SECTION 5 Step-by-Step Instruction

Objectives

As you teach this section, keep students focused on the following objectives to help them answer the Section Focus Question and master core content.

- Explain how new discoveries in astronomy changed the way people viewed the universe.
- Understand the new scientific method and how it developed.
- Analyze the contributions that Newton and other scientists made to the Scientific Revolution.

Prepare to Read

Build Background Knowledge L3

Emphasize that changes in science happened at the same time as social, political, and artistic changes of the Renaissance. Remind students that many artists were interested in science and nature, and their art reflected those interests.

Set a Purpose L3

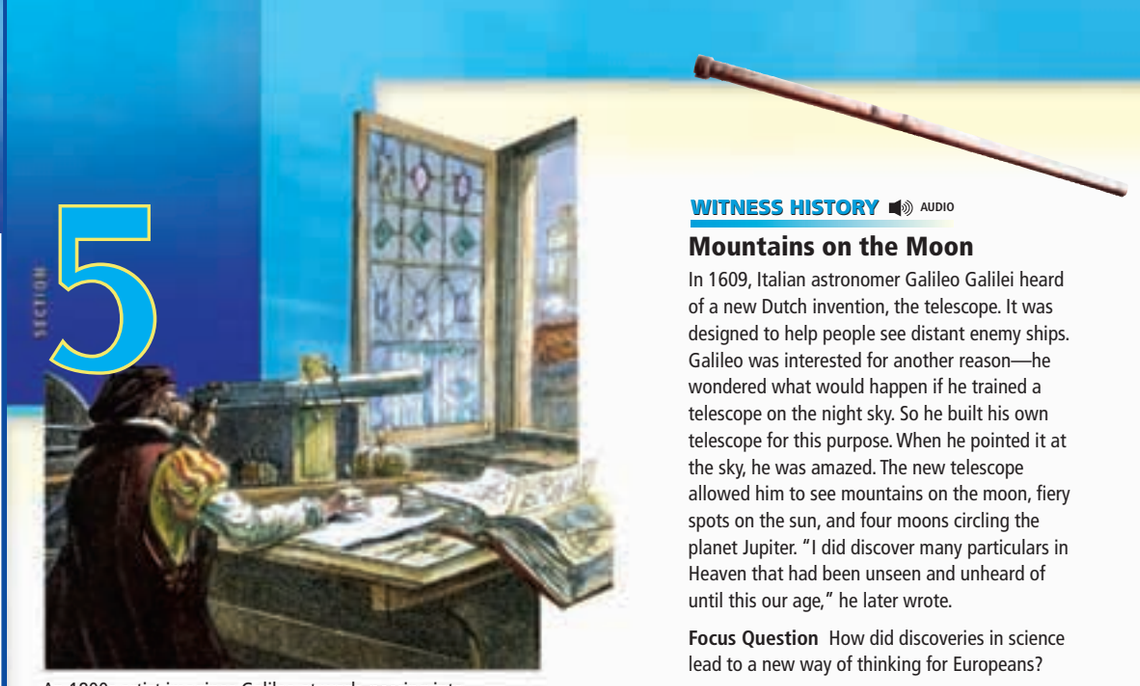
- **WITNESS HISTORY** Read the selection aloud or play the audio.

  AUDIO **Witness History Audio CD,** Mountains on the Moon

  Ask **What Renaissance characteristics does Galileo display in this story?** *(He shows great curiosity and inventiveness; he shows a worldview expanded by re-examining the universe.)*

- **Focus** Point out the Section Focus Question and write it on the board. Tell students to refer to this question as they read. *(Answer appears with Section 5 Assessment answers.)*
- **Preview** Have students preview the Section Objectives and the list of Terms, People, and Places.
- **Note Taking** Have students read this section using the Paragraph Shrinking strategy (TE, p. T20). As they read, have students fill in the table showing the important people of the Scientific Revolution.

  Reading and Note Taking Study Guide, p. 127



An 1800s artist imagines Galileo at work, peering into the sky. Galileo's telescope is shown at top right.

