

The Scientific Revolution



California Standards

History–Social Science

7.10 Students analyze the historical developments of the Scientific Revolution and its lasting effect on religious, political, and cultural institutions.

English–Language Arts

Speaking 7.2.4b Describe the points in support of the argument and employ well-articulated evidence.

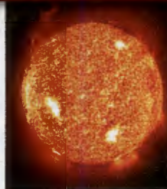
Reading 7.2.0 Students read and understand grade-level-appropriate material.

FOCUS ON SPEAKING



A Defense One of Europe's greatest scientists, Galileo Galilei, has been arrested and is being put on trial for contradicting Church teachings. You think he's innocent, and you've been hired to defend Galileo to the court. As you read this chapter, you will gather information that you can use to give a short speech in the scientist's defense.

1543
Copernicus publishes his theory of the sun-centered solar system.



CHAPTER EVENTS

1525

WORLD EVENTS

1537
Francisco Pizarro conquers the Incas.



▶ video series

Watch the video to understand the impact of the Renaissance and Reformation.



What You Will Learn...

In this chapter you will learn about the discoveries and inventions of the Scientific Revolution. The Scientific Revolution laid the foundations for modern science. This photo shows a powerful telescope that astronomers use to study the skies.

c.1590

Zacharias Janssen invents the microscope.

1609

Galileo uses his telescope to study planets.

**1687**

Sir Isaac Newton publishes *Principia Mathematica*.

**1575**

1620
The *Mayflower* sets sail for North America.

1625

c.1631
Construction begins on the Taj Mahal in India.

**1675**

1690
John Locke argues that people have certain natural rights.

1725

Economics

Geography

Politics

Religion

Society and Culture

Science and Technology

Focus on Themes This chapter will discuss the advances in **science and technology** made during the Scientific Revolution. As you read this chapter you will learn about such great scientists as Nicolaus Copernicus, Galileo, and Isaac Newton—scientists

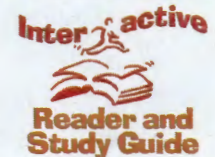
whose ideas are respected and admired even today. They and other scientists like them have greatly influenced **society and culture**, not just in Europe but around the world. Think how much different our lives would be without science!

Comparing and Contrasting Historical Facts

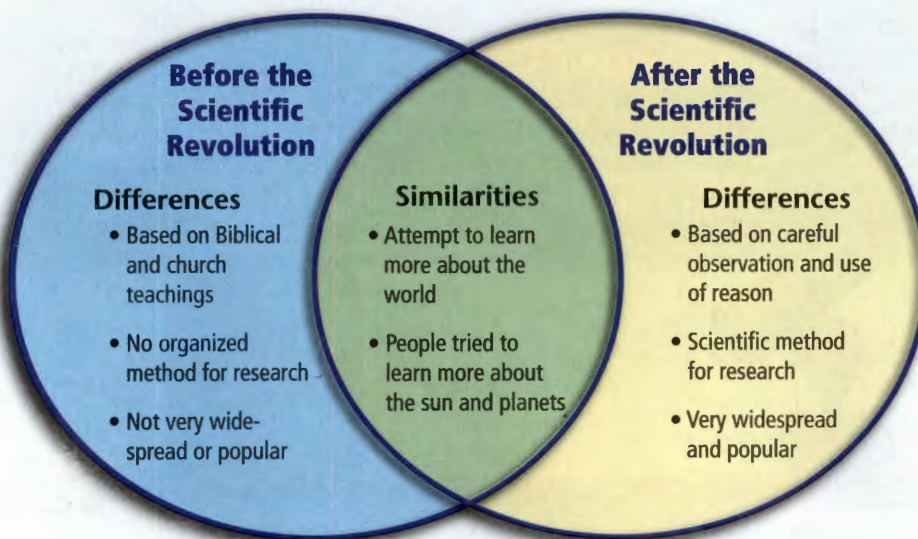
Focus on Reading Comparing and contrasting facts, ideas, or concepts is a good way to learn more about them. That's one reason historians use comparison and contrast to explain people and events in history.

Understanding Comparison and Contrast To **compare** is to look for likenesses, or similarities. To **contrast** is to look for differences. Sometimes writers point out similarities and differences. Other times you have to look for them yourself. You can use a diagram like this one to keep track of similarities and differences as you read.

