram parsimony cladistics	• Describe characteristics used to classify organisms. • Explain the process of phylogenetic analysis. • Interpret phylogenetic trees, or cladograms.	**Science Journal** Structured Inquiry Support pp. 20–21 Guided Inquiry Support pp. 22–23 ***Online Teacher Resource*** Lesson Support, Skill Builder, and Scoring Rubrics
End-of-Chapter Features	People in Science: Leonard Brand SE/TE p. 44 Science and Technology: The Geoscience Research Institute SE/TE p. 45		**Assessment Options**

Inquiry and Hands-On Activities

 **Structured Inquiry:** **Natural Selection in 15 Seconds** SE/TE p. 20 **Materials:** targets (black, white, black and white newspaper), meterstick, paper (black, white, newspaper), paper punch, paper cup, stopwatch  **Guided Inquiry:** **Hiding in a Haystack** TE p. 20 **Materials:** beads, beans, or colored paperclips, straw or hay, different-colored drinking straws  **Structured Inquiry:** **No Two Things Are Quite the Same** SE/TE p. 22 **Materials:** crickets, container with lid, metric ruler, leaves, graph paper	**Explore-a-Lab** SE/TE p. 21 **Materials:** several copies of the given sentence, scissors, envelope, drawing paper
 **Structured Inquiry:** **When You've Seen One, You've Seen Them All** SE/TE p. 33 **Materials:** variety of cars in school parking lot  **Guided Inquiry:** **Changing Cars** TE p. 33 **Materials:** Internet access or car magazines	**Lesson Activity** SE/TE p. 31 **Materials:** library or Internet access, visual presentation materials, craft supplies
 **Structured Inquiry:** **Using a Dichotomous Key** SE/TE p. 38 **Materials:** samples from a bag of bean soup mix, paper cups  **Guided Inquiry:** **Using a Field Key** TE p. 38 **Materials:** library access, field key for organisms	**Explore-a-Lab** SE/TE p. 37 **Materials:** assortment of fruits and vegetables, drawing paper, paper plates, plastic knives **Explore-a-Lab** SE/TE p. 42 **Materials:** assortment of silverware and kitchen utensils, large sheet of paper

Chapter Test TE pp. **xx–xx** and as an ***Online Teacher Resource***
Concept Check SE/TE pp. 27, 35, and 43

Unit 1 Life Science

Introduce the Unit

Have students examine the photo and describe what they see. Then have students read the overview and make a list of questions they have. Ask students to think about how the plant life in the photograph is different from the plant life in their own environment.

Connect the Content

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

Ch. 1 How Life on Earth Has Changed Scientists have different opinions on how the life forms in this image came into existence and how they have changed over time. Creationists believe God created all forms of life. Evolutionists believe life evolved from a single common ancestor over millions of years.

Ch. 2 Types of Plants Comparing and contrasting the divisions that make up the plant kingdom provide critical information about plant life and the environment in which plants live.

Ch. 3 How Plants Survive Many factors influence plant survival. Analyzing relationships, examining processes, and distinguishing between factors that promote or deter survival provide information and insight into the past, present, and future Earth.

Ch. 4 How Animals Survive Investigating the ways animals adapt to changing environments and analyzing the impact of humans on plants, animals, and ecosystems help scientists to make predictions and recommendations for positive change.

Science and Society

Life Discoveries People of primitive societies had no means by which to explain what they observed about Earth. These ancient people created stories to explain what they did not understand. Throughout the centuries, many have challenged these stories. These challenges, often driven by the curiosity of great thinkers such as Francesco Redi and Stanley Miller, have led to the discovery of evidence for scientific explanations. Curious scientists today continue to use many different methods to search for explanations about what they observe. There is still more to be discovered. Learning about life on Earth provides the basis for future discoveries.

Unit Overview

How have living things on Earth changed over time? Are there forces that cause changes that are passed on to offspring? How are living things classified? Do we classify them according to how their structures look, how they function, or both? If they change, how would that affect our classifications?

In this unit, you will learn about theories surrounding the origins of life and theories about how life has changed, or evolved. What evidence is used to support scientific assumptions? How do you think these compare with Scripture? Scientists organize their findings and classify the organisms they study.

As you continue your studies in this unit, you will focus on the plant kingdom. This large division of life consists of vascular and nonvascular plants. How do scientists classify the plants? What structures and functions are compared? You will develop an understanding of plant reproduction and how botanists use this knowledge to classify the organisms.

You will also learn about plant and animal survival by analyzing relationships, examining processes, and distinguishing between factors that promote or deter survival. How do you think plants and animals adapt to changing environments? What impact do humans have on plant and animal species? You will conclude this unit by analyzing the impact of human behavior on ecosystems.

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

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Science Background

Blue Lake Blue Lake on North Stradbroke Island in Australia is a scientific wonder and one that seems to have had little change over thousands of years. Scientists have discovered that this lake appears to be nearly unchanged by climate change happening all around it. This lake has its water replenished about every 36 days, thanks to the aquifer that flows into it. Scientists believe that this has helped the water depth, the chemistry of the water, and the water temperature to remain stable over nearly 7000 years. Blue Lake supports a population of the Oxleyan Pygmy Perch, an endangered fish, so scientists are watching the lake closely for any changes that may occur.

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 Challenges described in the ***Science Journal.*** Check students' progress throughout the unit, and encourage students to discuss their challenges with their families and friends.

Teach Using Inquiry

Open Inquiry

Investigating Adaptation

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

Earth provides a wide variety of habitats and conditions in which organisms can live. The key to any organism's survival is adaptation. What plant or animal adaptations have you observed? How can you demonstrate the benefits of a particular adaptation?

Have students begin by doing research, asking questions, and making observations. Students should then develop a list of questions about cells. Challenge students to turn one of their questions into a question that can 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 to the class. You may wish to schedule a one-day Science Expo in your classroom! Use the Guide to Science Projects in the ***Online Teacher Resource*** for additional support.

Chapter 1

How Life on Earth Has Changed

Introduce the Chapter

The Big Idea

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

There are many ideas about the origins of life. Several kinds of scientific evidence are consistent with the biblical story of Creation by God.

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.

What scientific evidence are you aware of that supports the story written in Genesis 1–2? Answers will vary. Students should be encouraged to provide specifics rather than generalities. Students may suggest evidence of Design to support the Creation story.

Activite Prior Knowledge

Students studied classification, DNA, and genetics in Grades 5, 6, and 7. **What characteristics do scientists use to classify organisms?** body type, cell type, and cell structure **How might DNA help us understand how life on Earth has changed?** If organisms have changed over time, so has DNA.

Essential Questions

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

- **What Are Theories of Origins?**
- **What Does the Evidence Show?**
- **What Is Phylogenetics?**

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

How Life on Earth Has Changed

Scripture Spotlight

Various theories of origins exist, some of which conflict with Creation as described in **Genesis**. Learn more about origins and grow your faith in God as Creator in the following passages in this chapter.

Isaiah 45:18 (p. 17)
Psalm 139:13–16 (p. 26)
Exodus 19:4 (p. 31)
Psalm 55:6 (p. 31)
Matthew 23:37 (p. 31)
Matthew 12:46–50 (p. 41)

Horseshoe crabs look exactly like the fossils of the animals that lived long ago. There is little evidence that they have changed over time.

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 45:18 (p. 17)
Psalm 139:13–16 (p. 26)
Exodus 19:4 (p. 31)
Psalm 55:6 (p. 31)
Matthew 23:37 (p. 31)
Matthew 12:46–50 (p. 41)

The Big Idea

There are many ideas about the origins of life. Several kinds of scientific evidence are consistent with the biblical story of Creation by God.

What scientific evidence are you aware of that supports the story written in **Genesis 1–2**?

Inquiry Kick-Off Engage

How do you think the horseshoe crab survived so long without much change? Why have some populations become extinct, while others survive? Is the survival of species random or is something more involved? In your ***Science Journal***, you will observe that what might be perceived as random isn't so random after all.

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Science Background

Creation "So God created man in his own image." (**Genesis 1:27**) "Here is clearly set forth the origin of the human race … There is no ground for the supposition that man was evolved … from the lower forms of animal or vegetable life. Such teaching lowers the great work of the Creator … The genealogy of our race, as given by inspiration, traces back its origin, not to a line of developing germs, mollusks, and quadrupeds, but to the great Creator. Though formed from the dust, Adam was `the son of God.'" (*Patriarchs and Prophets*, pp. 44–45) Although we will be examining scientific evidence that is consistent with what the Bible teaches, it is the Bible itself that provides the foundation for our belief in Creation.

Engage

Start with an Activity

Inquiry Kick-Off

Use this activity to engage students, determine students' background knowledge, and create excitement about the lesson content.

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

Include popular and unpopular candies in the bowl. Use a variety of colors, sizes, and brands. Avoid candies with nuts. Allow for two candies per student plus many unpopular candies among students, such as black licorice.

Create Explanations

1. Sample answer: Traits that allow for evading predators can help a species or individual survive.
2. Sample answer: The candies selected from the bowl were similar to organisms that are easily preyed upon. Those candies did not "survive" because they had traits that were disadvantageous for survival.

Set a Goal

Before students begin this chapter, have them preview the objectives and vocabulary on the first page of each lesson. Discuss what the objectives mean and ask students which terms are familiar or unfamiliar. Have them record unfamiliar terms in their notebooks so they can find definitions and explanations as they read.

Lesson 1

Essential Question

What Are Theories of Origins?

Preview Lesson Content

Read the objectives with students and help them pronounce each term in the vocabulary list. Make a K-W-L chart (What I **K**now, What I **W**ant to Know, What I **L**earned) on the board. Add some ideas to the first two columns before reading. Complete the last column after reading.

Explain

Origins

Objective

- Compare and contrast the theories of origins that are consistent with the biblical worldview and those that are consistent with the naturalistic worldview.

Set Goals

As they study this lesson, ask students to evaluate the various ideas about origins against their own worldview.

Develop Key Vocabulary

origin This term comes from the Latin word meaning "beginning" or "source."

Teach Science Concepts

Aristotle offered the idea of spontaneous generation long before scientists conducted experiments. **If Aristotle had been an experimenter, how might he have tested his hypothesis?** He might have looked for fish eggs surviving in the dried mud of the pond.

Explain that spontaneous generation is at the basis of evolution. According to evolutionists, there was something, such as nonliving elements, at the beginning from which life evolved. These nonliving elements had to generate somehow.

Lesson 1

Essential Question

What Are Theories of Origins?

Objectives

- Compare and contrast the theories of origins that are consistent with the biblical worldview and those that are consistent with the naturalistic worldview.
- Describe the Miller-Urey experiment.
- Explain Darwin's contribution to the theory of evolution.
- Compare and contrast microevolution with macroevolution.

Vocabulary

origins
creationism
Informed Interventionism
abiogenesis
macroevolution
spontaneous generation
primordial soup
exogenesis
panspermia
fixity of species
artificial selection
natural selection
microevolution
mutation
Intelligent Design

Do you know the two primary theories of origins—how life began on Earth? What do these two theories have in common? What are their differences? What have you learned before that can help you answer this question? Is it possible to use the scientific method to determine the origins of life? Why or why not?

Origins Explain

You may recall that **origins** means "beginnings." In the study of origins, scientists develop theories that try to explain where the world came from and how life on Earth began. How do they find evidence that helps them explain past events in Earth's history? They face many obstacles in their study of origins. The scientific process, which works so well when observations are made and experiments are repeated in the present, is limited in its ability to help with historical science.

You have already learned that all scientists are influenced by their worldviews. This is especially true when they are studying historical science. Recall what you learned in the ***Inquiry Handbook*** about the assumptions of the biblical and naturalistic worldviews. Scientists from both worldviews agree that supernatural events—like Creation by God—cannot be tested scientifically. For naturalistic scientists, this assumption prevents them from considering the possibility that God is the Creator, but for scientists with a biblical worldview, it is the starting point from which they do their research and experiments. See the chart on the next page for a comparison of the two approaches to studying the origins of Earth.

Science Background

Not a Myth It has been suggested that the Creation story in Genesis is a myth. It has even been suggested that the biblical account borrows from other famous myths written earlier. Drs. Gerhard and Michael Hasel investigated this issue in an article called "The Unique Cosmology of Genesis 1 Against Ancient Near Eastern and Egyptian Parallels." After comparing the Creation account with the numerous ancient Near Eastern (ANE) stories, they concluded that the Bible account is without rival. In contrast with ANE myths in which Earth had no beginning, Creation happened through struggle, and the gods created people to do labor for them, the Genesis account describes a beginning and people lovingly created to be in a relationship with God. The biblical story of Creation, which had only been passed on orally to that point, was probably written down for the purpose of combatting the untruths of the ANE myths.

Theories of Origins

Although there are multiple variations of each theory, there are two basic ideas about where life came from: Creation by God or the origins of life through evolutionary processes. Study the chart to compare the two theories.

Creation and Informed Intervention

Creationism is the idea that God created the Universe and all life, as described in **Genesis 1–2**. **Informed Interventionism** is a broader concept that also acknowledges God's intervention at other times in history, such as the biblical Flood.

Abiogenesis

Abiogenesis, the idea that life came from nonliving things, goes back to the time of the Greek philosopher Aristotle in the fourth century B.C. Aristotle observed that no plant or animal survived when a pond dried up. When rain refilled the pond, he saw tiny fish. He concluded that the fish must have generated from the sand of the pond through **spontaneous generation**, the idea that life can arise from nonliving materials.

Fast-forward to the 1600s. Observers reported what they thought were examples of spontaneous generation. Jean-Baptiste van Helmont explained that mice would form if wheat grains were put in a pot with a dirty shirt. Many people observed maggots on rotting meat. They assumed the maggots formed from the meat.

Scripture Spotlight

What does **Isaiah 45:18** say about God's purpose in Creation?

	Worldview	
	Biblical Worldview	Naturalistic Worldview
	Theory	
	Creationism and Informed Interventionism	Abiogenesis and Evolution
Origins	Living and nonliving matter were created by God. (**Genesis 1–2**)	**Abiogenesis**: Life arose spontaneously from nonliving matter many millions of years ago.
Explanation for what we see around us now	Sin has caused change. (**Genesis 3**) Change is limited and not progressive.	**Macroevolution**: All present life forms descended from a simple, one-celled organism.

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Science Background

Theories Be sure students understand the nuances of the word *theory*. Outside scientific circles, people sometimes use the word *theory* rather carelessly. They may say they have a theory about something, meaning only that an idea has occurred to them, not that they have drawn a particular conclusion based on a lot of evidence. When scientists use the word *theory*, they are referring to a widely accepted statement based on scientific evidence. Scientific theories must be testable, and it must be possible to falsify them, or prove them to be untrue. Since the origins of life are not observable or repeatable, they are not testable scientifically. It is appropriate to call microevolution a theory because it can be tested. Scientifically speaking, however, the term *theory* cannot be accurately applied to either macroevolution or Creation because neither can be tested or falsified using the scientific process.

Theories of Origins

Objectives

- Compare and contrast the theories of origins that are consistent with the biblical worldview and those that are consistent with the naturalistic worldview.
- Describe the Miller-Urey experiment.
- Explain Darwin's contribution to the theory of evolution.
- Compare and contrast microevolution with macroevolution.