WITNESS HISTORY AUDIO

Mountains on the Moon

In 1609, Italian astronomer Galileo Galilei heard of a new Dutch invention, the telescope. It was designed to help people see distant enemy ships. Galileo was interested for another reason—he wondered what would happen if he trained a telescope on the night sky. So he built his own telescope for this purpose. When he pointed it at the sky, he was amazed. The new telescope allowed him to see mountains on the moon, fiery spots on the sun, and four moons circling the planet Jupiter. "I did discover many particulars in Heaven that had been unseen and unheard of until this our age," he later wrote.

Focus Question How did discoveries in science lead to a new way of thinking for Europeans?

The Scientific Revolution

Objectives

- Explain how new discoveries in astronomy changed the way people viewed the universe.
- Understand the new scientific method and how it developed.
- Analyze the contributions that Newton and other scientists made to the Scientific Revolution.

Terms, People, and Places

Nicolaus Copernicus
heliocentric
Tycho Brahe
Johannes Kepler
Galileo
Francis Bacon
René Descartes
scientific method
hypothesis
Robert Boyle
Isaac Newton
gravity
calculus

Note Taking

Reading Skills: Identify Main Ideas Use a table like the one below to record information about important people of the Scientific Revolution.

Thinkers of the Scientific Revolution	
Nicolaus Copernicus	Developed sun-centered universe theory

The Renaissance and the Reformation facilitated the breakdown of the medieval worldview. In the mid-1500s, a profound shift in scientific thinking brought about the final break with Europe's medieval past. Called the Scientific Revolution, this movement pointed toward a future shaped by a new way of thinking about the physical universe. At the heart of the Scientific Revolution was the assumption that mathematical laws governed nature and the universe. The physical world, therefore, could be known, managed, and shaped by people.

Changing Views of the Universe

Until the mid-1500s, Europeans' view of the universe was shaped by the theories of the ancient writers Ptolemy and Aristotle. More than 1,000 years before the Renaissance, they had taught that Earth was the center of the universe. Not only did this view seem to agree with common sense, it was accepted by the Church. In the 1500s and 1600s, however, people began to question this view.

Copernicus Challenges Ancient Astronomy In 1543, Polish scholar **Nicolaus Copernicus** (koh PUR nih kus) published *On the Revolutions of the Heavenly Spheres.* In it, he proposed a **heliocentric,** or sun-centered, model of the universe. The sun, he said, stands at the center of the universe. Earth is just one of several planets that revolve around the sun.

Vocabulary Builder

Use the information below and the following resources to teach the high-use words from this section.

All in One **Teaching Resources, Unit 3,** p. 7; **Teaching Resources, Skills Handbook,** p. 3

High-Use Words	Definitions and Sample Sentences
contradict, p. 435	*v.* to go against The evidence **contradicted** the scientist's original theory.
philosopher, p. 435	*n.* a person who is an expert in the study of knowledge The **philosopher** Aristotle developed a system of logic.

Most experts rejected this revolutionary theory. In Europe at the time, all scientific knowledge and many religious teachings were based on the arguments developed by classical thinkers. If Ptolemy's reasoning about the planets was wrong, people believed, then the whole system of human knowledge might be called into question. But in the late 1500s, the Danish astronomer **Tycho Brahe** (TEE koh BRAH uh) provided evidence that supported Copernicus's theory. Brahe set up an astronomical observatory. Every night for years, he carefully observed the sky, accumulating data about the movement of the heavenly bodies.

After Brahe's death, his assistant, the brilliant German astronomer and mathematician **Johannes Kepler,** used Brahe's data to calculate the orbits of the planets revolving around the sun. His calculations supported Copernicus's heliocentric view. At the same time, however, they showed that each planet does not move in a perfect circle, as both Ptolemy and Copernicus believed, but in an oval-shaped orbit called an ellipse.

Views of the Moon
Galileo sketched the views of the moon he saw through his telescope in 1609 (left). Pictures of the moon taken through a modern telescope (right) look remarkably similar.

Galileo's "Heresies" Scientists from many different lands built on the foundations laid by Copernicus and Kepler. In Italy, **Galileo** Galilei assembled an astronomical telescope. As you have read, he observed that the four moons of Jupiter move slowly around that planet—exactly, he realized, the way Copernicus said that Earth moves around the sun.