Additional reading support can be found in the



Science



Clues for Comparison-Contrast

Writers sometimes signal comparisons or contrasts with words like these:

Comparison—*similarly, like, in the same way, too*

Contrast—*however, unlike, but, while, although, in contrast*



ELA Reading 7.2.0 Read and understand grade-level-appropriate material.

You Try It!

The following passage is from the chapter you are about to read. Read this passage looking for what two things are being compared and contrasted.

Nicolaus Copernicus

Copernicus was familiar with Ptolemy's theories and writings. Ptolemy had written that the earth was the center of the universe and that the sun and other planets orbited, or circled around, the earth. For 1,400 years, people accepted this belief as fact.

As Copernicus studied the movements of the planets, however, what Ptolemy stated made less and less sense to him. If the planets were indeed orbiting the earth, they would have to be moving in very complex patterns.

So Copernicus tried a different explanation for what he observed in the sky. Copernicus asked, What if the planets actually orbited the sun? Suddenly, complex patterns weren't necessary to make sense of what Copernicus observed. Instead, simple circular orbits would account for the planets' movements.

*From
Chapter
13, pages
359–360*

After you read the passage, answer the following questions.

1. What two figures does this passage compare?
2. What is one way in which Ptolemy and Copernicus were similar? What is one way in which they were different?
3. Draw a diagram like the one on the previous page comparing Ptolemy and Copernicus. How will your information be arranged?
4. Why do you think the author organized this passage as a comparison and contrast?

Key Terms and People

Chapter 13

Section 1

Scientific Revolution (p. 354)
science (p. 355)
theories (p. 355)
Ptolemy (p. 356)
rationalists (p. 356)
alchemy (p. 357)

Section 2

Nicolaus Copernicus (p. 359)
Tycho Brahe (p. 360)
Johannes Kepler (p. 360)
Galileo Galilei (p. 361)
Sir Isaac Newton (p. 362)
barometer (p. 363)

Section 3

Francis Bacon (p. 364)
René Descartes (p. 365)
scientific method (p. 365)
hypothesis (p. 366)

Academic Vocabulary

Success in school is related to knowing academic vocabulary—the words that are frequently used in school assignments and discussions. In this chapter, you will learn the following academic words:

logical (p. 355)
procedure (p. 365)
principles (p. 366)

As you read Chapter 13, look for examples of text arranged as comparisons and contrasts.

A New View of the World

What You Will Learn...

Main Ideas

1. The Scientific Revolution marked the birth of modern science.
2. The roots of the Scientific Revolution can be traced to ancient Greece, the Muslim world, and Europe.

The Big Idea

Europeans drew on earlier ideas to develop a new way of gaining knowledge about the natural world.

Key Terms and People

Scientific Revolution, p. 354
 science, p. 355
 theories, p. 355
 Ptolemy, p. 356
 rationalists, p. 356
 alchemy, p. 357



HSS 7.10.1 Discuss the roots of the Scientific Revolution (e.g., Greek rationalism; Jewish, Christian, and Muslim science; Renaissance humanism; new knowledge from global exploration).

If YOU were there...

You are a student in Germany in the early 1500s. You love to watch the changing phases of the moon and draw the star patterns at different times of year. You've asked your teachers many questions: Why does the moon hang in the sky? Why do the stars move? But their answers don't seem convincing to you.

How can you find the answers to your questions?

BUILDING BACKGROUND In the 1500s, Europe was undergoing dramatic changes. The Renaissance was well under way. During the Renaissance, great advances were made in art, writing, and education. The stage was set for another revolution in thinking.

The Birth of Modern Science

During the 1500s and 1600s, a handful of brilliant individuals laid the foundations for science as we know it today. Some historians consider the development of modern science the most important event in the intellectual history of humankind.

A Revolution in Thinking

The series of events that led to the birth of modern science is called the **Scientific Revolution**. It occurred between about 1540 and 1700. Why would the birth of science be called a "revolution"? The answer is that science was a radical new idea. It was a completely different way of looking at the world.

Before the Scientific Revolution, most educated people who studied the world took guidance from the explanations given by authorities like ancient Greek writers and Catholic Church officials. After the Scientific Revolution, educated people placed more importance on what they observed and less on what they were told. They gained knowledge by observing the world around them and coming up with logical explanations for what they saw.

Understanding Science

Science is a particular way of gaining knowledge about the world. In fact, the word *science* comes from a Latin word meaning “knowledge” or “understanding.”