Develop Key Vocabulary

Creationism This term describes the idea that the Universe and life were created by God. Because science is committed to discovering the natural causes for phenomenan in the natural world, many scientists believe that creationism should not be a part of scientific discussions.

Informed Interventionism This term is a broader concept that goes beyond the Creation event to include God's intervention at other times in history. Using this term has enabled some scientists to minimize the negative connotations sometimes attached to the term *creationism* in scientific circles.

abiogenesis This term was coined by T. H. Huxley in 1870. The prefix *a-* means "not" or "without." The word part *bio* means "life" and *genesis* means "beginning." Ask students to reason out the meaning of the word *abiogenesis* from its parts. It literally means "beginning without life." This term is synonymous with the term *spontaneous generation*.

spontaneous generation This term is synonymous with *abiogenesis*. It is the idea that life can arise from nonliving materials.

Scripture Spotlight

Isaiah 45:18 says that He created the Earth to be inhabited.

Explain *(cont.)*

Develop Key Vocabulary

primordial soup This term was coined by J. B. S. Haldane in 1929. The adjective *primordial* is from the Latin word *primordialis,* meaning "first of all, original." Have students state a definition for this term using their understandings from the text.

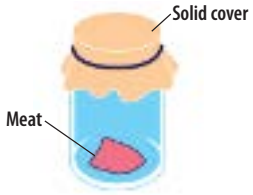
Teach Science Concepts

Why might air be an important variable in Redi's experiment? By using the net, Redi controlled all the variables in his experiment except the independent variable he wanted to study: the access of flies to the meat. In the experiments in which he sealed out the air, his result might have been caused by the absence of air, and his conclusion could have been questioned. **How did Redi's experiment refute Aristotle's idea?** It showed that life did not spring from nonliving matter. The source of the maggots was the flies that landed on the meat and laid their eggs there.

After studying the Miller-Urey experiment, have students discuss the materials, procedure, and results. **What did Miller and Urey do?** They boiled a mixture of water and gases in a flask and then sent electrical charges periodically through it. **What did Miller and Urey find?** Several types of amino acids formed in the mixture. **How did the Miller-Urey experiment impact the idea of evolution?** The results showed that it is possible for organic molecules (amino acids) to form from inorganic materials. However, many of the amino acids that were formed are not the ones found in living organisms. Furthermore, recent experiments have cast doubt on the composition of the original mixture.

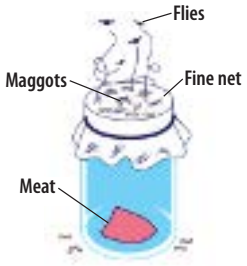
Understand Visuals

How does Redi's experiment support his hypothesis? The results of Redi's experiment proved that spontaneous generation does not happen. Specifically, maggots do not come from meat; they come from flies.



Jar Completely Sealed

Open Jar



Jar Covered with Fine Net

Redi suspected that flies laid eggs too small to be seen with the naked eye on the meat.

How does Redi's experiment support his hypothesis?

In 1668, Francesco Redi, an Italian physician and biologist, designed and carried out a controlled experiment to test spontaneous generation. He placed equal samples of meat into several jars. He left some open to the air. He covered others with a fine net. Other jars were sealed completely. Redi observed flies entering and maggots forming in the open jars. In the other jars, the meat decayed, but there were no maggots and no new flies. What was an important variable in Redi's experiment? You have already learned how Louis Pasteur's experiments in the 1800s, which were built on Redi's work, finally disproved the theory of spontaneous generation. What other method could Redi have used to test spontaneous generation?

In the twentieth century, scientists investigating the origins of life shifted their attention away from whole organisms. They began looking at the organic molecules that make up living things and wondering how they originated. In 1924, the idea of abiogenesis was resurrected when Alexander Oparin proposed that life on Earth began in the oceans. In spite of the facts that Redi and Pasteur had already demonstrated that the spontaneous generation of life is not possible, Oparin suggested that it had been possible at some time in the past when conditions on Earth were different. It was hypothesized that at some previous time, the oceans were filled with carbon dioxide, methane, ammonia, and water. This is sometimes referred to as **primordial soup**. Next, it was suggested that the energy needed to change inorganic compounds into organic chemicals of life could have come from the Sun's ultraviolet radiation. It was further hypothesized that those organic compounds formed into short segments of DNA that then linked together to form longer chains. From there, the hypothesis suggested that the first actual life forms, thought by scientists to be prokaryotes, formed.

You may recall that in 1953, Stanley Miller and Harold Urey designed experiments that attempted to simulate this process and create organic molecules, such as amino acids, in the laboratory. They simulated an atmosphere made up of water, methane, ammonia, and hydrogen, shot electrical charges through it to simulate lightning, and let it bubble for a week to simulate Earth's hot environment. How did Miller and Urey know the composition of Earth's atmosphere?

When Miller and Urey analyzed the mixture, they found several different amino acids in it, which caused great optimism among scientists. Their excitement turned out to be premature, however, because of several issues.

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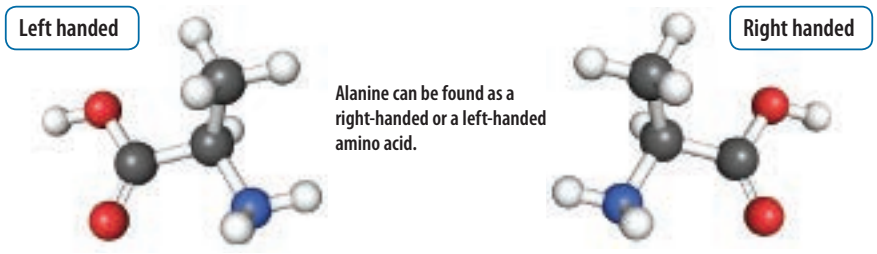
Scaffolded Questions

Approaching Level **Where do the offspring of a mouse, a fly, or any other organism come from?** The offspring come from the parents.

On Level **Why was it important for Redi to leave some jars of meat uncovered and others covered?** Redi hypothesized that flies came from other flies. It was important to keep some jars uncovered so that flies had a chance to come in contact with the meat. The covered jars kept the flies away.

Above Level **Imagine you are a scientist in 1670. How would you set up an experiment to disprove the idea that mice came from dirty shirts and grain?** Sample answer: I would place dirty shirts and grain in a sealed jar and set the jar next to dirty shirts and grain in a barn. I would observe the jar and the barn every day until mice were observed in one of the areas.

Issues with Miller-Urey Experiment
• Many of the molecules produced were not useful for creating life and were sometimes even destructive.
• Some processes responsible for generating the amino acids and molecules could break them down even faster.
• Opinions about what Earth's atmosphere was actually like continue to change.
• Except for glycine, amino acids are either left handed or right handed, which means they are mirror images of each other. The amino acids found in living things are all left handed. The amino acids produced in the Miller-Urey experiments were a mixture of left and right handed. How would that affect the probability of the correct left-handed amino acid sequences forming naturally?



Alanine can be found as a right-handed or a left-handed amino acid.

Despite the initial optimism, the work of Miller and Urey and modified experiments by other researchers since then have come nowhere near producing life. This recognition has caused scientists to redirect their attention to other possibilities. Researchers have since investigated an idea called *RNA world,* which suggests that life began when self-replicating RNA formed an intermediate, "pre-cellular" life form with similar results as the Miller-Urey experiments.

As scientists recognize how impossible it would be for life to have sprung from nonliving material here on Earth, some have suggested a hypothesis called **exogenesis**, which suggests that life began somewhere else. Because organic molecules have been found in comets and meteorites, it has been suggested that the earliest living things traveled to Earth on an asteroid or inside a comet. In what way does this help naturalistic scientists show how life originated on Earth?

A similar idea, known as **panspermia**, suggests that life is actually widespread throughout the Universe. Many scientists reject this idea. Does suggesting that the origins of life happened somewhere else in the Universe solve any of the problems associated with its origins here?

Scientific research continues to discover the staggering complexity of cells, DNA, the proteins from which they are made, and the information they contain. As a result, the spontaneous origins of life from nonliving matter is recognized as an extremely improbable event.

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Science Background

RNA World RNA is composed of a long chain of ribonucleotides. Each ribonucleotide has three parts: (1) nitrogenous base (either purine or pyrimidine), (2) ribose sugar, and (3) phosphate. Wondering whether life began with RNA, scientists have tried to assemble ribonucleotides from these three parts. In the laboratory, scientists have been able to make all the individual parts. However, they have only been able to put all parts together in highly controlled experiments. One reason for this is that the presence of the parts necessary to make the nitrogenous base prevents ribose sugar production. Other difficulties include the fact that cytosine (one of the pyrimidine bases) has been shown to be very unstable and that ribose sugar, which is difficult to produce, decomposes rapidly. The production and maintenance of stable populations of all four ribonucleotides at the same time have not been demonstrated.

Develop Key Vocabulary

exogenesis This word comes from two Greek words: *exo* meaning "outside" and *genesis* meaning "beginning" or "origin." Ask students why this is a good word for the idea that life on Earth might have come from somewhere else.

panspermia This term originated from the Greek word *panspermos,* meaning "containing all kinds of seed." Ask students whether they recognize the root word in the term that refers to "seed." (*sperm*)

Teach Science Concepts

Post the question "Which came first—the chicken or the egg?" where students can see it as they enter the classroom. Build on the discussion that occurs to introduce a question scientists ask: Which came first—DNA, protein, or RNA? Remind students that DNA contains the genetic code for all proteins needed by the cell and that RNA is needed to translate this code and to make proteins. Explain that proteins are required to make DNA and RNA, but proteins cannot be made without DNA and RNA. Consider sharing the information about RNA World from the science background paragraph on this page.

Understand Visuals

Amino acids are organic molecules. They contain carbon. These are images of alanine, an amino acid. The colors of the spheres represent the following elements: grey—carbon, blue—nitrogen, red—oxygen, and white—hydrogren.

Incorporate Inquiry Practice

Practice: Model Have students build a structure using 12 interconnecting blocks of various sizes to represent an amino acid. Then place the modeled amino acid next to a hand mirror. Observe the mirror image of the modeled amino acid. How does this compare with the left- and right-handed amino acids in nature?

Discover

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

Structured Inquiry

Natural Selection in 15 Seconds

How does natural selection work?

Preparation and Tips

Consider cutting the 1-m squares in advance.

Predict **How will background colors affect the selection of colored dots?**

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

Inquiry Practice Tip

Record Carefully count the results and record data in the correct location on the data table.

Expected Results

On the black target, white dots will be selected more often. On the white target, black dots will be selected more often. The newspaper target results will vary depending on the amount of black and white in the newspaper.

Create Explanations

1. The organisms best suited for the environment are most likely to survive and reproduce.
2. The dots represent variety within a species.
3. Sample answer: White dots would most likely stand out against darker colors, while black dots would most likely stand out against lighter colors.
4. Sample answer: The model does not account for changes in the environment such as the number of predators or resources available to support the species.
5. Answers will vary. Students should support their answer with observations and personal beliefs.

Structured Inquiry

Discover

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

Science Journal

Natural Selection in 15 Seconds

How does natural selection work?

Materials
- paper cup
- meterstick
- paper (black, white, newspaper)
- paper punch
- stopwatch
- targets (black, white, black and white newspaper)

Procedure

1. Make three targets that measure 1 m × 1 m in size. Make one target from black paper, one from white paper, and one from newspaper.
2. Use the paper punch to make 10 paper dots each from black paper, white paper, and newspaper.
3. Mix the dots together in the paper cup.
4. Place the black paper target on the floor. Without letting your partner watch, scatter the mixed dots from the cup over the black paper target. Be sure the dots are not stacked on each other and that all are on the target.
5. See how many dots your partner can pick up in 15 s. **Record** the number of each color picked up. Repeat Steps 4 and 5 two more times.
6. Repeat Steps 3–5, first using the white paper target and then the newspaper target. Calculate the average number of dots picked up on each target.
7. Then switch roles with your partner and repeat Steps 3–6.

Analyze Results

Graph the average number of dots picked up on each color target.

Create Explanations

1. How does natural selection work?
2. How does this activity model natural selection?
3. Suppose you used a sheet of newspaper that was filled with color advertising. Which color dot do you think would be picked up the most? Why?
4. What are the limitations of this model? Explain.
5. Do you think that natural selection provides a complete explanation of the variety of life on Earth? Explain.

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Inquiry Extension

Extend

Guided Inquiry

Hiding in a Haystack

How does the color affect the natural selection of organisms?

Extend the Structured Inquiry by having students design their own natural selection experiment using the materials provided.

Teaching Tip Instead of using black and white dots, you may also use beads, beans, or colored paperclips. You may also substitute straw or hay and different-colored drinking straws for students to use in the activity.

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

Explore-a-Lab

Structured Inquiry

What might cause scientists to have different explanations even though they have access to the same data?

Scientists gather information and make hypotheses based on what they find. Oftentimes, as more data is gathered, hypotheses will change. With your group, you will also make and alter hypotheses.

1. Your group will be given an envelope with word cards in it. Randomly choose 5 cards from the envelope and place them face up on the table.
2. Discuss with your group what story you think the words form. Write your hypothesis on a sheet of drawing paper.
3. Randomly choose 5 more word cards and place them with the previous 5. Discuss with your group what the story could be with the 10 words.
4. Write a revised hypothesis on your paper.
5. Choose another 5 word cards randomly, combine them with the previous 10 cards, and write one more revised hypothesis with your group.
6. Did your group's hypothesis change with each addition of data? Each group will share its final hypothesis about what the complete story is about. Compare the groups' hypotheses. Your teacher will tell you the final story. How does it compare with your hypothesis?

Microevolution

For many centuries, people thought that animals and plants never changed. They believed that life on Earth was exactly the same as what was created by God during the Creation week. This idea was called the **fixity of species**. In the seventeenth century, however, Swedish botanist Carolus Linnaeus observed that plants could be the result of hybridization, or the crossing of two different species. As breeders purposely selected plants or animals with desirable characteristics to become parents of the next generation, the desirable traits were passed on to the offspring and changes in the species occurred over time. This process is known as **artificial selection**, and it was influential in the transition from a belief in the fixity of species to the acceptance of a new idea, the theory of evolution.

Evolution is often defined simply as "change over time." Remember that this change does not happen to individuals, but to populations, or species, which are groups of organisms consisting of similar individuals that interbreed in nature.

English Language Learners

Cognates Many of the terms used in this lesson have Spanish language cognates: *evolución (desarrollo gradual, transformismo), natural, artificial,* and *selección*. French cognates include *évolution, développement, graduelle, transformation, naturel, artificial,* and *sélection*. Have students practice the English pronunciation of the cognates and note the similarity of definitions across the languages.

Explain *(cont.)*

Develop Key Vocabulary

fixity of species The word part *-ity* means "condition or quality of being." *Fix*, in this case, means "established or settled." *Fixity* of species relates to species that are established, meaning they are not changing.

artificial selection This term refers to a process in which desirable characteristics from plants or animals are purposefully selected by breeders to be passed on from generation to generation.

Explore-a-Lab Structured Inquiry

Type the following sentence in a large font to fit several copies of the sentence on one sheet of paper. Do not include punctuation marks and make all letters capitalized. For each group of students, make a copy of the sentence, cut the words out, and place the words in an envelope.

The tall, skinny, green parrot carrying a pill bug flew into the red, wooden barn on the hill and ate a bag of seeds.