Galileo's discoveries caused an uproar. Other scholars attacked him because his observations contradicted ancient views about the world. The Church condemned him because his ideas challenged the Christian teaching that the heavens were fixed in position to Earth, and perfect.

Vocabulary Builder
contradict—(kahn truh DIKT) *v.* to go against

In 1633, Galileo was tried before the Inquisition, and for the rest of his life he was kept under house arrest. Threatened with death unless he withdrew his "heresies," Galileo agreed to state publicly in court that Earth stands motionless at the center of the universe. Legend has it that as he left the court he muttered, "And yet it moves."

Checkpoint **Why was Copernicus's theory seen as radical?**

A New Scientific Method

Despite the opposition of the Church, by the early 1600s a new approach to science had emerged, based upon observation and experimentation. During the Renaissance, the works of the ancient Greek philosopher Plato were rediscovered. Plato taught that man should look beyond simple appearances to learn nature's truths. He believed that mathematics, one of the greatest human achievements, was the key to learning these truths. His teachings were rediscovered by Renaissance scientists and helped shape people's view of the physical world.

Vocabulary Builder
philosopher—(fih LAHS uh fur) *n.* a person who is an expert in the study of knowledge

Teach

Changing Views of the Universe L3

Instruct

- **Introduce: Vocabulary Builder** Have students read the Vocabulary Builder terms and definitions. Ask them to predict how the word ***contradict*** might apply to Galileo's discoveries and the teachings of the Catholic Church.
- **Teach** Ask **Why was Galileo threatened with death because of his theories?** *(The Church feared that if its teachings on this matter were called into question, then all of its teachings could be questioned.)* **How might the experience of the Reformation have shaped the Church's response?** *(The Church had already seen itself as under attack by the Protestant Reformation. It was more aware than ever that it was in danger of losing authority.)*
- **Quick Activity** Point out the key term ***heliocentric*** (in blue) in the text. Explain to students how radical this theory was at the time. Have students formulate reasons why the Church was particularly opposed to this theory.

Independent Practice

Viewpoints To help students better understand the changing worldview of the time, have them read the selection *Does the Earth Move?*, which is from the correspondence between Galileo and Kepler, and complete the worksheet.

All in One **Teaching Resources, Unit 3,** p. 10

Monitor Progress

As students fill in their tables, circulate to make sure they understand the significance of the key scientists of the Scientific Revolution. For a completed version of the table, see

Note Taking Transparencies, 118

Differentiated Instruction Solutions for All Learners

L1 Special Needs **L2 Less Proficient Readers**

To help students understand the new discoveries, ask pairs of students to choose a scientist from this time period. Ask each pair to write a short encyclopedia entry summarizing the scientist's accomplishments, and then read their entry to the class. As a class, vote on which scientist was the most influential. Discuss the results.

L2 English Language Learners

Use the following resources to help students acquire basic skills:

Adapted Reading and Note Taking Study Guide

- Adapted Note Taking Study Guide, p. 127
- Adapted Section Summary, p. 128

Answer

It contradicted both Church teachings and common sense.

A New Scientific Method

Instruction

- **Introduce: Vocabulary Builder** Have students read the Vocabulary Builder term and definition. Ask them to speculate on why the work of a ***philosopher*** could be important to a scientist. Use the Think-Write-Pair-Share strategy (TE, p. T23) to structure group discussion.
- **Teach** Ask **What were the contributions of the philosophers Bacon and Descartes?** *(Their belief that truth can only be known after a process of investigation helped bring about the scientific method.)* **Why might a rigorous scientific method have particularly appealed to non-scientists?** *(Non-scientists could be assured that scientific conclusions were based on an established method of inquiry rather than on the idiosyncrasies of a particular scientist.)*
- **Quick Activity** Have student groups develop a quiz based on information in this section. Groups should first organize main ideas and key facts. Then they should decide on a format for their quiz—for example, multiple choice, matching, or a combination of questions. Finally, students should write their quizzes and present them to other groups to complete.

Independent Practice

To make sure that students understand that the Renaissance, Reformation, and Scientific Revolution were linked, have students construct a timeline that shows major events from all three.