Science starts with observation. Scientists observe, or look at, the world. By observing the world they can identify facts about it. A famous scientist once said, “Science is built up with facts, as a house is with stones. But a collection of facts is no more a science than a pile of stones is a house.”

So scientists do more than identify facts. They use logic to explain the facts they have observed. The explanations scientists develop based on these facts are called **theories**.

Theories are not accepted on faith. They must be tested to see if they are true. Scientists design experiments to test their theories. If the experiments keep showing that the theory makes sense, the theory is kept. If the experiments do not support the theory, scientists try a new theory. In this way, scientists learn more about the world.

As you can see, scientific knowledge is based on observations, facts, and logical ideas, or theories, about them. Before the Scientific Revolution, this method of gaining knowledge was uncommon.

READING CHECK Finding Main Ideas What was the Scientific Revolution?

Roots of the Revolution

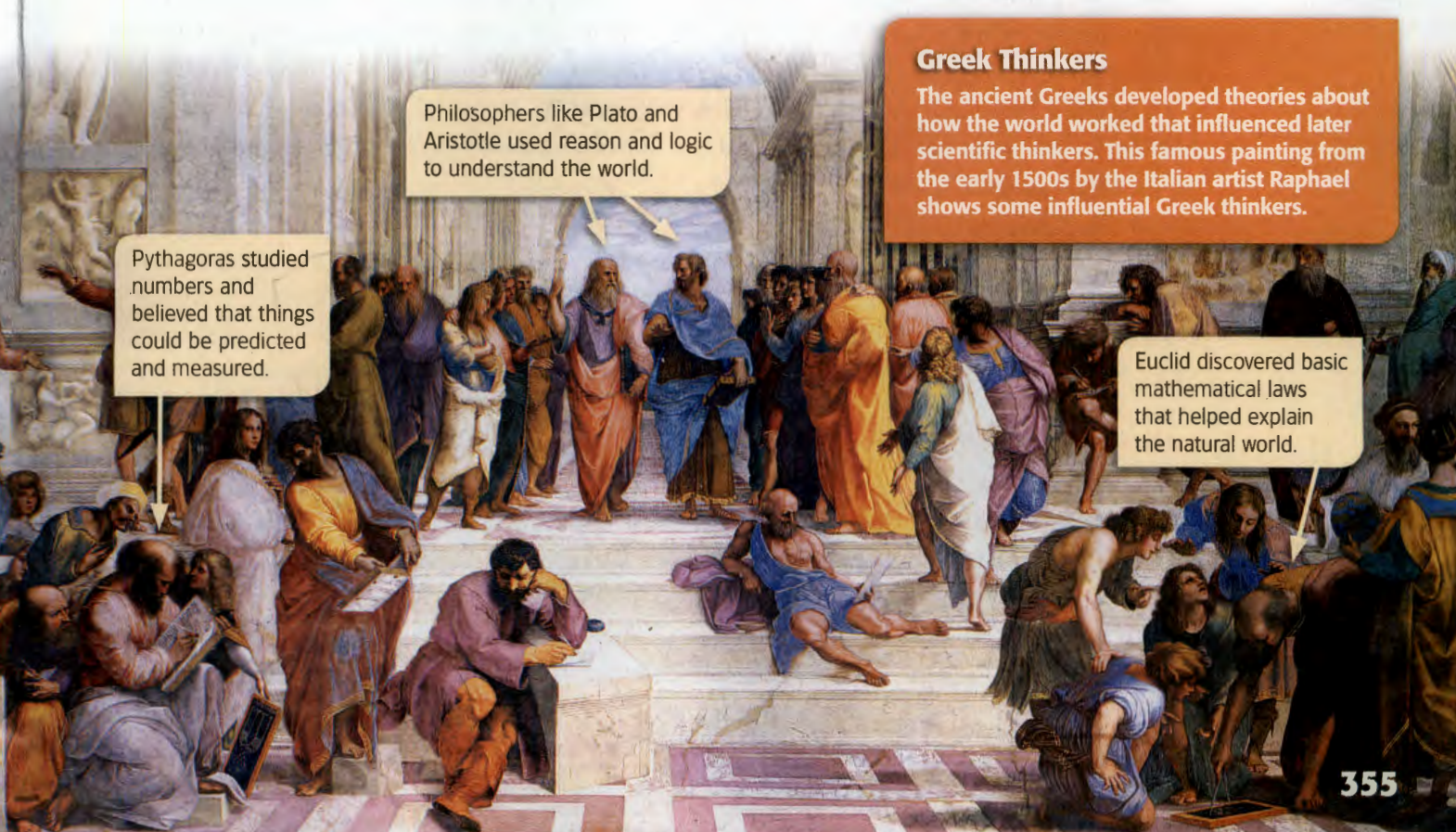
Some of the main ideas of science had been expressed long before the Scientific Revolution. In fact, some of the basic ideas of science are ancient.