As students begin working on the lab, remind them not to share their hypothesis with other groups. After all groups have had an opportunity to finalize their hypothesis, read the original story to students. Have groups discuss similarities and differences between their hypothesis and the original sentence.

What might cause scientists to have different explanations even though they have access to the same data? Sample answer: Scientists may receive the data at different times, in different orders. The order in which data is received may affect their hypothesis. A scientist's worldview may also influence how the information is interpreted.

Develop Key Vocabulary

natural selection Discuss how natural selection is like artificial selection. Environmental conditions, not people, act as forces of selection.

Extend

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

Structured Inquiry

No Two Things Are Quite the Same

How much variation is there in a species?

Preparation and Tips

Remind students that the range of data is the difference in variation (subtract the smaller number from the larger number).

Predict **How much variation will you find in the lengths of cricket femurs, human fingers, and leaves?**

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

Inquiry Practice Tip

Measure To be consistent, measure from the tip of the finger to the middle of the second joint. Measure at the longest point of the leaves.

Expected Results

Students might notice more variation among the human finger and leaf lengths and less variation among the cricket femur lengths.

Create Explanations

1. All species show differing degrees of variation.
2. Answers will vary.
3. Variation within a species shows God's Design of DNA that allows for diversity within living organisms.

Chinese shar-pei dogs have a history dating back to 200 B.C. Their uniquely wrinkled skin is a result of hundreds of years of artificial selection.

A number of different scientists over many years thought about the idea of evolution. When Charles Darwin published his book *On the Origin of Species by Means of Natural Selection* in 1859, his major contribution was his theory that the evolution of new species occurred as the result of natural selection. He suggested that a process similar to artificial selection is at work in nature.

Darwin's theory is summarized by these four points:

- **Competition** Each species produces more offspring than can actually survive. This leads to competition between the offspring for food, water, and space. What are some examples of competition among individual animals or species?
- **Variation** Each individual within a species has a slightly different genetic make-up, so its characteristics are different, producing variety within a species. How do dogs of the same breed differ? How do students in your classroom differ?
- **Adaptation** Because some variations are more advantageous than others, certain individuals within a species are better suited for surviving in their environment. What are some characteristics of individual polar bears that might make them better suited than other polar bears to survive in an Arctic environment?
- **Selection** Those that survive and reproduce pass their characteristics on to their offspring, making them better equipped to survive.

This pattern of variation, greater survival, and successful reproduction is called **natural selection**. You have already learned one of the most well-known examples of natural selection—the finches found by Darwin in the Galápagos Islands and studied later by Peter and Rosemary Grant. Over time, changes in the beak size of the finch population happened in response to changing weather conditions. During drought years, plants with smaller seeds did not grow well, which meant the small-beaked birds that ate them did not survive well.

Check out your ***Science Journal*** for a Structured Inquiry that explores variation in three different species.

Extend

Science Background

Natural Selection During the mid-1800s, two different men, Charles Darwin and British biologist Alfred Russel Wallace, each were thinking about similar ideas. Seeing artificial selection at work and wondering whether there was a similar process at work in nature, as well as being influenced by a book about population growth, both men devised a similar theory. Both men presented their theories at a meeting of the Linnaean Society in 1858. Darwin went on to publish his theory in his famous book *On the Origin of Species*. While others had suggested evolutionary ideas before Darwin, he was the first to suggest how the process could have happened. At that time, scientists did not understand about DNA and Mendelian genetics.

As a result, fewer survived to reproduce, and the number of small-beaked birds in the population declined. During years with large amounts of rain, the process reversed. Although no individual beak sizes changed, the frequency at which certain beak sizes appeared in the population changed over time.

Another common example that illustrates natural selection involves the peppered moth and its history over the last two hundred years in England. Originally, the light-colored moths were camouflaged against the trees and flourished as a result. The darker moths stood out more and were eaten more often by predators. During the Industrial Revolution, however, pollution became widespread and the trees were often covered with soot. Which kind of moth would be better camouflaged then? Which kind would be more likely to be eaten by predators? How do you think that affected the population of peppered moths? What do you think happened when improved environmental standards improved the pollution problem?

Small changes over time, such as the size of bird beaks changing a little from generation to generation in the finch population or the color changing within the peppered moth population, are examples of **microevolution**. Scientists from both worldviews acknowledge the presence of microevolution in nature. Where scientists from different worldviews disagree is in the discussion about macroevolution.

Peppered moth (*Biston betularia*)

How do changes in the coloring of peppered moths explain the concept of microevolution?

Macroevolution

Macroevolution involves much larger changes—the kind of changes that would have been necessary to change a microscopic cell to a fish or a reptile to a bird. What kind of new structures and physiological processes would have to evolve to change a prokaryote to a eukaryote, a single-celled organism to a multicelled one, an aquatic creature to one that lives on land, or an earthbound creature to one that can fly? Recall the evolutionary claim that all present life forms descended from a simple, one-celled organism and imagine the amount of change necessary to change a microscopic cell into a human being.

Social Studies Link

Pollution and the Industrial Revolution The Industrial Revolution began in Britain in the mid-1700s. It was a long, slow process that took place over many decades. Up until that time, most people worked the land, using simple tools for farming and agriculture. Improved methods of farming, new technologies such as the steam engine, the spinning mule, and steam-powered locomotives, and improved methods of harnessing energy through the use of burning coal led to industrial towns and cities. Factories grew all over Britain, increasing production of goods and jobs for workers. The soot from the factories, however, resulted in a cloud of soot over the countryside and the ensuing pollution.

Develop Key Vocabulary

microevolution The prefix *micro-* means "small." Have students pair this meaning with the meaning of the word *evolution* to develop a definition for *microevolution*.

Teach Science Concepts

Using the Industrial Revolution example, ask: **What effect have humans had on natural selection?** Sample answer: Human activity affected which variations in a species were more likely to be passed on. Ask students whether they see this as a positive or negative influence in nature. Allow students time to discuss the issue of human influence and intervention. They might discuss the idea of saving species from extinction as well.

As you discuss macroevolution with students, consider that eukaryotic cells are generally between 10 and 100 times larger than prokaryotic cells and contain many membrane-bound organelles that prokaryotic cells lack.

What changes would a single-celled eukaryote have to undergo to become a large multi-celled organism, such as a whale? Single-celled eukaryotes would have to develop a multitude of different systems that could be organized into the different kinds of tissues, organs, and organ systems that compose most multicellular organisms. **In your opinion, are changes like this possible? Why or why not?** Answers will vary, but students should base answers on scientific proof, observations, and their beliefs.

Understand Visuals

How do changes in the coloring of peppered moths explain the concept of microevolution? The peppered moth population exhibited small changes in its color over a short period as darker-colored moths were more likely to survive and pass on their traits. The lighter-colored moths became more common again after the soot was cleaned from trees, making those colored moths more likely to survive and pass on their traits.

Explain *(cont.)*

Develop Key Vocabulary

mutation This term comes from the Latin word *mutationem,* meaning "a changing, an alteration, a turn for the worse."

Teach Science Concepts

What does the evidence indicate about how much change a species might experience over hundreds of years? The evidence indicates that the amount of change in living organisms is limited. Ask students whether anyone remembers what happened to the finches on the Galápagos Islands that they learned about in fifth grade. If possible, ask a student to tell the rest of the class about finches on the Galápagos Islands. Although the beak size changed within the finch population, the finches remained finches. **What other animals have experienced similar changes?** Sample answer: the peppered moths and rat snakes

The theory of evolution would not expect major changes to happen within just a few generations, but experiments on fruit flies show that even after hundreds of thousands of generations, they are still fruit flies. Even the fossil record, which is discussed in greater detail in Chapter 10, contains very few creatures that could be considered intermediates. The usual pattern finds distinct creatures appearing in and disappearing from the fossil record with only limited changes. **What evidence do you think an evolutionary scientist would cite as proof of macroevolution?** Sample answers: genetic evidence of related DNA and similar structures with the same or different uses, for example, bat wings and penguin wings **How would a creation scientist explain these similarities?** a single designer reused some design elements to create variety among species

Understand Visuals

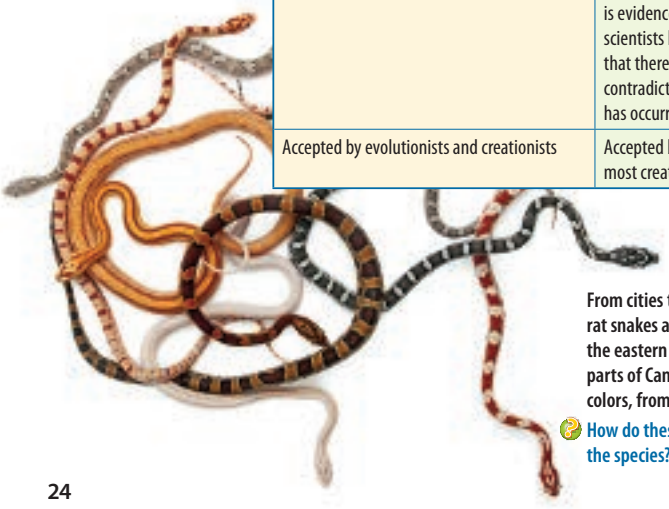
How do these color variations help the survival of the species? Color variations help the species survive in many locations with adaptations to their specific environment for better camouflage or to mimic other dangerous species.

How Much Change?

Although most people believe that some change has happened throughout history, the real question is, *how much change?* Many evolutionary scientists claim that macroevolution is nothing more than a lot of microevolutionary changes accumulated over billions of years. Tiny changes are introduced by genetic mutation. Those that improve an organism's chance for survival and reproduction are passed on to the offspring. Over billions of years, these tiny changes accumulate to produce major changes in body structures and physiological processes. Recall, however, that **mutations** are changes that occur when a gene is altered, damaged, or lost. Very few mutations have been shown to be positive. Most are harmful or even lethal. For this reason, many scientists, even some who believe in evolution, doubt that microevolutionary changes caused by mutations are capable of producing macroevolution.

The chart below summarizes the differences between microevolution and macroevolution. Scientific evidence for microevolution is abundant, but evolutionists and creationists disagree over what is considered evidence for macroevolution.

Microevolution	Macroevolution
Changes that occur among plants and animals of a population	Major changes in structure that result in changes from one kind of plant or animal to another
Numerous examples of microevolution found in nature	Macroevolution has not been shown to occur. While many scientists believe there is evidence for macroevolution, other scientists have other explanations and believe that there is considerable evidence that contradicts the theory that macroevolution has occurred.
Accepted by evolutionists and creationists	Accepted by evolutionists but rejected by most creationists



From cities to forests and mountains to coastlines, rat snakes are found in all types of habitats across the eastern and midwestern United States and parts of Canada. They come in a wide range of colors, from iridescent black to orange striped.

How do these color variations help the survival of the species?

Science Background

Direction of Change Former atheist John Sanford, professor at Cornell University with a Ph.D. in plant breeding and plant genetics, was a believer in evolution. He became convinced that the biblical account of Creation is correct after conducting his own research. Dr. Sanford explains that the evidence indicates that change is happening in the direction of entropy—the tendency toward degeneration, decay, and death. Geneticists agree that the human genome is deteriorating. At the rate of 100 new mutations per generation, we now have tens of thousands of bad mutations. Due to genetic entropy, population geneticists wonder why the human race has not become extinct many times over in the amount of time claimed by evolution for human history.

Theories of Origins—Variations

Recall from earlier in this lesson that there are two main theories of origins: Creation and evolution. There are variations of these two main theories. Several are summarized here.

Theories of Origins	
Name	**Description**
Young-Earth Creation	God created Earth and life on it in six literal 24-hour days several thousand years ago.
Creation Passive Gap Theory	God created the raw materials of Earth sometime in the past (maybe millions of years ago) and created life on Earth in six, literal 24-hour days several thousand years ago.
Creation Active Gap Theory	God created life, destroyed it, and created life again. Fossils are from the first Creation.
Progressive Creation	God performed several Creations at various times over long periods of Earth's history. Each Creation included more complex life forms. The days of Creation represent vast periods of time.
Theistic Evolution	God initially created life and then allowed the evolutionary process to progress on its own.
Evolution (Microevolution- Macroevolution)	As a result of lots of microevolution over billions of years, current life forms evolved from a common ancestor—the first single-celled living organism. God, if He exists, had nothing to do with it.
Punctuated Equilibrium	Evolution occurred in short, rapid bursts followed by long periods with little or no change.
Exogenesis or Panspermia	Life originated somewhere else in the Universe and was carried to Earth here in debris from space.

Science Background

Panspermia Presently, our knowledge of life in the Universe is that Earth uniquely contains life. The Universe is so vast, studying whether life exists, or began, elsewhere is virtually impossible. Panspermia, from the Greek words meaning "seeds everywhere," is a hypothesis that life is found throughout the entire Universe and travels the Universe on meteors and asteroids. This idea was first mentioned in the fifth century by Greek philosopher Anaxagora. It was brought back to modern studies by Sir Fred Hoyle and Chandra Wickramasinghe in1974. They proposed that dust in the Universe contained carbon. Also included in their hypothesis is the idea that life continues to enter Earth's atmosphere and could possibly be responsible for disease outbreaks and macroevolution. In 2009, physicist Stephen Hawking supported this hypothesis. Currently, there is no evidence to support the hypothesis of panspermia.

Teach Science Concepts

Some creation theories are consistent with the Genesis account, while others are not. The following information presents a discussion that identifies whether each theory fits with the biblical account of Creation.

Young-Earth Creation Bible scholars believe the Genesis account can be accurately interpreted in this way.

Passive Gap Theory The gap would be between verses 2 and 3 of **Genesis 1**. Bible scholars believe the Genesis account can be accurately interpreted this way as well. The Bible does not make it clear which is correct.

Active Gap Theory The gap would be between verses 1 and 2 of **Genesis 1**. This theory suggests the following wording: "And the earth *became* without form and void," but is not consistent with the Hebrew grammar of the verse. For more on this topic, see the article "The Biblical Account of Origins" by Richard M. Davidson in the *Journal of the Adventist Theological Society* 14/1 (Spring 2003): 4–43.

Progressive Creation This is not consistent with the Genesis account. The "days" in the Creation account are literally 24-hour days. For more on this topic, see the article "The 'Days' of Creation in **Genesis 1**: Literal 'Days' or Figurative 'Periods/Epochs' of Time?" in *Origins*.

Theistic Evolution This contradicts the biblical narratives in **Genesis 1–2**. Creation through the struggle and death of evolution is not consistent with the character of God as revealed in Scripture. The idea that death existed for millions of years before sin strikes is at the foundation of the plan of salvation. For more on this topic, see the article "In the Beginning" by Michael Hasel in the *Adventist Review* archives.

Explain *(cont.)*

Develop Key Vocabulary

Intelligent Design This view of origins is not creationism. Explain to students that Intelligent Design does not discuss origins from a religious point of view. It does state that living things and other features in the Universe are best explained by an intelligent designer. However, it does not attempt to identify the designer.

Scripture Spotlight

Students may suggest verses **Psalm 139:13–16** that describe how fearfully and wonderfully made we are and that suggests an intelligent designer.