Monitor Progress

Circulate to see that Quick Activity quizzes accurately reflect the material on the scientific method and that groups have correctly answered the questions.

Bacon and Descartes: Revolutionary Thinkers The new scientific method was really a revolution in thought. Two giants of this revolution were the Englishman **Francis Bacon** and the Frenchman **René Descartes** (day KAHRT). Each devoted himself to understanding how truth is determined. Both Bacon and Descartes, writing in the early 1600s, rejected Aristotle's scientific assumptions. They also challenged the scholarly traditions of the medieval universities that sought to make the physical world fit in with the teachings of the Church. Both argued that truth is not known at the beginning of inquiry but at the end, after a long process of investigation.

Bacon and Descartes differed in their methods, however. Bacon stressed experimentation and observation. He wanted science to make life better for people by leading to practical technologies. Descartes emphasized human reasoning as the best road to understanding. In his *Discourse on Method* (1637), he explains how he decided to discard all traditional authorities and search for provable knowledge. Left only with doubt, he concluded that doubt was the only thing he could not question, and that in order to doubt he had to exist as a rational, thinking being. Therefore he made his famous statement, "I think, therefore I am."

A Step-by-Step Process Over time, a step-by-step process of discovery evolved that became known as the **scientific method.** The scientific method required scientists to collect and accurately measure data. To explain the data, scientists used reasoning to propose a logical **hypothesis,** or possible explanation. They then tested the hypothesis with further observation or experimentation. Mathematical calculations were used to convert the observations and experiments into scientific laws. After reaching a conclusion, scientists repeated their work at least once—and usually many times—to confirm and refine their hypotheses or formulate better ones.

Checkpoint **How did Bacon and Descartes each approach the new scientific method?**

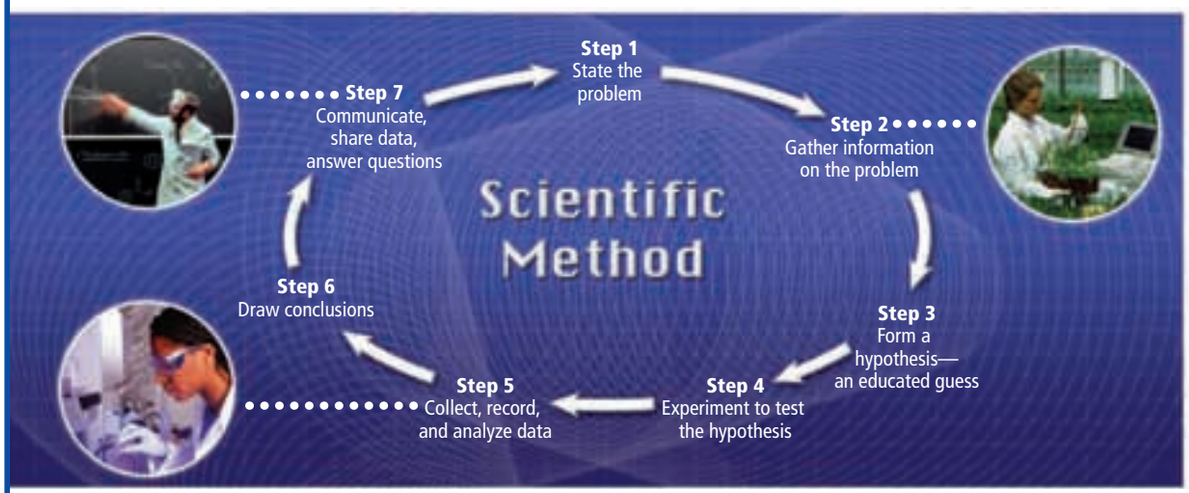


Diagram Skills The scientific method, still used today, is based on careful observation and measurement of data. *Why is Step 7 an important part of the process?*

History Background

Kepler's Laws Johannes Kepler wanted to know why Mars didn't appear where it was supposed to, based on mathematical calculations. Thanks to exact measurements by his mentor, Tycho Brahe, Kepler had excellent records of how Mars' position in the sky seemed to change. But the positions seemed wrong. They didn't fit any known theory of planetary movement. Racking his brain to work out a better theory, he finally came up with three principles of planetary motion, now known as Kepler's laws. Kepler was so exhilarated that he wrote, "Has not God himself waited 6,000 years for someone to contemplate his work with understanding?"