Greek Thinkers

Many Greek thinkers expressed ideas that, today, we would call scientific. The great philosopher Aristotle, for example, wrote about astronomy, geography, and many other fields. But his greatest contribution to science was the idea that people should observe the world carefully and draw **logical** conclusions about what they see.

ACADEMIC VOCABULARY

logical
reasoned, well thought out



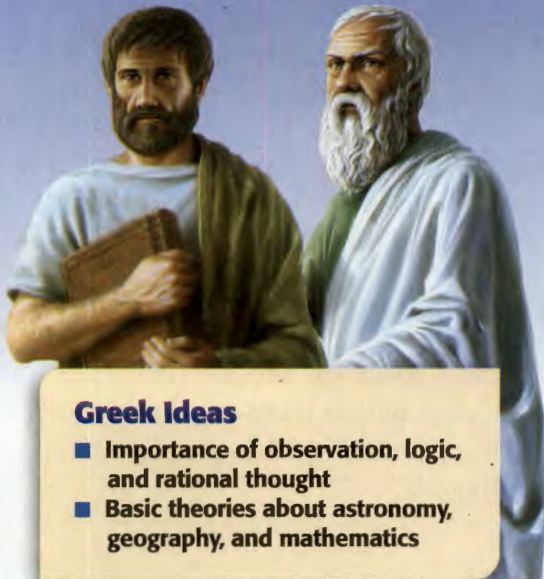
Philosophers like Plato and Aristotle used reason and logic to understand the world.

Pythagoras studied numbers and believed that things could be predicted and measured.

Greek Thinkers
The ancient Greeks developed theories about how the world worked that influenced later scientific thinkers. This famous painting from the early 1500s by the Italian artist Raphael shows some influential Greek thinkers.

Euclid discovered basic mathematical laws that helped explain the natural world.

Roots of the Scientific Revolution



Greek Ideas

- Importance of observation, logic, and rational thought
- Basic theories about astronomy, geography, and mathematics

Scholars of Three Faiths

- Muslim preservation and study of ancient texts
- Jewish study of Greek ideas and religion
- Christian study of Greek ideas and religion



THE GRANGER COLLECTION, NEW YORK

The use of observation and logic, as you have just read, is important in gaining scientific knowledge.

Another Greek thinker was **Ptolemy** (TAHL-uh-mee), an ancient astronomer. He studied the skies, recorded his observations, and offered theories to explain what he saw. Ptolemy was also a geographer who made the best maps of his time. His maps were based on observations of the real world.

Aristotle, Ptolemy, and other Greek thinkers were **rationalists**, people who looked at the world in a rational, or reasonable and logical, way. During the Renaissance, Europeans studied the works of Greek rationalists. As a result, they began to view the world in a rational way. They began to think like scientists.

Preserving Ancient Knowledge

European scholars could study ancient Greek writings because of the work of others. Muslim scholars translated Greek writings into Arabic. They studied them for centuries and added their own new ideas. Later, the Arabic versions were translated

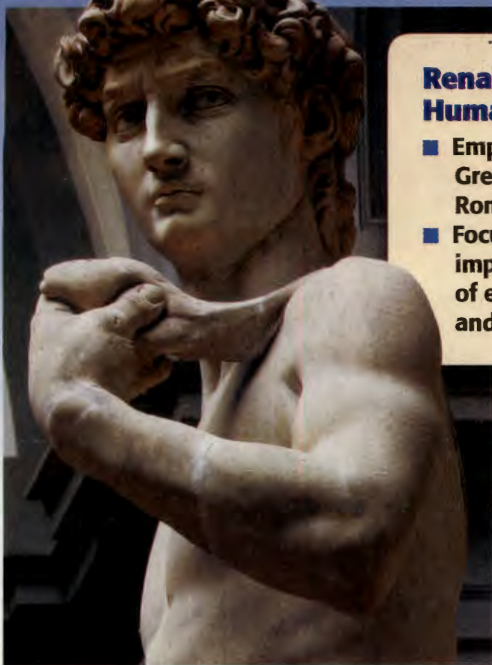
into Latin, which was read in Europe. This work preserved ancient knowledge and spread interest in science to Europe.