Teach Science Concepts

Show students pictures of ordinary rocks, rocks obviously eroded naturally (such as arches eroded by ocean waves), and rocks obviously carved by humans (such as Mount Rushmore). Ask students to identify which is man-made. Point out that we intuitively recognize design but that scientists have tried to make the design argument more scientifically rigorous. To recognize design, scientists use what is called the explanatory filter, which has three parts. The first is the contingency factor, which asks whether the feature in question could possibly have existed in some other form. If so, the complexity of the feature is analyzed. If the probability of it occurring by chance is less than 10^{150}, it is checked to see whether it is sufficiently specific (having meaning, such as "Please pass the lemonade" instead of a lot of random letters). If all three criteria are met, according to the explanatory filter the feature contains sufficient evidence to indicate that it was intelligently designed. More information about the explanatory filter appears at the bottom of page 34. Also, Michael Behe's book *Darwin's Black Box,* which helped to launch the Intelligent Design movement, discusses irreducible complexity and gives examples from nature that show evidence of Design.

Scripture Spotlight

Read **Psalm 139:13–16** and identify verses that sound like Intelligent Design and complexity.

Intelligent Design

Intelligent Design is the relatively recent theory that certain features of the Universe and of living things are best explained by an intelligent cause, not an undirected process such as natural selection. Although some of the scientists who work within the Intelligent Design movement are Christians who believe the Bible, the Intelligent Design movement itself claims to rely on scientific evidence, not scripture. Although it makes no claims about biblical chronology and does not identify the Designer as God, the Intelligent Design movement has generated considerable controversy in the scientific community. Intelligent Design does not see complexity alone as evidence of a designer because complex patterns can sometimes occur by chance. Instead, it focuses on two specific kinds of complexity.

Complex Patterns

Type of Complexity	Description
Irreducible complexity	This is a single system composed of several well-matched, interacting parts that contribute to the basic function. The removal of any one of the parts makes the system unable to function. Example: a mousetrap Because an irreducibly complex system cannot be produced through one small change at a time, it is evidence of a designer. Within every cell in your body, there are thousands of tiny molecular machines that are much more complex than a mousetrap. These molecular machines are evidence of a designer.
Specified complexity	This pattern of letters and spaces is complex but not specific: *Slek owjkel silejks wwezjkl.* Because it has meaning, this sequence is an example of specified complexity: *Please pass the lemonade.* Things that do not occur because of natural laws but are both complex and specific are evidence of design. The information contained in the billions of proteins (made up of chains of amino acids in specific orders that fold to specific 3-D shapes) is evidence of design.

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Social Studies Link

Intelligent Design in Schools Conflict over the teaching of evolution or Creation in public schools has resulted in much legal debate. In 1925, Tennessee state law prohibited evolution from being taught in its public schools. In the Scopes Monkey Trial, high school biology teacher John Scopes was found guilty of teaching evolution and fined $100. A year later, the decision was reversed and the case was dismissed. Since *Edwards v. Aguillard*, (1987), the Supreme Court has ruled just the opposite: it is illegal to teach creationism because it is based on a religious doctrine. Since then state laws and school board initiatives have grappled with whether the theory of Intelligent Design, which claims to be based on science rather than religious writings, can be taught in public schools. Usually opinions about this are affected by how one interprets the Establishment Clause in the First Amendment.

Whether scientists believe in evolution or Creation, they do so because of certain basic assumptions they have chosen to accept as true. While science cannot prove whether God intervened in history, scientific evidence can be evaluated with each worldview in mind. In the next lesson, you will study scientific evidence that is consistent with the biblical story of Creation.

Concept Check Assess/Reflect

Summary: What are theories of origins? Although there are variations of each, two basic ideas about our origins exist: Creation and evolution. Creationists believe in Creation by God. Believers in Intelligent Design recognize that some things are best explained by a designer, but they do not attempt to identify the designer. Evolution claims that life arose spontaneously from nonliving matter and that all present life forms descended from a single-celled common ancestor. Microevolution involves small changes that can be documented, and all scientists agree that it happens. Macroevolution involves much larger changes, and not all scientists agree that the evidence supports it.

1. What evidence supports the hypothesis of exogenesis? Do you find it convincing?
2. Summarize Redi's evidence that helped lead to the rejection of the hypothesis of spontaneous generation.
3. Describe fixity of species. How was this idea disproved?
4. Think of the wide variety of dogs in the world. How did this variation come about? How does it compare to natural selection?
5. Compare microevolution with macroevolution.

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Science Background

In God's Image "Considering man's opportunities for research; how brief his life; how limited his sphere of action; how restricted his vision; how frequent and how great the errors in his conclusions, especially concerning the events thought to antedate Bible history; how often the supposed deductions of science are revised or cast aside; with what readiness the assumed period of Earth's development is from time to time increased or diminished by millions of years; and how the theories advanced by different scientists conflict with one another, shall we, for the privilege of tracing our descent from germs and mollusks and apes, consent to cast away that statement of Holy Writ, so grand in its simplicity, 'God created man in His own image, in the image of God created He him'? Shall we reject that genealogical record, prouder than any treasured in the courts of kings, 'which was the son of Adam, which was the son of God?'" *Education*, p. 130

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: Organic molecules and liquid water have been found in comets. This suggests that primitive life forms could have been present in the water or that the organic molecules could have evolved and developed into simple life forms. Allow students to offer their opinion about the evidence being convincing.
2. Redi's experiment showed that flies had to lay eggs in rotting meat for maggots (and more adult flies) to form. He proved that meat that flies could not get to would not bring about more flies.
3. Fixity of species is the idea that species did not change throughout time. This idea was disproved by the results of artificial selection.
4. The variety of dog breeds came about by the breeders of dogs who purposely selected certain traits to breed. Natural selection "selects" traits as well, but no humans are involved in the selection.
5. Microevolution describes small changes to a population over time. Macroevolution describes large changes to an organism, such as a single cell changing into a reptile over time.

Lesson 2

Essential Question

What Does the Evidence Show?

Preview Lesson Content

Read the objectives with students and help them pronounce each term in the vocabulary list. Have students locate the various charts in the lesson. Explain that the charts will help organize the interpretations of the evidence.

Explain

Embryology

Objectives

- Assess the evidence that scientists use to support theories of origins.
- Compare and contrast creationist and naturalistic interpretations of observable data.

Set Goals

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

Understand Visuals

Point out to students that the drawings made by Haeckel do not correctly portray the actual embryos. Haeckel modified his drawings so they would better support his theory of evolutionary history.

Lesson 2

Essential Question

What Does the Evidence Show?

Objectives

- Assess the evidence that scientists use to support theories of origins.
- Compare and contrast creationist and naturalistic interpretations of observable data.
- Define vestigial structure.
- Compare homologous structures with analogous structures.

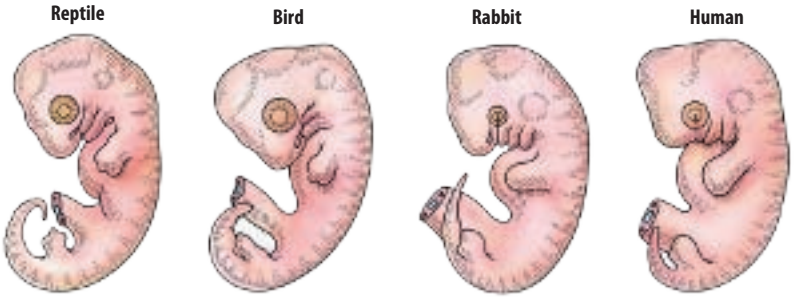
Vocabulary

vestigial structures
homologous structures
analogous structures
conservation of design

With so many different ideas about the origins of life on Earth, how is it possible to know whether any of them are correct? If origins falls into the category of historical science, what kind of data is available on which to base conclusions? Scientists from both worldviews are interested in how scientific evidence matches up with their theories of origins. This lesson will describe several lines of observable data—embryology, vestigial organs, genetic similarities, the fossil record, homology and analogy, and design—and how evolutionists and creationists interpret them.

Embryology Explain

In the late 1800s, Ernst Haeckel drew pictures that compared the embryonic development of lizards, chicks, rabbits, and humans. What similarities do you see in the embryos? What differences are evident? After observing that embryos of these vertebrates were much more similar than the adults, he theorized that during its development in the womb, the embryo actually passed through the different stages of its evolutionary history. Although it is true that embryos of many vertebrates are similar, Haeckel altered his drawings to support his theory, which did not hold up to modern genetic evidence.



In early stages of development, vertebrate animals may be very similar.

Science Background

Embryology The theory that embryological development summarizes evolutionary history was suggested by Ernst Haeckel in the nineteenth century when he noticed that embryos of different vertebrates were similar. Haeckel's critics suggested that his drawings exaggerated the similarities. The theory did not hold up to genetic evidence. A more modern theory suggests that, although the entire evolutionary history of an organism is not repeated during development, an embryo does resemble the embryonic stages of its ancestors because of evolutionary descent. Creationists suggest a different explanation. Most vertebrates have a similar body plan. Because embryos develop the basic body plan first, it would not be surprising for a Designer to have used an efficient basic plan for the early development of multiple organisms, which would then develop unique characteristics later on.

Observable Data — Embryology	
Embryos of different animals appear to be similar, although not as similar as originally portrayed by Haeckel's drawings shown on the previous page.	
Creationist Interpretation	**Evolutionist Interpretation**
Because the basic structure of vertebrates is similar, similarities in organisms are visible in the early stages of development. The Designer created an efficient plan to make basic structures first and to then specialize as the process continued.	An embryo resembles the embryonic stages of its ancestors because of evolutionary descent from a common ancestor.

Vestigial Structures

According to the theory of macroevolution, as species evolve new structures, certain older structures that are no longer necessary will slowly disappear. Until a structure disappears completely, a remnant, or vestige, of it may remain. Structures that do not appear to have any use are often presumed to be "leftovers" and are called **vestigial structures**. In 1895, a long list of vestigial organs in mammals was compiled that was considered convincing evidence for macroevolution. More than 80 structures were on that list, including the thyroid, pituitary glands, and the middle ear. Scientists now know that these structures have very specific and important functions. As scientists continue to gather evidence, the list continues to shrink.

Some organs, however, seem to be truly vestigial. Some salamanders that live in dark caves have sightless eyes. Populations of birds found living on islands without predators sometimes have small wings and have lost the ability to fly. It is important to notice that these changes are examples of microevolution, not macroevolution. Also, instead of evolving new structures, these animals lost certain traits.

Observable Data — Vestigial Organs	
Some body parts, called vestigial organs, appear to have no function. Examples include the human coccyx (tailbone), small leg bones in some snakes, eyes in blind amphibians, and wings in flightless birds.	
Creationist Interpretation	**Evolutionist Interpretation**
Just because we don't understand a structure's purpose doesn't mean it doesn't have one. Scientists have discovered the purpose of many structures that used to be considered vestigial. Some vestigial structures may be the result of microevolution that has happened since Creation.	Vestigial organs are remains of an animal's evolutionary history.

Writing Link

Vestigial Organs Robert Wiedersheim was a German anatomist who published a list of vestigial organs. His list was later expanded to include 180 vestiges. Encourage interested students to research the list as well as the explanations of many of these structures that have since been discovered. For example, the tonsils, adenoids, and appendix, which were once thought to be vestigial, help protect our bodies from infections. Other research topics could include sightless salamanders or flightless birds. Emphasize two major points about vestigial structures. First, just because we don't know what something is used for does not mean it is useless. Second, structures that are truly vestigial represent a loss of function rather than evolution. Have students explain these ideas to someone else or write a journal entry about them.

Vestigial Structures

Objectives

- Assess the evidence that scientists use to support theories of origins.
- Define vestigial structure.

Develop Key Vocabulary

vestigial structure The word part *vestige* is French for "a mark, trace." *Vestigial* is an adjective that describes a structure. According to evolutionists, it is a structure that was once something more useful, but is now functionless.

Teach Science Concepts

What is an organ or structure that you think might be vestigial? Explain why you think it could be classified as vestigial. Students may list any organ or structure as long as their explanation includes that they do not think it has a purpose in the organism. Discuss with students the purpose of any structure or organ that they name that is not vestigial. **What impact do you think technology has had on our understanding of vestigial structures and organs?** Technology has increased our understanding of the workings of the human body, so we have a better understanding of the functions of different organs and structures. Therefore, technology may have helped decrease the number of vestigial organs and structures.

Explain *(cont.)*

Genetic Similarities

Objective

- Assess the evidence that scientists use to support theories of origins.

Teach Science Concepts

Provide students with two different books containing completely different information, for example, a Bible and an English textbook. Ask them to describe how similar the two books are, based on the following things: (1) the material they are made of, (2) the letters used, (3) the words used, and (4) the sentence structures. **How similar are the books?** Answers will vary, but most students will agree that the letters used are identical. The letter *d* is always the letter *d*. They will also find that both texts use many of the same words. The word *the* is always the word *the*. However, students will most likely agree that the information in each book is quite different. This is a good analogy to genomes. DNA is made of the same four nucleotide bases (like letters), but they are combined in different ways to form genes (like chapters in a book). The same building blocks can make vastly different creatures (like the same letters and words make books with vastly different content).

Understand Visuals

What are some physical differences between you and a chimpanzee? Sample answer: Focusing on the head, the shape and size of the chimpanzee's brow, nose, ears, mouth, and chin are different from mine. The hands look much larger, and the hair is denser and covers most of the body of the chimpanzee.

Fossil Record

Objective

- Assess the evidence that scientists use to support theories of origins.

In spite of many genetic similarities, humans and chimps are very different.

What are some physical differences between you and a chimpanzee?

Genetic Similarities **Explain**

Has anyone ever told you that the human and chimpanzee genomes are 98 percent identical? When the chimpanzee genome was actually sequenced, the ratio dropped to 96 percent. Although the published numbers may vary, understanding what these numbers mean can be tricky. Clearly, the human and chimpanzee genomes are more like one another than either is to the banana genome (about half the genes in bananas are similar to human genes). However, there are some very important differences. In particular, the *Y*, or male sex chromosome, is very different. Although the proteins are quite similar, the regulatory genes that control how these proteins are used are different. This is like very different houses being put together with the same types of nails and lumber. Can you think of other examples that illustrate this concept?

Observable Data — Genetic Similarities	
Humans, chimpanzees, and bananas have many similar, but not necessarily identical, genes.	
Creationist Interpretation	**Evolutionist Interpretation**
When the Creator designed different organisms, He used similar parts to build them, just as a builder may use similar bricks to design different buildings. Bananas have relatively few genes in common with humans and chimpanzees, because bananas differ more from either of them than they do from each other. Where necessary, God made different genes for the unique needs of bananas, chimps, and humans.	Similar genes are inherited from a common ancestor. The common ancestor of bananas and humans existed long before the common ancestor of humans and chimpanzees. Therefore, humans and chimps share fewer genes with bananas than they do with each other. Unique genes in each organism evolved by mutation and natural selection. Because this requires random unguided changes, the process takes long periods of time.

Fossil Record

The fossil record is often used to support the theory of evolution. Evidence about the fossil record will be presented in Chapter 10, but a short summary is included in the chart below.

Observable Data — Fossil Record	
Beginning with a sudden profusion of diverse life forms, the sequence of fossils (from bottom to top of the geologic column) includes invertebrates, fish, amphibians, reptiles, mammals, and humans. New organisms appear abruptly with relatively few examples of gradual "transitions."	
Creationist Interpretation	**Evolutionist Interpretation**
The fossil record is a record of the sequence in which the fossils would have been buried by the Flood and later geologic activity.	The fossil record is a record of the evolution of life forms from common ancestors.