Answers

Bacon emphasized experimentation and observation, while Descartes emphasized human reasoning.

Diagram Skills because it allows other scientists to uncover possible errors or to use the results as a starting point for further investigation

Breakthroughs in Medicine and Chemistry

The 1500s and 1600s saw dramatic changes in many branches of science, especially medicine and chemistry. The rapid changes in science and technology that began in this period still continue to this day.

Exploring the Human Body Medieval physicians relied on the works of the ancient physician Galen. Galen, however, had made many errors, in part because he had limited knowledge of human anatomy. During the Renaissance, physicians made new efforts to study the human body. In 1543, Andreas Vesalius (vuh SAY lee us) published *On the Structure of the Human Body,* the first accurate and detailed study of human anatomy. Vesalius used whatever means he could to increase his knowledge of anatomy. He used friendships with people of influence to get invitations to autopsies. He also autopsied bodies that he himself obtained—counting on friends in the local government to look the other way.

In the early 1540s, French physician Ambroise Paré (pa RAY) developed a new and more effective ointment for preventing infection. He also developed new surgical techniques, introduced the use of artificial limbs, and invented several scientific instruments. Then in the early 1600s, William Harvey, an English scholar, described the circulation of the blood for the first time. He showed how the heart serves as a pump to force blood through veins and arteries. Later in the century, the Dutch inventor Anton van Leeuwenhoek (LAY wun hohk) perfected the microscope and became the first human to see cells and microorganisms. These pioneering scientists opened the way for further discoveries.

Human Anatomy
Renaissance artists and scientists, determined to learn how things really worked, studied nature with great curiosity. In the 1400s, Leonardo drew the muscles of the human arm with amazing accuracy (right). Renaissance doctors learned much about human anatomy from dissections (left). *How does this painting from the 1500s reflect the advances in scientific thinking?*

Breakthroughs in Medicine and Chemistry/Isaac Newton Links the Sciences

L3

Instruct

- **Introduce** Discuss the contributions and importance of Isaac Newton. Mention that his contributions to science are sometimes referred to as the "Newtonian Revolution." Ask students to discuss why Newton's work was revolutionary.
- **Teach** Review the rapid changes that occurred in medicine and chemistry at this time. Emphasize the expanding worldview, characterized by Leonardo's anatomical drawings, that led to greater knowledge of the human body. Discuss the visual titled Human Anatomy, Past and Present on this page. Ask **How is knowledge of the human body still expanding today?** *(Scientists are constantly developing and refining new technologies such as MRIs, computers, and lasers to give us more accurate views of the body.)*
- **Quick Activity** Display **Color Transparency 76: Hans Holbein's *The Ambassadors*** to investigate the links between Renaissance art and science. Use the lesson suggested in the transparency book to guide a discussion.

  Color Transparencies, 76

Independent Practice

Have students write a paragraph about a recent scientific discovery or debate. Paragraphs should include details describing the discovery or debate and an explanation of its significance.

Monitor Progress

Check Reading and Note Taking Study Guide entries for student understanding of the major figures of the Scientific Revolution and their accomplishments.

Answers

Caption It shows medical students engaged in learning about human anatomy by direct observation—an essential part of the scientific method.

Boyle established that all matter is composed of tiny particles that behave in certain knowable ways.

Assess and Reteach

Assess Progress

L3

- Have students complete the Section Assessment.
- Administer the Section Quiz.

All in One **Teaching Resources, Unit 3,** p. 6

- To further assess student understanding, use

Progress Monitoring Transparencies, 57

Reteach

If students need more instruction, have them read the section summary.

Reading and Note Taking Study Guide, p. 128 — L3

Adapted Reading and Note Taking Study Guide, p. 128 — L1 L2

Spanish Reading and Note Taking Study Guide, p. 128 — L2

Extend

L4

See this chapter's Professional Development pages for the Extend Online activity on Galileo's experiments.

Answers

Checkpoint He posited that objects he observed falling to Earth must have been pulled by the same forces that moved the planets.

PRIMARY SOURCE It suggests that Newton was highly respected and seen as a symbol of his time.