Other religious scholars also played a role in preserving Greek ideas. The Jewish scholar Maimonides (my-MAHN-uh-deez) studied and wrote about Aristotle, trying to unite his work with Jewish ideas. The Christian scholar Thomas Aquinas tried to unite the work of Aristotle with Christian ideas. Other Christian scholars studied Greek ideas in Europe's universities.

Developments in Europe

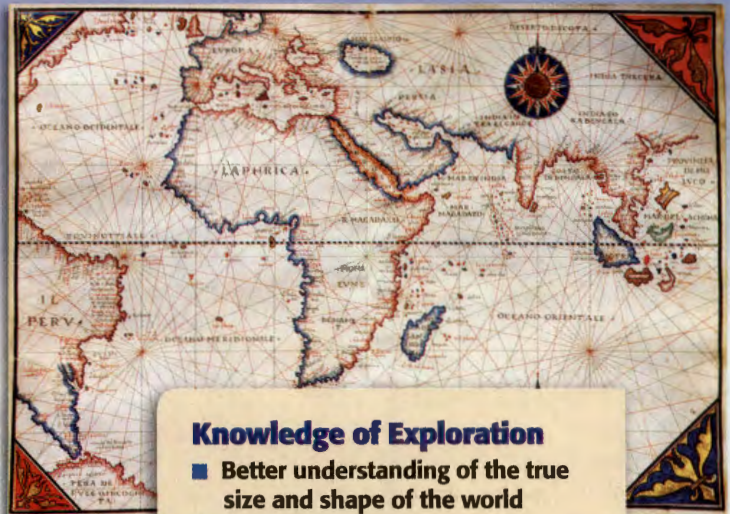
The Scientific Revolution was not just the result of European scholars studying ancient Greek writings. Developments in Europe also helped bring about the Scientific Revolution.

One development that helped lead to the Scientific Revolution was the growth of humanism during the Renaissance. Humanist artists and writers spent much of their time studying the natural world. This interest in the natural world carried forward into the Scientific Revolution.



Renaissance Humanism

- Emphasis on Greek and Roman ideas
- Focus on the importance of education and learning



Knowledge of Exploration

- Better understanding of the true size and shape of the world
- Increase in knowledge
- Development of new technologies

Another development was a growing interest in alchemy (AL-kuh-mee). **Alchemy** was a forerunner of chemistry. Alchemists experimented with various natural substances. They were best known for trying to change other metals into gold. Although they failed at that, alchemists succeeded in using experiments to learn more about how nature worked.

All of these developments—the interest in ancient Greek writings, the growth of humanism, the experiments of alchemists—came together in the early 1500s to bring about the Scientific Revolution.

READING CHECK Understanding Cause and Effect How did Greek rationalism help lead to the Scientific Revolution?

SUMMARY AND PREVIEW The Scientific Revolution was the birth of modern science. Greek, Muslim, and European thought all contributed to its beginning. Next you will read about specific events of the Scientific Revolution.

Section 1 Assessment

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Online Quiz

KEYWORD: SQ7 HP13

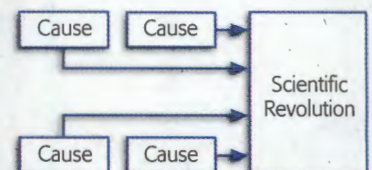
Reviewing Ideas, Terms, and People **HSS** 7.10.1

1. **a. Define** What is science?
b. Explain Why was the **Scientific Revolution** important in world history?
c. Elaborate What might cause scientists to reject a theory?
2. **a. Identify** Who was **Ptolemy**?
b. Analyze What qualities did Greek **rationalists** have?
c. Elaborate Why might alchemists have thought they could turn other metals into gold?

Critical Thinking

3. Identifying Cause and Effect

Draw a graphic organizer like the one here. In the boxes to the left, identify four causes of the Scientific Revolution.



FOCUS ON SPEAKING

4. **Explaining Science** As part of your defense of Galileo, you'll probably need to explain what science is. Look back through this section and take some notes that you might use to explain the basic principles of science.