Science and Society

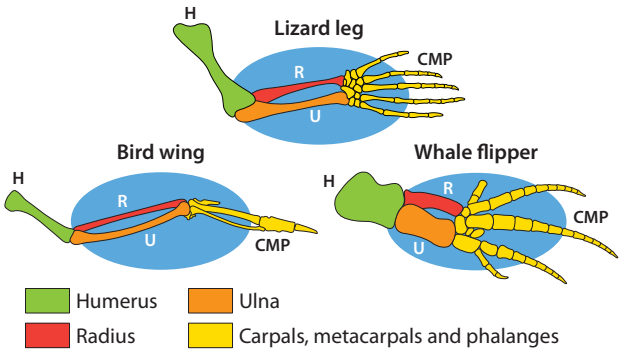
The Saber-Toothed Cat, *Smilodon* Does your state have a state fossil? California does. It is the saber-toothed cat, *Smilodon californicus*. From fossil evidence, researchers have concluded that this extinct member of the cat family was smaller, but heavier, than a modern lion. Its upper canine teeth measured a fearsome 20 cm. *Smilodons* were meat-eaters and, apparently, very successful predators or scavengers. They were once numerous and widespread in California. Fossil bones of *Smilodon californicus* have been found in large numbers in the tar pits of Rancho La Brea in Los Angeles. *Smilodon* was named the official California state fossil in 1973.

Homology and Analogy Explain

Scientists have noticed that many animals share similar body structures. For example, the human arm and hand, a whale's flipper, a bat's wing, and a lizard's leg have roughly the same sort of bones in the same order. But despite how similar these appendages appear, their functions are very different. Humans can grasp things, whales can swim, birds can fly, and lizards can run using this same basic arrangement of bones. Structures that are similar in construction but that have different functions are called **homologous structures**.

Scripture Spotlight

What types of wings are mentioned in these verses: **Exodus 19:4**, **Psalm 55:6**, and **Matthew 23:37**?



Similar structures that have different functions are called homologous structures.

Which bones are homologous in these three animals?

Notice also how different the structure is in the wings of the butterfly, bird, bat, and pterosaur on the next page. Yet, each of these different structures still results in the ability to fly. Different structures that have the same function are called **analogous structures**. What other homologous and analogous structures can you describe in nature?

Lesson Activity

Think about the many kinds of winged animals. With a partner, make a list of at least 10 different winged animals. Are all wings the same? Comparing the wings of animals can reveal more differences than you may have considered. Choose two different types of winged animals from your list and research their structures. Organize your research into a visual presentation. Include photographs, diagrams, or your own drawings and models in your presentation. Be sure to add captions and labels as needed. Then create a Venn diagram to record the differences between the wings of the two types of winged animals you researched. Share your visuals and research with the rest of the class.

What differences can you identify relating to the structure and function of wings?

Scaffolded Questions

Approaching Level Have students point out the humerus in each animal limb shown. **Are those three bones homologous?** yes Repeat the pointing and questioning for the radius and ulna.

On Level **Why are the lizard leg, whale flipper, and bird wing considered homologous and not analogous?** The bones in the leg, flipper, and wings have a similar shape and arrangement.

Above Level **How might two unrelated animals been designed to have a similar appearance? Give an example.** Sample answer: Parts of the body were designed to have similar functions. Dolphins and sharks are not even in the same class, but they have similar appearances. These appearances help them swim.

Homology and Analogy

Objectives

- Assess the evidence that scientists use to support theories of origins.
- Compare homologous structures with analogous structures.

Develop Key Vocabulary

homologous structure The prefix *homo-* is derived from the Greek word meaning "the same." Homologous structures are similar in construction, but have different functions.

analogous structure Point out to students that an analogy is a comparison between two different things. The term *analogous structure* refers to two different structures that have the same function.

Scripture Spotlight

Exodus 19:4 mentions eagles' wings; **Psalm 55:6** mentions doves' wings; **Matthew 23:37** mentions hens' wings.

Understand Visuals

Which bones are homologous in these three animals? Each has a humerus, a radius, an ulna, and a group of smaller bones (the carpals, metacarpals, and phalanges).

Lesson Activity

Students will need access to the Internet or others sources of information on wing structures. For students who want to create models, provide craft supplies such as straws, toothpicks, tissue paper, feathers, and glue. Encourage students to include photos or drawings in their Venn diagrams. Allow time for all groups to share their models and research.

What differences can you identify relating to the structure and function of wings? Students should notice size, shape, and function.

Explain *(cont.)*

Teach Science Concepts

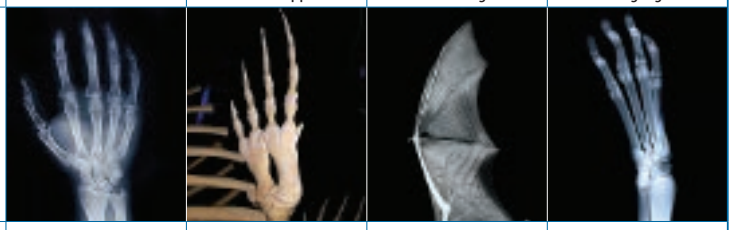
Emphasize to students that the basic assumption of the theory of universal common descent is that the more similar two organisms are, the more closely related they must be. **Which word on page 32 refers to this idea?** *homology* Explain that there are numerous examples of organisms that are extremely different except for a single common trait. Show pictures of a mole (mammal) and a mole cricket (insect), pointing out their similar forelimbs. **How closely related do you think evolutionists would say these animals are because of their forelimbs?** Evolutionists realize that one similar characteristic is not enough to assume the animal got that trait from a common ancestor. **If animals did not inherit a trait from a common ancestor, where would evolutionists say it came from?** Evolutionists believe the trait evolved twice. (It could be argued that it is extremely unlikely for evolution to happen once. You may wish to explore the idea that it would be exponentially less probable for something to evolve multiple times.) Explain that this is called *convergent evolution*. Point out that the more times similar traits are explained by convergent evolution, the more the original argument from homology is negated. Homology affirms that similarity implies common ancestry—except in those many cases when it does not! According to evolutionists, another example of convergent evolution is the eye in cephalopods, mammals, and cnidarian. Still another example is the echolocation abilities in bats and whales.

Understand Visuals

Using the chart, in what way does the function of the human hand/arm differ from the function of the whale flipper, the bat wing, and the dog leg? Sample answer: The human hand/arm does not help with the mobility of humans. The whale's flipper, the bat's wing, and the dog's leg all help these animals to be mobile.

Observable Data — Homology and Analogy

Homology

	Human hand/arm	Whale flipper	Bat wing	Dog leg
Same structure				
Different functions	Fine manipulations	Swimming	Flying	Running fast

Analogy

	Butterfly wing	Bird wing	Bat wing	Pterosaur wing
Different structure				
Same functions	No bones at all	Finger bones reduced; feathers are the main flight surface	A thin membrane stretches between the digits	Fourth finger alone supports the wing membrane

Creationist Interpretation	Evolutionist Interpretation
An intelligent Creator designed a flexible general plan, which could be altered for different animals. It might be like a computer programmer writing a basic program that could be modified and reused efficiently in other more complex programs. Sometimes this is called the **conservation of design**.	**Homology** Similar structures are said to suggest common ancestry. In other words, these traits were passed down to these animals from a common ancestor. **Analogy** Even though animals with analogous structures did have common ancestors at some point in the past, these structures are thought to have evolved sometime since the last common ancestor. That means those traits would have to have evolved more than once, each in a separate evolutionary line.

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English Language Learners

Develop Vocabulary Write the words *analogous* and *homologous* on the board. Underline the *-gous* endings and tell students that the *-ous* suffix, or ending, means "full of" or "having." Underline the prefix *homo-* and explain that this prefix means "the same."

Structured Inquiry

Discover

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

Science Journal

When You've Seen One, You've Seen Them All

Does similar design mean a common ancestry?

Materials
- a variety of cars

Procedure

1. As a class, visit your school parking lot. Select three cars that are obviously different.
2. **Observe** the cars and identify these common characteristics: headlights, taillights, and side-view mirrors.
3. Then choose two more characteristics that the cars have in common.
4. Create a five-column chart and record one common characteristic at the top of each column. Describe or draw the design of the five characteristics for each of the cars. Record your observations on the chart.

Analyze Results

Compare the common characteristics of the cars. Based on your observations, how does the design of the common characteristics of the cars differ? What are the similarities of the design?

Create Explanations

1. Does similar design mean a common ancestry?
2. Why do different makes of cars share the same features?
3. How are similarities and differences in cars similar to what is found in nature?
4. How does this activity relate to the conservation of design?

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Inquiry Extension

Extend

Guided Inquiry

Changing Cars

How have cars changed in design through the years?

Extend the Structured Inquiry by having students compare and contrast one particular feature of a car, such as windows, the driver's seat, instrumentation, steering wheel controls, door latches, and the like. They should also compare and contrast the advantages and disadvantages of the selected feature.

Teaching Tip Provide access to the Internet or provide several different car magazines for picture research.

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

When You've Seen One, You've Seen Them All

Does similar design mean a common ancestry?

Prior to the activity, discuss with students the safety of working in the school parking lot.

Predict What similarities will be noticed while observing different makes of cars?

Science Journal

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

Inquiry Practice Tip

Observe Students may wish to observe the cars at different angles.

Expected Results

Results will vary based on the cars that are observed.

Create Explanations

1. Answers will vary.
2. Sample answer: Designers recognize the need for the same features on all cars.
3. Sample answer: The similarities seen in cars point to the need of similar functions. The variety present in cars points to the appeal of variety for customers. In a similar way, the similarities seen among living things point to the need of similar functions. The variety points to the Creator's love for variety.
4. If there is an efficient design (two axles, four wheels, and a chassis), there needs to be only a small amount of change in style. Very little change to the basic design is called conservation of design.

Explain *(cont.)*

Design

Objective

- Assess the evidence that scientists use to support theories of origins.

Teach Science Concepts

If possible, before studying this page, take students on a walk outside and have them "discover" a product that was manufactured, such as a pen, paperclip, small toy, or other item. Ask students to brainstorm how the item got there. Point out to students that all their ideas probably include the fact that someone was involved in the appearance of this item in this place. Connect the discussion to the information on this page.

Design Explain

If you were walking in the woods and found a watch on the ground, where would you assume it came from? Back in the eighteenth century, a British philosopher and clergyman named William Paley used this question to illustrate the idea that when we see evidence of planning, craftsmanship, beauty, and usefulness, we recognize that those things come from a designer. Since that time, scientists have continued to gather data about the stunning precision of universal constants, the staggering complexity of the molecular machines inside our bodies, and the fascinating processes found in the natural world.

Although most people would immediately recognize design in this data, scientists wanted to find a way to be more scientifically objective about the process of identifying design. William Dembski developed something called the *explanatory filter* to help determine whether direct intervention by a designer should be inferred. If it can be determined that the object could have existed in more than one format, is complex enough that it could not have happened by chance, and is not random but specific, then design can be inferred.

Observable Data — Design		
We live in a finely tuned Universe with dozens of factors, such as gravity, that have to be exactly the way they are for life to exist.	Humans and other animals are made of complex systems, which are made of organs, which are made of tissues, which are made of cells, which are made of organelles, which have hundreds of tiny molecular machines, which are themselves irreducibly complex and work together to accomplish cell processes.	Caterpillars that crawl, eat leaves, and spin silk cocoons but that cannot reproduce melt into a jellylike substance before reassembling into butterflies that fly, drink nectar, and can reproduce caterpillars.
Creationist Interpretation	**Evolutionist Interpretation**	
These are examples of organisms designed, created, and maintained by God.	These organisms arose from random evolutionary processes, directed by environmental constraints, but they have the appearance of conscious design.	

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Science Background

Explanatory Filter William A. Dembski believes that design can be detected empirically. He infers design only if it can be demonstrated that the object or event is not the result of either law or chance. When using the three-stage explanatory filter, Dembski first asks the question, does a law explain it? If so, he does not infer design. Next he asks, does chance explain it? Just being extremely unlikely is not enough to infer design. If it is not specified, Dembski would attribute the object or event to chance because extremely unlikely things do happen sometimes. If it is both extremely unlikely and specified, he believes that design can be inferred. Dembski suggests that this is the same process used all the time by people in many different fields, including detectives, forensic scientists, statisticians, and even those in NASA's SETI program.

Evaluating the Evidence

Remember that two parts of the scientific process are gathering and interpreting data. As more data is gathered, scientists evaluate it and make adjustments to their theories. As you have seen, scientists with different worldviews can interpret the same data in completely different ways. Both creationists and evolutionists show strong commitments to their worldviews and the assumptions that go with them. As you evaluate the evidence presented here, keep the following points in mind:

- Each theory is ultimately accepted by faith.
- Each theory depends on assumptions that cannot be proved.
- Each theory is supported by scientific evidence.
- Each theory is unable to explain all the scientific evidence.

Moths' eyes do not reflect light. Instead, the light is absorbed and deflected. This antiglare quality helps keep the moth safe from predators.

Concept Check Assess/Reflect

Summary: What does the evidence show? Evolutionists and creationists interpret the same observable data in different ways. Evidence used frequently to debate life's origins includes embryological similarities, vestigial organs, genome similarities, the fossil record, homologous and analogous structures, and design. Ultimately, neither evolutionism nor creationism is a provable theory. Both are based on scientific evidence, but not all is explainable. They are accepted by faith.

1. In your opinion, which is more useful to biologists when studying ancestry: homologous structures or analogous structures? Explain.
2. Would scientists classify the wings of a dragonfly and the wings of a pigeon as homologous or analogous structures? Explain.
3. How might an evolutionist and a creationist describe the evidence that wings on flightless birds give for the origins of life?
4. How would an evolutionist say similarities in genetic make-up suggest that humans and chimpanzees evolved from a common ancestor?
5. Give an example and explanation of something that appears to have been created with design in mind, rather than falling together randomly.

Science Background

Faith and Science Science is often said to be based on evidence, while religion is based on faith. How is faith different from scientific evidence? Faith can be defined as "belief that is not based on proof." When partial evidence exists, faith is what takes us beyond the partial evidence to belief, even when proof is not possible. Because neither Creation nor abiogenesis and macroevolution are provable scientifically, belief in either requires faith. Similarly, it is not possible to prove the existence or nonexistence of God, which are assumptions basic to Creation and naturalism, respectively. Note that proving a negative is especially problematic. The fact that neither theory is able to explain all the scientific evidence need not be troubling but can inspire scientists to continue seeking answers to the questions that remain.

Evaluating the Evidence

Objective

- Assess the evidence that scientists use to support theories of origins.

Understand Visuals

How do the antiglare qualities of a moth's eye show evidence of Design and Creation by God? The eyes were made specifically and with purpose to keep the moth from being seen easily by predators. These antiglare eyes show that God purposefully created complex structures on a moth.