An English poet wrote the following as an epitaph for Newton's gravestone. What does it suggest about how people of the time viewed Newton's importance?

Primary Source

"Nature and Nature's Laws lay hid in night,
God said, Let Newton be! and all was light."
—Alexander Pope,

Transforming Chemistry The branch of science now called chemistry was in medieval times called alchemy. Alchemists believed that any substance could be transformed into any other substance, and many of them tried unsuccessfully to turn ordinary metals into gold. With the advances of the Scientific Revolution, the experiments of alchemists were abandoned. However, some of their practices—especially the manipulation of metals and acids—set the stage for modern chemistry.

In the 1600s, English chemist **Robert Boyle** refined the alchemists' view of chemicals as basic building blocks. He explained all matter as being composed of tiny particles that behave in knowable ways. Boyle distinguished between individual elements and chemical compounds, and explained the effect of temperature and pressure on gases. Boyle's work opened the way to modern chemical analysis of the composition of matter.

Checkpoint How did Boyle transform the science of chemistry?

Isaac Newton Links the Sciences

As a student in England, **Isaac Newton** devoured the works of the leading scientists of his day. By age 24, he had formed a brilliant theory to explain why the planets moved as they did. According to one story, Newton saw an apple fall from a tree. He wondered whether the force that pulled that apple to Earth might not also control the movements of the planets. In the next 20 years, Newton perfected his theory. Using mathematics, he showed that a single force keeps the planets in their orbits around the sun. He called this force **gravity.**

In 1687, Newton published a book explaining the law of gravity and other workings of the universe. Nature, argued Newton, follows uniform laws. All motion in the universe can be measured and described mathematically. To many, Newton's work seemed to link the sciences just as gravity itself bound the universe together.

For more than 200 years, Newton's laws held fast. In the early 1900s, startling new theories of the universe called some of his ideas into question. Yet his laws of motion and mechanics continue to have many practical uses. For example, **calculus**—a branch of mathematics partially developed by Newton and used to explain his laws—is still applied today.

Checkpoint How did Newton use observations of nature to explain the movements of the planets?

5 Assessment

Progress Monitoring *Online*
For: Self-quiz with vocabulary practice
Web Code: naa-1351

Terms, People, and Places

1. What do all of the key people listed at the beginning of this section have in common? Explain.

Note Taking

2. **Reading Skill: Identify Main Ideas** Use your completed table to answer the Focus Question: How did discoveries in science lead to a new way of thinking for Europeans?

Comprehension and Critical Thinking

3. **Recognize Ideologies** Why did the theories of Copernicus and Galileo threaten the views of the Church?
4. **Make Generalizations** In what ways did the scientific method differ from earlier approaches to learning?
5. **Recognize Cause and Effect** What impact did Renaissance ideas have on medicine?
6. **Synthesize Information** How did Newton use the ideas of Plato?

Writing About History

Quick Write: Write a Conclusion Write a conclusion to a persuasive essay about the Scientific Revolution. Your conclusion should restate a thesis statement, supported by one or two strong arguments. You may want to end your essay with a quotation. For example, you could use the Pope quotation to support a thesis that Newton's ideas were the most important of the Scientific Revolution.

Section 5 Assessment

1. Sentences should reflect an understanding of each term, person, or place listed at the beginning of the section.
2. As new astronomical discoveries challenged accepted views of the universe, scientists in all fields began to rely on observation rather than accepted wisdom.
3. They contradicted the teachings of the Church, which had been accepted for more than a thousand years.
4. Before, people learned accepted truths, dictated by tradition or religion. The scientific method was based on the idea that truth could come only through investigation.
5. The Renaissance worldview led people to explore the human body in new ways to see how it really worked, sparking new discoveries in anatomy and medicine.
6. He used Plato's emphasis on mathematics and reality to discover nature's laws.

Writing About History

Conclusions should strongly restate the thesis, but should not be merely repetitive.