Discoveries and Inventions

What You Will Learn...

Main Ideas

1. The discovery of the Americas led scholars to doubt ancient Greek ideas.
2. Advances in astronomy were key events of the Scientific Revolution.
3. Sir Isaac Newton developed laws that explained much of the natural world.
4. New inventions helped scientists study the natural world.

The Big Idea

During the Scientific Revolution, new ideas and inventions changed the nature of knowledge.

Key Terms and People

Nicolaus Copernicus, p. 359

Tycho Brahe, p. 360

Johannes Kepler, p. 360

Galileo Galilei, p. 361

Sir Isaac Newton, p. 362

barometer, p. 363



HSS 7.10.2 Understand the significance of the new scientific theories (e.g., those of Copernicus, Galileo, Kepler, Newton) and the significance of new inventions (e.g., the telescope, microscope, thermometer, barometer).

If YOU were there...

You are an innkeeper in Spain in 1498. Many of the guests who stay at your inn are sailors. Today they are telling stories about a vast new land filled with strange peoples, plants, and animals. No one had ever thought such a land really existed before.

How does this news change your view of the world?

BUILDING BACKGROUND During the Scientific Revolution advances in science allowed people to discover new lands and to build new machines. Some of these new machines allowed people to study the world in ways they had never been able to before.

Discovery Leads to Doubt

During the Renaissance, European scholars eagerly read and studied the works of Greek rationalists. Aristotle, Ptolemy, and others were viewed as authorities.



This drawing shows the earth at the center of the universe. Before Copernicus, most people believed that the sun revolved around the earth.

Saturn

Jupiter

Then an event took place that caused Europeans to doubt some of what the Greeks had said. In 1492, Christopher Columbus sailed west across the Atlantic Ocean in hopes of reaching Asia. As a guide, he took the map of the world that Ptolemy had created. Columbus never reached Asia because he ran into North America instead. Within a few years voyages of exploration made it clear that there was an entire continent that Europeans hadn't even known existed.

This discovery stunned Europeans. This continent was not on Ptolemy's map. Ptolemy was wrong. Observation of the real world had disproved the teachings of an ancient authority. Soon, European scholars began to question the accuracy of other Greek authorities. More and more, observations the Europeans made did not fit with what the authorities had described. Such observations helped lead to the Scientific Revolution.

READING CHECK **Identifying Cause and Effect** How did the European discovery of America affect the Scientific Revolution?

Advances in Astronomy

In 1543 an astronomer published a book that contradicted what a Greek authority had written. Many historians think the publication of this book marks the beginning of the Scientific Revolution.

Nicolaus Copernicus

The book thought to have marked the beginning of the Scientific Revolution was written by a Polish astronomer, **Nicolaus Copernicus** (kuh-PUHR-ni-kuhs). His 1543 book was called *On the Revolution of the Celestial Spheres*.

Copernicus was familiar with Ptolemy's theories and writings. Ptolemy had written that the earth was the center of the universe and that the sun and other planets orbited, or circled around, the earth. For 1,400 years, people accepted this belief as fact.