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: Homologous structures might help evolutionists study how animals are related.
2. Dragonfly wings and pigeon wings are considered analogous structures. They have different structures, but they do have similar functions; they help the animals fly.
3. Sample answer: An evolutionist would say the flightless bird devolved from earlier bird ancestors and survived because there weren't as many predators in the area. Creationists would say God reused the design of a bird's wing but for a different function.
4. Sample answer: An evolutionist might suggest that humans and chimpanzees got their similar genes from a common ancestor.
5. Sample answer: A kangaroo is made of complex organ systems, tissues, cells, organelles, and smaller molecular pieces. The kangaroo can move, eat, respond to the environment, and reproduce. These all point to specific Creation by Design.

Lesson 3

Essential Question

What Is Phylogenetics?

Preview Lesson Content

Read the objectives with students and help them pronounce each term in the vocabulary list. Write the following terms on the board in a random sequence: *species, phylum, order, class, domain, kingdom, genus, family.* Have students recall what they learned in previous studies (or use the example at the bottom of the page) to draw a Venn diagram that shows the relationship of each group to all the others. A correct diagram is a series of concentric circles with *species* in the center circle and *domain* in the outermost one that encircles all the others.

Explain

How Classification Has Changed

Objective

- Describe characteristics used to classify organisms.

Set Goals

Ask students to identify the main ideas and supporting details for each paragraph on this page and the next.

Understand Visuals

What are some differences between the domains Archaea, Bacteria, and Eukarya? Sample answer: All organisms in Archaea and Bacteria are unicellular, whereas only some species of Eukarya are unicellular, while others are multicellular. Eukaryotic cells have nuclei; organisms in Archaea and Bacteria have no nuclei. There is one kingdom each in Archaea and Bacteria. Eukarya has four kingdoms classified under it.

Lesson 3

Essential Question

What Is Phylogenetics?

Objectives

- Describe characteristics used to classify organisms.
- Explain the process of phylogenetic analysis.
- Interpret phylogenetic trees, or cladograms.

Vocabulary

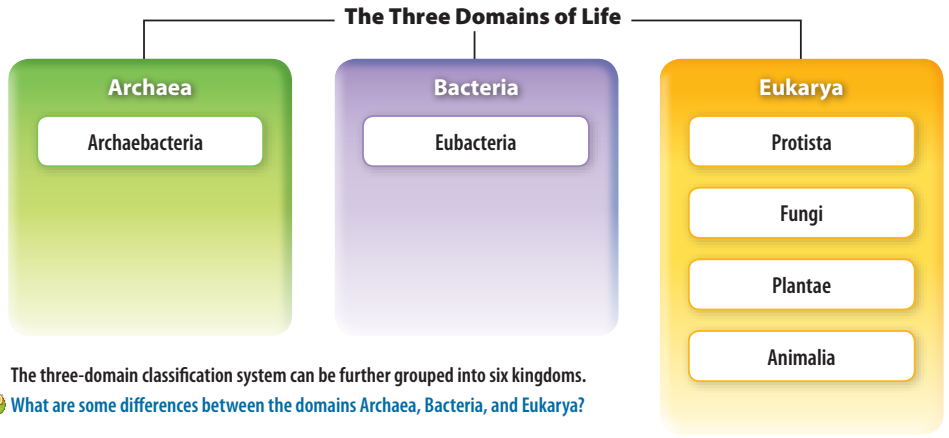
systematics
phylogenetic analysis
phylogenetic tree
cladogram
parsimony
cladistics

When you sort your room or organize this class, does your view of where things came from affect how you classify the things? How does the scientist's worldview change the classification of life? Does the assumption of where something comes from change the classification of science? Can you think of an example?

Looking for evidence about the assumption that organisms evolved from common ancestors is the foundation for the work of many taxonomists. You have already learned quite a bit about classification. What do you recall about the reasons for classifying organisms, the scientists who began this work, and the categories into which organisms are classified?

How Classification Has Changed Explain

Classifying organisms today is different in at least two important ways from how it was done back in the 1700s when Carolus Linnaeus began his well-known classification work. The first has to do with the characteristics used to group the organisms.



The three-domain classification system can be further grouped into six kingdoms.

What are some differences between the domains Archaea, Bacteria, and Eukarya?

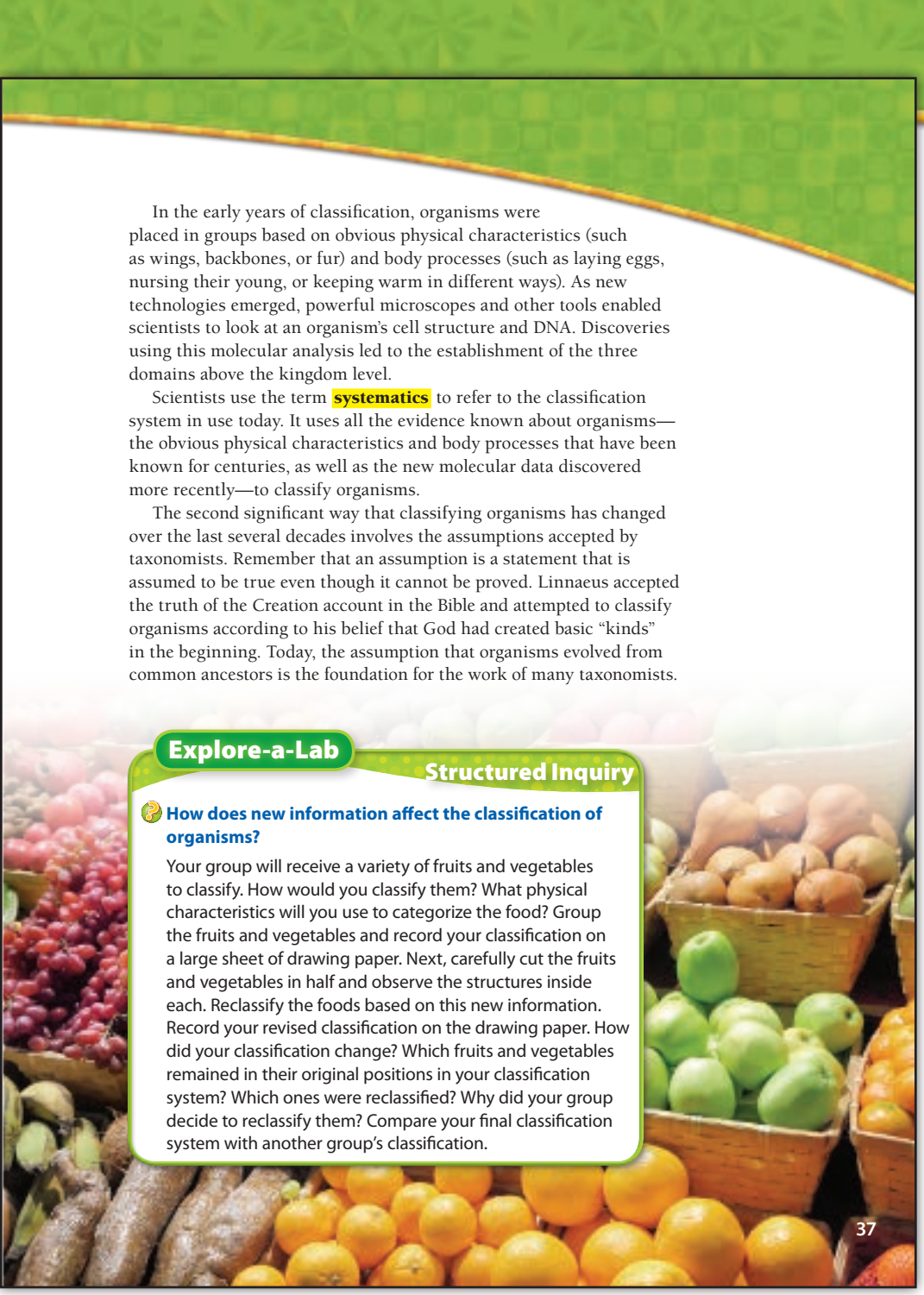
Science Background

Classification Debate The history of biological classification is rife with debates between lumpers and splitters. Lumpers look for generalizations; they want to bring many groups of organisms together. Splitters focus on details. They find reasons to invent a larger number of more specific groups. In the last two decades, various lumped and split classification systems have been proposed based on new evidence from DNA studies. As a result, the number of suggested kingdoms has varied from as few as three (from the lumpers) to as many as thirty (from the splitters). Hopefully, a time soon may come when lumpers and splitters compromise on a fluid approach to classification, one based on the probability (large or small) that one organism is closely (or not so closely) related to another.

In the early years of classification, organisms were placed in groups based on obvious physical characteristics (such as wings, backbones, or fur) and body processes (such as laying eggs, nursing their young, or keeping warm in different ways). As new technologies emerged, powerful microscopes and other tools enabled scientists to look at an organism's cell structure and DNA. Discoveries using this molecular analysis led to the establishment of the three domains above the kingdom level.

Scientists use the term **systematics** to refer to the classification system in use today. It uses all the evidence known about organisms—the obvious physical characteristics and body processes that have been known for centuries, as well as the new molecular data discovered more recently—to classify organisms.

The second significant way that classifying organisms has changed over the last several decades involves the assumptions accepted by taxonomists. Remember that an assumption is a statement that is assumed to be true even though it cannot be proved. Linnaeus accepted the truth of the Creation account in the Bible and attempted to classify organisms according to his belief that God had created basic "kinds" in the beginning. Today, the assumption that organisms evolved from common ancestors is the foundation for the work of many taxonomists.



Explore-a-Lab Structured Inquiry

How does new information affect the classification of organisms?

Your group will receive a variety of fruits and vegetables to classify. How would you classify them? What physical characteristics will you use to categorize the food? Group the fruits and vegetables and record your classification on a large sheet of drawing paper. Next, carefully cut the fruits and vegetables in half and observe the structures inside each. Reclassify the foods based on this new information. Record your revised classification on the drawing paper. How did your classification change? Which fruits and vegetables remained in their original positions in your classification system? Which ones were reclassified? Why did your group decide to reclassify them? Compare your final classification system with another group's classification.

English Language Learners

Develop Vocabulary Have students copy this table into their notebooks.

Analogy	Dichotomy

Explain that an analogy is a comparison of two things and that a dichotomy is a division between two things. Read the following statements. Ask students to write each in its proper column. *Are you cheering for the red team or the blue team?* (D) *I feel like a fish out of water.* (A) Have students write one more example for each.

Develop Key Vocabulary

systematics This term describes a system of classification. Have students describe ways that items are classified in their house, classroom, library, and home improvement store. Then have students recall the classification system used to group living organisms.

Teach Science Concepts

To check students' understandings of classification, draw a Venn diagram. Label the right and left sections as *Then* and *Now*. Have students suggest main ideas about classification and record them in the Venn diagram.

Then: Classification is based on obvious physical characteristics; Linnaeus assumed the truth of the Creation account.

Now: Classification is based on obvious physical characteristics as well as on genetic data; many taxonomists assume that evolution occurred.

The middle section: Classification, then and now, is the process of grouping organisms according to similar characteristics.

Explore-a-Lab Structured Inquiry

Have students work in small groups. Provide students with large drawing paper, paper plates, plastic knives, and a variety of fresh fruits and vegetables. Choose produce of different colors, shapes, sizes, and smells, along with those that have seeds and those that have no seeds. Provide time for groups to compare their classification systems of the produce.

How does new information affect the classification of organisms? Sample answer: When new information is gathered, it can alter the way organisms are classified. It may combine species that were once thought different. Or, it may split what was thought to be one species into two or more species.

Discover

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

Structured Inquiry

Using a Dichotomous Key

How can dichotomous keys help scientists identify organisms?

Preparation and Tips

Place samples of legumes (beans) in paper cups for distribution to students.

Predict **How can an unknown organism be identified using dichotomous keys?**

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

Inquiry Practice Tip

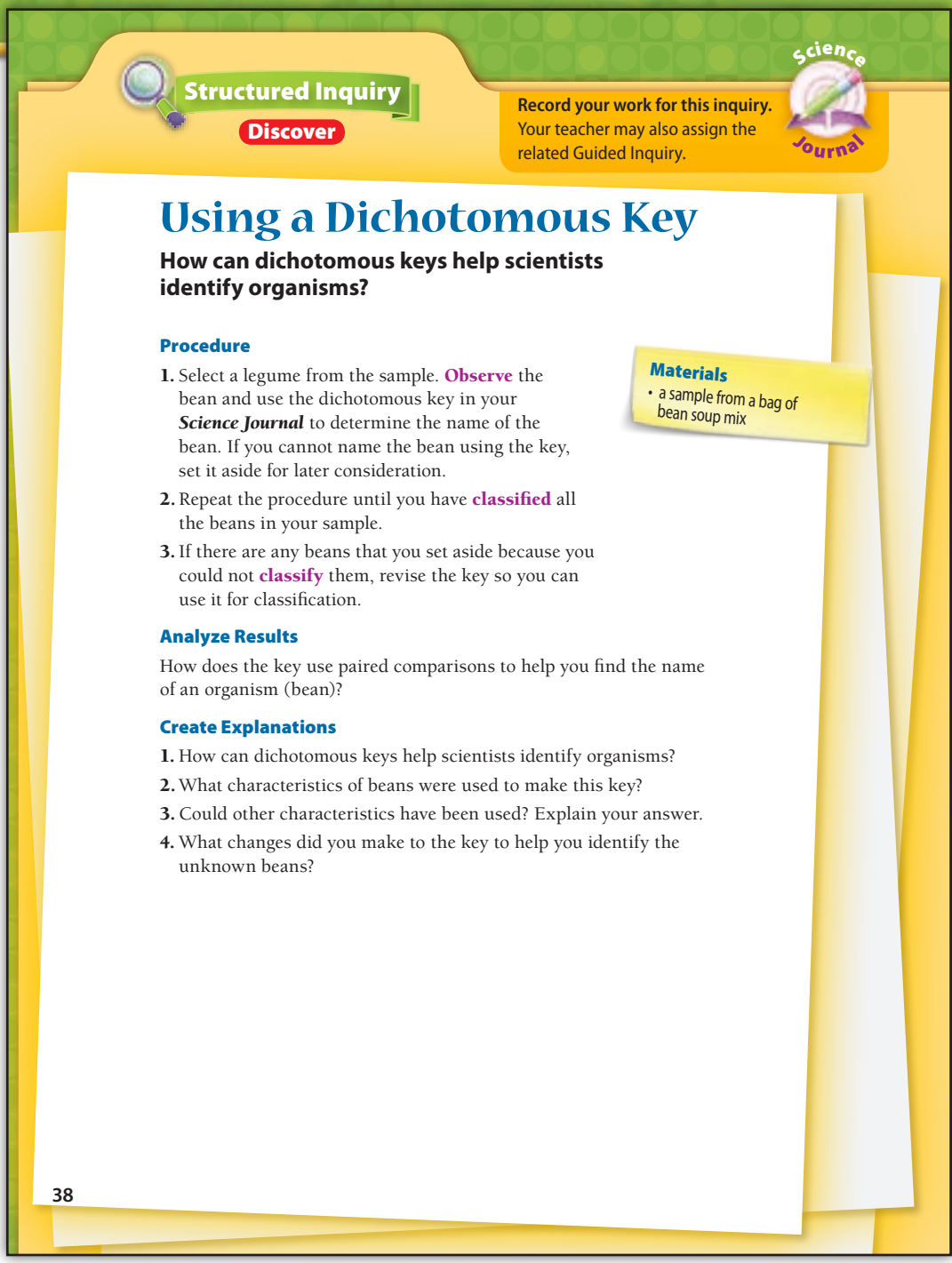
Observe and Compare Students may jump immediately to the beans' names. Discourage that approach. Follow the key from Step 1, as indicated, for each bean students pick from the sample.