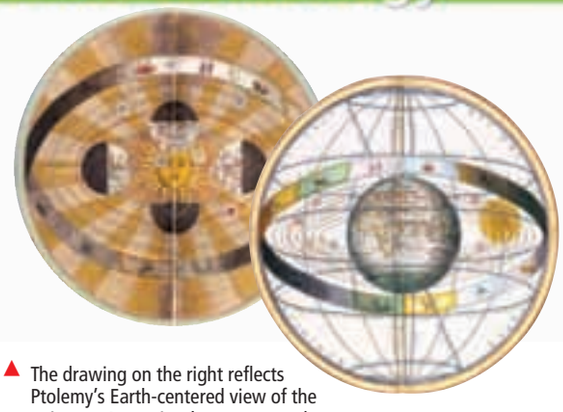
For additional assessment, have students access **Progress Monitoring *Online*** at **Web Code naa-1351.**

Concept Connector

Science and Technology

How has science changed people's lives throughout history?

Copernicus played a critical role in the Scientific Revolution. His heliocentric theory, supported by the work of Kepler, Galileo, and other scientists, undermined the existing worldview of the Church and of most European scholars. It helped lead to a whole new approach to science, based on observation and experimentation. Despite its revolutionary nature, Copernicus's theory did not directly change people's lives. Yet many of the scientific observations and experiments that followed had important practical effects, as the following medical examples reveal.



▲ The drawing on the right reflects Ptolemy's Earth-centered view of the universe. Copernicus's sun-centered universe is shown at left.

Organ Transplantation

An organ transplant is the transfer of a living body organ to an ill person in order to restore that person's health. Dr. Joseph Murray performed the first transplant in 1954 when he transferred a kidney from one twin to the other. Since then, the success rate for transplants has grown steadily, thanks to new techniques and new drugs that keep the body from rejecting a donated organ. During 2003, surgeons transplanted more than 25,000 organs, including hearts, lungs, livers, and kidneys.

▲ Alonzo Mourning plays in his first basketball game after receiving a kidney transplant.

Vaccination

You probably received your first vaccination as an infant. Vaccination, also called immunization, introduces killed or altered bacteria or viruses into the body. This triggers the body's immune system, enabling it to defend against the disease. In the 1790s, Edward Jenner launched the scientific study of immunization when he discovered a vaccine against smallpox, a disease that had plagued humankind since ancient times. By 1980, vaccination had finally rid the world of smallpox.

▲ This French illustration shows Edward Jenner administering a vaccine.

Microscope

Anton van Leeuwenhoek had a hobby. In his spare time, he liked to grind lenses and use them to observe worlds formerly hidden from sight. In 1684, using his simple microscope, he became the first person to describe red blood cells accurately. In modern times, the microscope has served as a vital tool for saving lives. Doctors use it to identify the bacteria and other germs causing an illness. Based on their findings, they can tailor their treatment to fight the patient's specific disease.

▲ A greatly enlarged image of tiny bacteria

Thinking Critically

1. How did the Scientific Revolution pave the way for the medical successes described above? How have those successes changed people's lives?
2. **Connections to Today** Do research to find out more about these and other examples of scientific breakthroughs. Choose one breakthrough and write a press release announcing it to the world.

Concept Connector

Science

Objectives

- Understand how the Scientific Revolution ushered in a period of great change in science and technology.
- Describe the medical advances made possible by the microscope, vaccination, and organ transplants.

Build Background Knowledge L3

Discuss the important connection between science and technology. Ask them if they think it would be possible today to have a major breakthrough in science without the use of technology.

Instruct L3

Direct students' attention to the question at the top of the page: **How has science changed people's lives throughout history?** Have students think of both direct changes, such as developing the cure to a disease, and more indirect changes, such as the effects of scientific discoveries on how non-scientists work through problems.

Independent Practice

Concept Connector Have students fill in the Concept Connector worksheet on Science, which includes additional examples and critical thinking questions.

Reading and Note Taking Study Guide, p. 372

Monitor Progress

Circulate to make sure that students are filling in their Concept Connector worksheets accurately.

Thinking Critically

1. The Scientific Revolution brought about a new worldview of observation and systematic investigation of the physical world, paving the way for medical and other scientific discoveries. The microscope, vaccinations, and organ transplants have all saved lives and improved people's well-being.
2. Students' press releases should emphasize the drama of the breakthrough, the science and technology that made it possible, and the importance of science to everyday life.