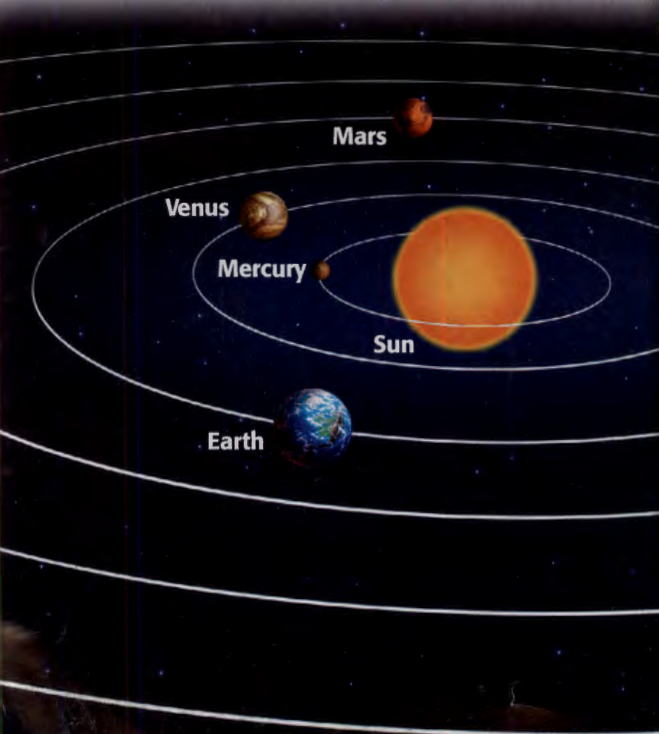
BIOGRAPHY

Nicolaus Copernicus

1473–1543

Nicolaus Copernicus realized that sharing his revolutionary ideas about the universe could be dangerous. He feared persecution or even death at the hands of Church leaders. He was also worried that the scientific community would reject his theories. Eventually, he was persuaded to publish his theories, and the "Copernican system" became a landmark discovery of the Scientific Revolution.

Making Decisions If you were Nicolaus Copernicus would you have published your theories? Why or why not?



As Copernicus studied the movements of the planets, however, what Ptolemy stated made less and less sense to him. If the planets were indeed orbiting the earth, they would have to be moving in very complex patterns.

So Copernicus tried a different explanation for what he observed in the sky. Copernicus asked, What if the planets actually orbited the sun? Suddenly, complex patterns weren't necessary to make sense of what Copernicus observed. Instead, simple circular orbits would account for the planets' movements.

What Copernicus had done was practice science. Instead of trying to make his observations fit an old idea, he came up

with a different idea—a different theory—to explain what he observed. Copernicus never proved his theory, but the Scientific Revolution had begun.

Brahe and Kepler

Another important astronomer of the Scientific Revolution was **Tycho Brahe** (TYOO-koh BRAH-huh). Brahe, who was Danish, spent most of his life observing the stars. In the late 1500s, he charted the positions of more than 750 of them.

What Brahe did, however, was less important than *how* he did it. Brahe emphasized the importance of careful observation and detailed, accurate records. Careful recording of information is necessary so that other scientists can use what has previously been learned. In this way, Brahe made an important contribution to modern science.

Brahe was assisted by the German astronomer **Johannes Kepler**. Later, Kepler tried to map the orbits of the planets. But Kepler ran into a problem. According to his observations, the planet Mars did not move in a circle as he expected it to.

Kepler knew that Copernicus had stated that the orbits of the planets were circular. But Kepler's observations showed that Copernicus was mistaken. In 1609 Kepler wrote that Mars—and all other planets—moved in elliptical, or oval, orbits instead of circular ones. Here was a new theory that fit the observed facts. Kepler's work helped



Kepler demonstrated that planets move in elliptical orbits.

Kepler's Discoveries

QUICK FACTS

- Planets orbit the sun in elliptical, not circular, orbits.
- Planets move faster when they are closer to the sun.
- The human eye sees images reversed, like a camera.

prove Copernicus's theory that the planets orbit the sun. In fact, Kepler became one of the first scientists to speak out in support of Copernicus.

Kepler continued to study the planets for the rest of his life. His basic ideas about the planets' movements are still accepted by scientists today.

Galileo Galilei

Galileo Galilei (gal-uh-LEE-oh gal-uh-LAY) was one of the most important scientists of the Scientific Revolution. He was the first person to study the sky with a telescope. With his telescope, Galileo discovered craters and mountains on the moon. He also discovered that moons orbit Jupiter.

Galileo was interested in more than astronomy, however. He also was interested in such things as how falling objects behave. Today, we use the term *mechanics* for the study of objects and motion.

Galileo's biggest contribution to the development of science was the way he learned about mechanics. Instead of just observing things in nature, he set up experiments to test what he observed. Galileo was the first scientist to routinely use experiments to test his theories. For this, he is remembered as the father of experimental science.

READING CHECK **Summarizing** What were two major achievements in astronomy?

THE IMPACT TODAY

Astronomers still study Kepler's ideas, which they call his laws of planetary motion.

Primary Source

LETTER

Galileo Defends His Work

In 1613, Galileo (1564–1642) wrote a letter to the Grand Duchess Christina of Tuscany, the mother of the great banker Cosimo de' Medici. In this letter, he defended himself against attackers who claimed that his ideas went against church teachings. Galileo opened his letter with an explanation of his discoveries.

Galileo points out that many people are unhappy with his discoveries simply because they are new.

Galileo defends his discoveries by pointing out that God created the heavens. Humans can only study what God put there.