Expected Results

Use the key to identify 10 legumes. The paired statements in the key make identification logical. Two legumes that may be set aside are the garbanzo beans and brown lentil beans. Each student or team will use its own approach in modifying the key.

Create Explanations

1. They help identify the organism by pairing characteristics and determining which given characteristic an organism has.
2. color and shape
3. Other characteristics, such as mass or length, could have been used.
4. Answers will vary.



Inquiry Extension

Extend

Guided Inquiry

Using a Field Key

How can a field key be used to identify organisms found in your surroundings?

Extend the Structured Inquiry activity by having students go on a field trip or walk around your school building and use a field guide to find the common and scientific names of the organisms.

Teaching Tip Check your library for a field manual that includes a key to plants, mammals, birds, or insects in your area.

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

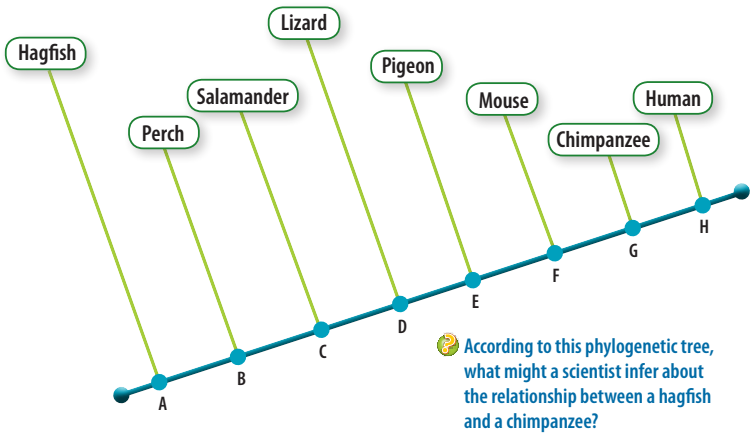
Phylogenetic Analysis Explain

Phylogenetic analysis is the process of grouping organisms based on multiple shared characteristics (which scientists refer to as characters) or traits that were not shared with organisms thought to have been their ancestors. It is based on the assumption that evolution has occurred. The results of this process are displayed in graphics called **phylogenetic trees**.

Study the phylogenetic tree below. Each node, labeled A–H, represents the presence of a new trait that the presumed ancestors did not have. For example, node B represents the presence of jaws. No animal to the left of the perch on the diagram has a jaw, but every animal to the right of the perch has a jaw.

So you can look at how close different organisms are to each other on these trees and draw conclusions about how similar they are to each other. On this tree, scientists would infer that the salamander shares more characters with the lizard than with the chimpanzee. From an evolutionary perspective, it would be inferred that the shared characters result from a shared evolutionary history. From a creationist perspective, the tree simply shows which organisms are designed to be more similar and which traits are shared by multiple creatures.

Phylogenetic Tree



Science Background

Phylogenetics Phylogenetic analysis is based on the assumption that evolution has occurred. From an evolutionary perspective, each node on the phylogenetic tree above (labeled A–H) represents the evolution of a new trait that the organism's ancestor did not have. Each animal at and after node A has a brain cavity. Each animal at and after node B has jaws. Similarly, C=four limbs, D=amniotic sac, E=hair and mammary glands, F=placenta, G=no tail, and H=bipedal. Traits shared with an ancestor are plesiomorphic. New traits not shared with the ancestor are apomorphic. Each new trait that the ancestors did not have but that the descendants do is called a synapomorphy. Each new branch of a phylogenetic tree is determined by a new synapomorphy.

Phylogenetic Analysis

Objective

- Explain the process of phylogenetic analysis.
- Interpret phylogenetic trees, or cladograms.

Develop Key Vocabulary

phylogenetic analysis This term describes the study of heredity, specifically, common ancestors shared among organisms.

phylogenetic tree This is a branching diagram that resembles a tree. Evolutionary scientists use it to show the relations between organisms. This type of analysis is based on the assumption that evolution happened and that organisms came from common ancestors and have diverged into new varieties as a result of natural selection. Creation scientists look at this and see where God possibly reused some design elements to create new creatures.

Teach Science Concepts

After reading **Phylogenetics** at the bottom of this page, you may wish to share the information about nodes A–H with students.

Understand Visuals

According to this phylogenetic tree, what might a scientist infer about the relationship between a hagfish and a chimpanzee? Sample answer: The hagfish is farther away from the chimpanzee on the tree, so an inference might be that the two organisms are not closely related to each other. The idea of relatedness suggests an evolutionary development for simple to complex development over time.

Incorporate Inquiry Practices

Practice: Communicate Have pairs of students make cards for each organism on the phylogenetic tree. They will take turns shuffling the cards, drawing two, and explaining the relationship between the organisms based on the diagram.

Explain *(cont.)*

Develop Key Vocabulary

cladogram This term is synonymous with *phylogenetic tree*. It is a branching diagram that shows the relationships between organisms.

Teach Science Concepts

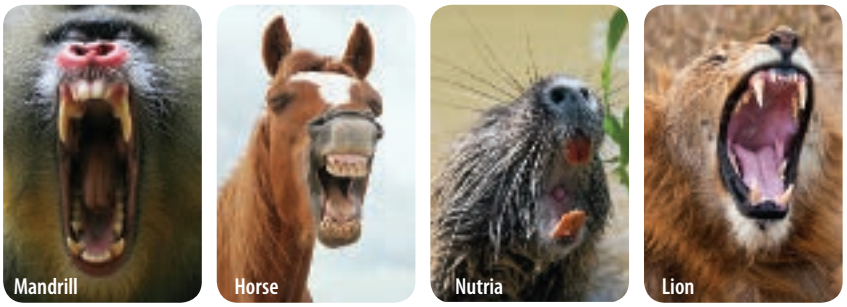
Remind students that an assumption is something that cannot be proved and emphasize that the process of phylogenetic analysis is based on the assumption that evolution has occurred. Scientists do not do this kind of analysis to prove evolution; they do it to figure out which organisms are most related to each other, having already assumed that evolution happened. Read about outgroups in the science background paragraph on this page and consider sharing with students how the choice of an outgroup can affect the phylogenetic tree produced by a set of data.

Understand Visuals

How are these mammals' teeth similar? How are they different? Would a scientist place these mammals on a phylogenetic tree based solely on teeth structure? Explain. The mandrill and lion have sharp, pointed teeth on the top and bottom jaws. The horse and nutria have flat teeth. The nutria's teeth are extremely long. The number of teeth in each mammal's mouth is different. I don't think a scientist would classify these mammals based solely on teeth structure because there are so many other body structures and behaviors to consider before grouping them.

As you learn about how the process of phylogenetic analysis works, keep in mind that scientists who are evolutionists begin with the assumption that organisms evolved. Their purpose is to try to figure out which organisms are most closely related to other ones based on the characteristics they share. Their study may include living organisms as well as fossils.

In the first step of this process, scientists collect data about specific traits that similar species of organisms have. Examples of the kinds of data they collect include visible things such as bone structure, as well as molecular data about cell structure and DNA. Sometimes they gather very detailed data, such as how many cusps there are on a tooth, tooth size (which may vary by only a millimeter or less), or the order of the base pairs in a gene. Often more than 100 different characteristics may be gathered for each organism.



Physical characteristics are one type of evidence used to place organisms within a phylogenetic tree.

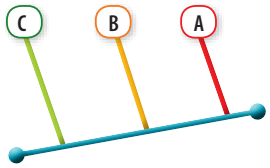
How are these mammals' teeth similar? How are they different? Would a scientist place these mammals on a phylogenetic tree based solely on teeth structure? Explain.

Once scientists have gathered the data, it is entered into a computer database. A computer program analyzes the data, looks for similarities, and generates phylogenetic trees, which are also called **cladograms**. A phylogenetic tree is based on presumed relatedness that supports evolutionary progressive development, an idea that is inconsistent with a biblical worldview. The phylogenetic trees are inferred from the similarities shared by various organisms. It is easy to imagine how, depending on which characteristics are entered into the computer, different relationships might be suggested.

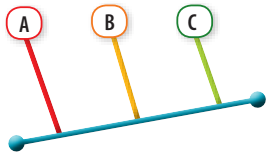
Science Background

Phylogentic Analysis Using Parsimony PAUP is a software program used by scientists in the process of phylogenetic analysis. Scientists select the characteristics that they will study and enter them into a computer. Scientists can then compare hundreds of different characteristics at once. An outgroup must be designated, with which the characteristics of each of the other species will be compared. The species that appears to be the most primitive will be chosen for the outgroup, and the assumption is made that each of the other species evolved from something like the outgroup animal. Once all this data has been entered, the program will analyze it and create a phylogenetic tree that is the most parsimonious; i.e., it will select the simplest sequence that would require the fewest number of evolutionary steps. The species selected as the outgroup can greatly influence the resulting tree.

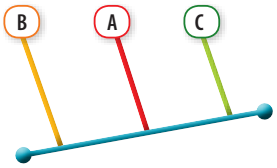
To illustrate this, let A, B, and C stand for three imaginary organisms. Imagine a scientist gathering data about dozens of different characteristics, or traits, of all three creatures. When the computer analyzes the data, it suggests that according to several of the traits, A is more closely related to B than to C.



Data from several other characteristics suggests that C is more closely related to B than to A.



Data from still other traits might suggest that C is more closely related to A than to B.



Scientists actually do encounter such conflicting data when they conduct a phylogenetic analysis. In fact, every phylogenetic tree contains some data that appears to be out of order. Scientists then have to decide which tree to choose. They decide based on something called **parsimony**, which means that they select the simplest option, or the one that requires the fewest evolutionary changes. What do you think might account for differences in data?

Scripture Spotlight

In **Matthew 12:46–50**, Jesus describes how people can be as closely related to Him as His own mother and brothers were. What characteristic makes us like family?

Develop Key Vocabulary

parsimony This term comes from the Latin word *parsimonia* which means "frugality, thrift." Ask students whether a scientist who uses parsimony to make decisions is being a "frugal" or "thrifty" scientist.

Teach Science Concepts

Explain to students that if phylogenetic analysis resulted in only one unanimously agreed upon evolutionary tree, there would be no need for parsimony. However, because every suggested evolutionary tree has characteristics that appear to be out of place, it is necessary to select the one with the least number of out-of-sequence characteristics. To illustrate the idea of parsimony, have students imagine that when they come to school in the morning, they find a horse in the parking lot (or an elephant on the roof). Give them a few minutes to write an explanation of how the animal got there. After students have read their explanations aloud, lead a discussion about which of the possible stories is the simplest, least complicated explanation. Connect it to the idea that scientists try to find the simplest explanation with the fewest evolutionary steps when they are choosing between different evolutionary trees.

Scripture Spotlight

Matthew 12:46–50 explains that those who do the will of God become like family to Jesus.

Scaffolded Questions

Approaching Level **Describe a phylogenetic tree.** It is a drawing used by evolutionists to show relatedness of organisms. It is made of lines that connect and resemble a tree with a few branches or many branches.

On Level **Have students study the first tree on the page. Why is C so far from A on the tree?** C has fewer similarities, so it is placed farther away from A on the tree.

Above Level **Why might a computer program generate more than one phylogenetic tree for the same organisms?** There may be different physical characteristics observed and entered into the computer program. With each additional bit of information, the computer may suggest a new version of the phylogenetic tree.

Investigating Adaptation

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.)*

Teach Science Concepts

Scientists use the scientific method to analyze the traits of the developed phylogenetic tree or cladogram. There is no way to measure whether a particular phylogenetic hypothesis is accurate. **What are some potential problems that scientists should consider before making conclusions about evolutionary groups?** Organisms can obtain genes through two different ways: parent to offspring (vertical gene transfer) or genes are transferred between unrelated organisms (horizontal gene transfer). Drawing conclusions or developing hypotheses about groups of organisms can be a "tricky" situation. Another thing to discuss with students is whether outside influences disturbed the process.

Understand Visuals

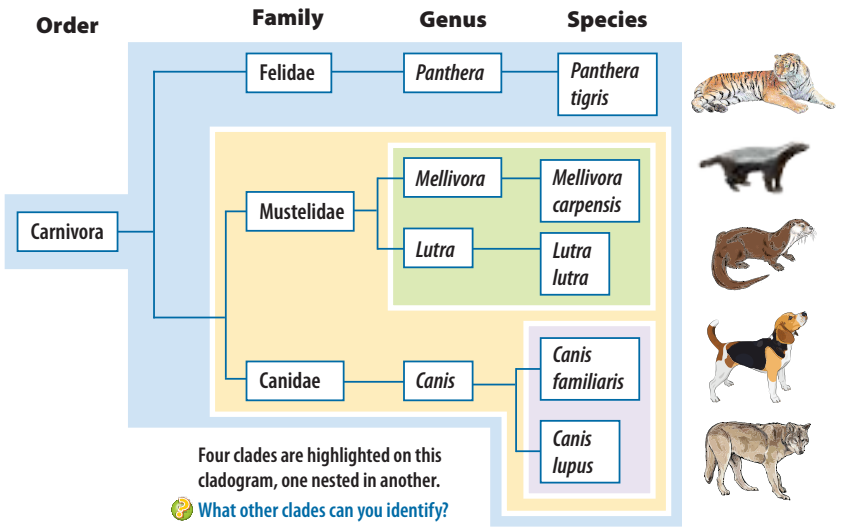
What other clades can you identify?
Sample answer: Another clade on the cladogram contains *Canis familiaris, Canis lupus, Canis,* and *Canidae*.

Explore-a-Lab Structured Inquiry

Have students work in small groups. Provide an assortment of silverware and kitchen utensils, such as a butter knife, dinner fork, salad fork, teaspoon, soup spoon, ice cream scoop, salad tongs, slotted serving spoon, spork, steak knife, chopsticks, and rubber-tipped baby spoon. Allow time for groups to compare their cladograms.

How many ways can the same organisms be grouped into different cladograms?
Sample answer: Depending on the oberservations made and the assumptions made about how structures are formed and function, organisms can be listed in a variety of ways on a cladogram.

Look at this example of a cladogram. Groups of animals that share similar characteristics are called *clades*. Notice how the clades are nested within larger clades.



Four clades are highlighted on this cladogram, one nested in another.
What other clades can you identify?

By doing phylogenetic analyses on many different clades, scientists create trees or bushes that they think best approximate evolutionary history. As you might guess, not all scientists agree with each other about how the bush should look, and changes continue to be made as they gather more data.

Explore-a-Lab Structured Inquiry

How many ways can the same organisms be grouped into different cladograms?

Your teacher will provide your group with an assortment of silverware and utensils. In your group, discuss the characteristics of the items and sort the items into two groups. Draw the beginnings of a cladogram on a large sheet of paper and record these two groups. Then sort the two groups into two more groups each. Record these new groups on the cladogram. Observe other groups' cladograms. Compare the different ways the items were grouped. How might a scientist interpret your cladogram?

42

Science and Society

To Teach or Not? During the famous Scopes Trial in 1925, a substitute high school teacher was found guilty of teaching evolution in a public school. Since that time, public bias has reversed to such an extent that **only** evolution may be taught in public school science classes. Pro-evolutionary bias is illustrated by the major controversy that erupted when an article by Stephen Meyer about the Cambrian Explosion appeared in a journal called *Proceedings of the Biological Society of Washington* in 2004. Because the article suggested Intelligent Design as an explanation for the Cambrian Explosion, editor Richard Sternberg, himself an evolutionary biologist, faced severe criticism for allowing the article to be peer reviewed and published. The DVD *Expelled: No Intelligence Allowed* explores the claim that bias against scientists interested in Intelligent Design exists.

In spite of the fact that phylogenetic analysis is based on the assumption that evolution has occurred, it can still be a useful tool for creationists as well as evolutionists. A cladogram is a valid way to represent the similarities and differences between different organisms, but it is important to remember that there are limits to what questions it can answer. Consider these two questions:

1. Which animals are most closely related to each other?
2. Did organisms evolve?

Cladistics, which is another name for the process of phylogenetic analysis, can suggest answers to Question 1, but it cannot answer Question 2. It assumes that evolution happened and tries to figure out the evolutionary history of organisms based on similar characteristics.

We examined biological evidence related to Question 2 in the last lesson. We looked at observable data and compared different interpretations of that data. Let us do the same thing with cladistics. The information gathered about organisms and entered into the computer is data. The suggestions of evolutionary relationships generated by the computer and selected by the scientists are interpretations of that data based on evolutionary assumptions. Scientists who believe in the biblical story of Creation might use the same data to draw conclusions about the similarities of various organisms created by God.

Concept Check Assess/Reflect

Summary: What is phylogenetics? Organisms are classified based on body processes, obvious physical characteristics, cellular structure, and DNA. Organisms can also be classified based on assumptions that they evolved from common ancestors. This process of grouping is called phylogenetic analysis, or cladistics. The results of the analysis are displayed using phylogenetic trees, or cladograms. Often the cladograms show conflicting data, and scientists will choose the simplest option.

1. How have advances in technology changed the way organisms are classified?
2. Why do scientists use parsimony to select a phylogenetic tree?
3. What are some limits in the use of phylogenetic analysis?

Science Background

Classifying and Phylogenetic Trees All mammals can be classified into one of the following groups: monotremes (egg layers), marsupials (live, early birth), and placentals (live, regular birth). The Tasmanian wolf has a marsupial reproductive system but has limbs like a dog. Because Tasmanian wolves and dogs are in different groups, they would not be very close to each other on a phylogenetic tree. Evolutionists would suggest that the leg structure had to evolve twice, once on each branch of the family tree. A similar situation exists with saber-toothed tigers. There is a marsupial saber-toothed tiger and a placental saber-toothed tiger. A creationist could look at the phylogenetic trees and infer that God used the same leg structure when he created marsupial and placental wolves and a similar teeth structure when he created marsupial and placental tigers.

Develop Key Vocabulary

cladistics This term is synonymous with *phylogenetic analysis*. It is a system of classification based on phylogenetics. To further vocabulary knowledge, ask students to identify other words in this lesson that are synonymous. Students may suggest *systematics/classification, phylogenetic analysis/cladistics,* and *phylogenetic trees/cladograms.*

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: Because of advances in technology, scientists are able to classify organisms based on similarities at the cellular and molecular level. Technology also helps scientists compare hundreds of characteristics, a task that would have been hard to do by hand.
2. Sample answer: Scientists may have too many choices when selecting a cladogram. Choosing the one with the simplest explanation is often considered the best choice when evolutionists are describing how organisms are related.
3. Sample answer: There may be limits of phylogenetic analysis, such as incomplete data and observations or large variations in a species that make it look like a different species. In addition, phylogenetic analysis can only answer certain questions about shared traits, not about whether evolution occurred.

People in Science

Extend

Set Goals

After students study this page, ask them to think about how the study of taphonomy may extend our knowledge of the life history of the once-living organism.

Leonard Brand Teach Science Concepts

Taphonomy, the study of an organism after its death, includes the chemical and physical activities that affect the remains of the once-living organism. Factors that affect what happens to the organism's remains depend on whether the organism is immediately buried by sediments or whether the organism remains exposed in its environment. An organism can be preserved in a variety of ways. Soft body parts are preserved through the process of mummification, burial in tar, and encasement in amber, sediments, or ice. Skeletons, shells, or other hard parts often form molds and casts.

Called to Serve

Leonard Brand has written an easy-to-understand textbook called *Faith, Reason, & Earth History,* published by Andrews University Press and, with David Jarnes, authored a book called *Beginnings*, published by Pacific Press Publishing Association.

Concept Check

1. By studying geological processes that form fossils, scientists can explain why some animals are preserved and others are not.
2. Scientific evidence can support the religious concepts that are presented in religious texts such as the Bible, for example, the sequence of events in Genesis.

People in Science

Extend

Get to Know
Leonard Brand

Leonard Brand is a professor of biology and paleontology at Loma Linda University in California. He was educated at Cornell University, earning his PhD in ecology and evolutionary biology. As a biologist, one of Brand's areas of expertise is in taphonomy. Taphonomy is the study of organisms after they die. The events that take place after an organism dies, such as decomposition, burial, and fossilization, are all part of taphonomy.

As a paleontologist, Brand applies his understanding of taphonomy to the fossilized remains of organisms that lived long ago. He researches the processes that cause different types of fossils to form. His research often includes an analysis of the geological processes involved in fossil formation, such as weathering and erosion.

Brand has done extensive research into the taphonomy of vertebrates. He has studied whale fossils in Peru, which are preserved in the sedimentary rock of the Pisco Formation. He has studied fossilized turtles in Wyoming, where deposition in the Bridger Formation has preserved many turtle remains in sedimentary rock. Throughout his research, Brand aims to show that science and religion can work together.

Called to Serve

Leonard Brand has written extensively on ways that science and religion can work together. He believes that scientific theories are important "stepping-stones in our search for truth."

Concept Check

1. How can studying geological processes help us understand fossil formation?
2. Why is it important for Brand to think about ways that science and religion can work together?

Science Background

The Pisco Formation The Pisco Formation is an area near the coast of Peru that contains thousands of fossils of whales and other marine vertebrates that include seals, dolphins, penguins, sharks, and fish. Many of the whales are complete fossils and include preserved baleen. The area of the buried fossils reaches a depth of 80 meters through a thick section of sedimentation.

The Bridger Formation is a combination of rock-layer deposits that extend about 800 meters in depth. The layers of rock vary in color and composition, including sandstone, mudstone, claystone, and ash-fall tuff beds that were formed by volcanic ash. Turtle fossils are the most abundant of the highly diverse vertebrates found, which include fish, amphibians, reptiles, birds, and mammals.

The Geoscience Research Institute

Does science give us the answers to philosophical questions about our origin and destiny and about our purpose for living? A significant conflict of science and religion is between the theory of evolution with its billions of years for the progressive development of life and the biblical account of the Creation of life by God in six literal days a few thousand years ago.

The **Geoscience Research Institute (GRI)** is an official research institute of the Seventh-day Adventist Church. The GRI was founded in 1958 to advise the Seventh-day Adventist Church on issues relating science to faith. The Institute uses both science and revelation to study the question of origins because it considers that both sources of information can contribute to our understanding of Earth's history. The Institute serves the Seventh-day Adventist Church in two major areas, research and education.

Raúl Esperante, PhD, is a scientist engaged in paleontology research for the GRI in Peru and Spain. He was part of a team that studied a 370-acre area in Peru containing 346 fossilized whales. The nearly perfect preservation of these whales indicates that the whales had to have been buried very quickly—not over millions of years.

What caused so many whales to die in one place? What caused the rapid burial? Esperante and his colleagues theorize about what may have happened. One wonders if this may be more easily explained by a global flood that once covered Earth, and the rapid geological processes after that flood. Could these unusual events possibly explain how 346 whales were buried so rapidly and completely in Peru?

Science and technology are successful methods of applying knowledge to improve our understanding of how we do things and how things work. They have improved our standard of living — from better shelters, time-saving appliances, life-saving medical advances, and new types of recreation to faster and safer methods of communication and transportation. However, our knowledge that God was active in Creation means that questions of origins should be studied in the context of the information revealed in the Bible. The GRI provides the resources to respond to questions about science and faith.

Concept Check

1. Why was the GRI established?
2. What does the GRI do to try to settle the perceived conflict between religion and science?

Science Background

Geoscience Research Institute GRI's mission is to discover and share an understanding of nature and its relationship with the biblical revelation of the Creator God. It seeks to discover through original research, through study of the scientific and biblical literature, and through interaction and discussion with other scholars. It seeks to share through its website, publications, and lectures; through field conferences and seminars; and through regular contact with SDA educators and students. GRI is committed to serving the SDA church in its commission of preaching the gospel and bringing to all the truth of salvation in Jesus Christ. GRI's website contains a newsletter, archives of *Origins*—a peer-reviewed journal that addresses both scientific and theological issues related to origins—research archives, science news, and other resources.

Extend

Set Goals

As students study this page, ask them to think about how science and religion can answer basic questions about the origins of life and the evolutionary process.

The Geoscience Research Institute Teach Science Concepts

The study of the fossilized whales in the Pisco Formation indicates that they did not undergo the normal fossilization process. Whales that die and descend to the ocean floor generally undergo a process in which the whale blubber is decomposed by bacteria and eaten by scavengers. Invertebrates such as snails, clams, crustaceans, and the like bore into the bones to feed on the blubber inside. The remains of the whale bones are often broken apart and scattered through the motion of waves and storms. The fossils of the Pisco Formation have a large number of skeletons that are whole with little evidence of burrowing or scavenging by invertebrates or dispersal by ocean currents or waves. Rapid burial is indicated by the absence of invertebrates colonizing the bones and their traces. The presence of baleen appears in the fossilized skeletons. Baleen decomposes rapidly. The presence of baleen in the whale fossils also indicates rapid burial.

Concept Check

1. The GRI was established to advise Seventh-day Adventists on issues relating science to faith, such as the study of evolution and origins of life.
2. The GRI tries to settle the perceived conflict between religion and science by using both science and revelation as it studies questions relating to geologic history and origins of life.

Chapter 1

Assess/Reflect

Study Guide

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

Family Link

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

At Home Classification Select a location that could benefit from some organization and classification. Begin by cataloging all the items you find there. Then develop a classification system that sorts the items. Talk about how this method of classification resembles the approach scientists use when they categorize organisms.

More Fun with Science

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

Scientists and Christians Many well-known scientists are also devout Christians. Ask students to research a Christian scientist and prepare a report for the class. Student could be encouraged to dress as their scientist or show models or diagrams of their scientist's contributions to science and how these contributions support their faith as well.

Answer Key

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

1. panspermia

2. fixity of species

3. mutations

4. spontaneous generation

5. vestigial

6. homologous

7. C

8. B

Chapter 1

Review Assess/Reflect

Study Guide

Lesson 1

1. Origins of life attempt to describe where the world came from and how life began. Two basic ideas about the origins of life are Creation by God and life arising through the evolutionary process. Intelligent Design is the theory that the Universe and all life are the result of a designer. Evolution is the theory that all species evolved as a result of natural selection.

2. The Miller-Urey experiment attempted to simulate the conditions of early Earth and the process by which the first life formed.

3. Darwin theorized that new species evolved as a result of natural selection.

4. Microevolution refers to small changes in a species over time. Macroevolution refers to large-scale evolutionary changes over time. While microevolution is supported by considerable evidence, macroevolution has not been shown to have taken place.

Lesson 2

1. Evidence for different theories of origins can be found by studying embryology, vestigial structures, homology and analogy, genetic similarities, design, and fossil records. Interpretation of this evidence is used to support theories of the origins of life.

2. The creationist and naturalistic interpretations of the observable data concerning the origins of life are quite thorough and extensive. Creationists interpret the fossil record as representative of the sequence of species, burial during the Flood and later geologic activity. Evolutionists interpret the fossil record as the evolution of life forms that all arose from common ancestors.

3. Vestigial structures may be the result of the loss of genetic material, or they may not even be vestigial at all. It may be that scientists have not yet discovered the function of these structures.

4. Homologous structures have similar construction but differ in function. Analogous structures have different construction but the same function.

Lesson 3

1. Scientists use the process of systematics to classify organisms. Systematics uses physical characteristics, body processes, and molecular data to classify organisms.

2. Phylogenetics classifies organisms based on shared, common characteristics that were not shared by the presumed ancestors.

3. A phylogenetic tree graphically displays the grouping of organisms based on multiple shared characteristics that are not shared with organisms thought to have been their ancestors.

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:** Draw two circles to create a Venn diagram. Label one *Evolution*, and label the other *Creation*. Compare and contrast the two ideas.

Vocabulary Check

Fill in the blanks with the correct vocabulary word.

1. The idea that life is actually widespread throughout the Universe is known as _____.
2. The idea that living organisms never change is called _____.
3. Microevolutionary changes in a species can be introduced through genetic _____.
4. When Redi found no maggots forming on meat inside a closed container, his evidence refuted the idea of _____.
5. Body parts that are thought to have no function are called _____.
6. A human hand and a whale's flipper have similar construction but different functions, so they are _____ structures.

Multiple Choice

Choose the best answer.

7. Phylogenetics is used by evolutionary scientists to support which statement?
   A. Species with analogous structures are distantly related.
   B. Species with homologous structures are closely related.
   C. Species with similar genes are closely related.
   D. Species with similar genes are distantly related.
8. Whose experiments and studies involved combining electricity and nonliving compounds?
   A. Aristotle
   B. Miller and Urey
   C. Linnaeus and Redi
   D. Jean-Baptiste van Helmont
9. A paleontologist discovered a new species of snail that emerged rapidly in prehistoric times. Which evidence is most likely being studied?
   A. genetic similarity
   B. embryology
   C. fossil records
   D. homologous structures
10. What does natural selection select?
    A. genes
    B. ancestors
    C. analogous structures
    D. homologous structures

Check Point

Answer the following questions.

11. Francesco Redi had to **control variables** in his experiment regarding spontaneous generation. Describe how he controlled the variables.
12. How did Darwin **classify** the Galápagos finches?
13. There is an increasing number of wild Asian elephants being born tuskless. Although poaching elephants for their ivory has decreased, it still exists. Based on this information, what can you **infer** about the connection between poaching and the changing elephant species?
14. A scientist is studying the structure of lizard legs and crab legs. Are these homologous or analogous structures? Explain.

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Performance Assessment Rubric: Use the following rubric for evaluation.

3—Students correctly describe the ideas of evolution and Creation. Students correctly identify the similarities between the two ideas.

2—Students provide a partially correct description of the ideas of evolution and Creation. Students provide partially correct similarities between the two ideas.

1—Students provide a partially correct description of either evolution or Creation. Students are not able to identify the similarities between the two ideas.

0—Students do not correctly describe the ideas of evolution and Creation and do not identify any similarities between them.

9. C

10. A

11. Redi used the same type of meat in similar jars. He changed the type of covering on the jars—netting, sealed completely, and no cover.

12. Darwin classified the Galápagos finches based on their beak shapes.

13. Sample answer: Poaching elephants with tusks is reducing the tusk gene in the population. The elephants without tusks are not being poached, so their tuskless gene is increasing slowly in the population.

14. Sample answer: A scientist would consider lizard legs and crab legs as analogous structures. Simply put, the legs have the similar function of walking, but the legs have no similar structures.