“Some years ago, as Your Serene Highness well knows, I discovered in the heavens many things that had not been seen before our own age. The novelty [newness] of these things, as well as some consequences which followed from them in contradiction [contrast] to the physical notions [ideas] commonly held among academic philosophers, stirred up against me no small number of professors—as if I had placed these things in the sky with my own hands in order to upset nature and overturn the sciences. They seemed to forget that the increase of known truths stimulates [encourages] the investigation, establishment, and growth of the arts; not their diminution [decrease] or destruction.”

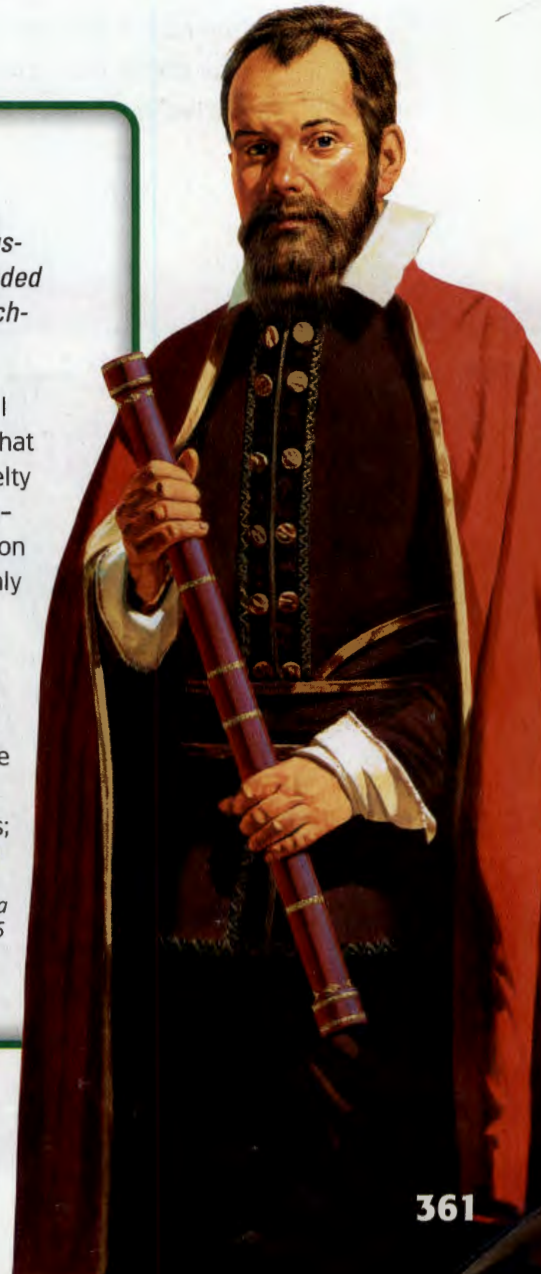
—from *A Letter to the Grand Duchess Christina of Tuscany* from Galileo Galilei, 1615

ANALYSIS SKILL

ANALYZING PRIMARY SOURCES

How does Galileo justify his search for knowledge?

Galileo studied the sky and performed experiments to learn about motion mechanics.



Sir Isaac Newton

The high point of the Scientific Revolution was marked by the publication of a remarkable book. This book, published in 1687, was *Principia Mathematica*. Its author was the English scientist **Sir Isaac Newton**. Newton was one of the greatest and most influential scientists who ever lived.

Newton studied and simplified the work of earlier scientists. In doing so, he:

- reviewed everything scientists had been learning,
- coupled it with his own observations and ideas, and
- identified four theories that described how the physical world worked.

Some of his theories have been proven so many times that they are no longer called theories, but laws.

One of Newton's laws is called the law of gravity. You may know that gravity is the force that attracts objects to each other. It's the force that makes a dropped apple fall to the ground and that keeps the planets in orbit around the sun.

Newton's other three laws are called the laws of motion. They describe how objects move in space. You may have heard of one of them: "For every action there is an equal and opposite reaction."

Newton proposed that the universe was like a huge machine. Within this machine, all objects follow the laws he identified. In short, Newton explained how the physical world worked—and he was correct. Newton's laws became the foundation of nearly all scientific study until the 1900s.

Newton also invented calculus, an advanced form of mathematics that scientists use to solve complex problems. For this, and for his laws of motion, Newton is remembered as a great scientist.

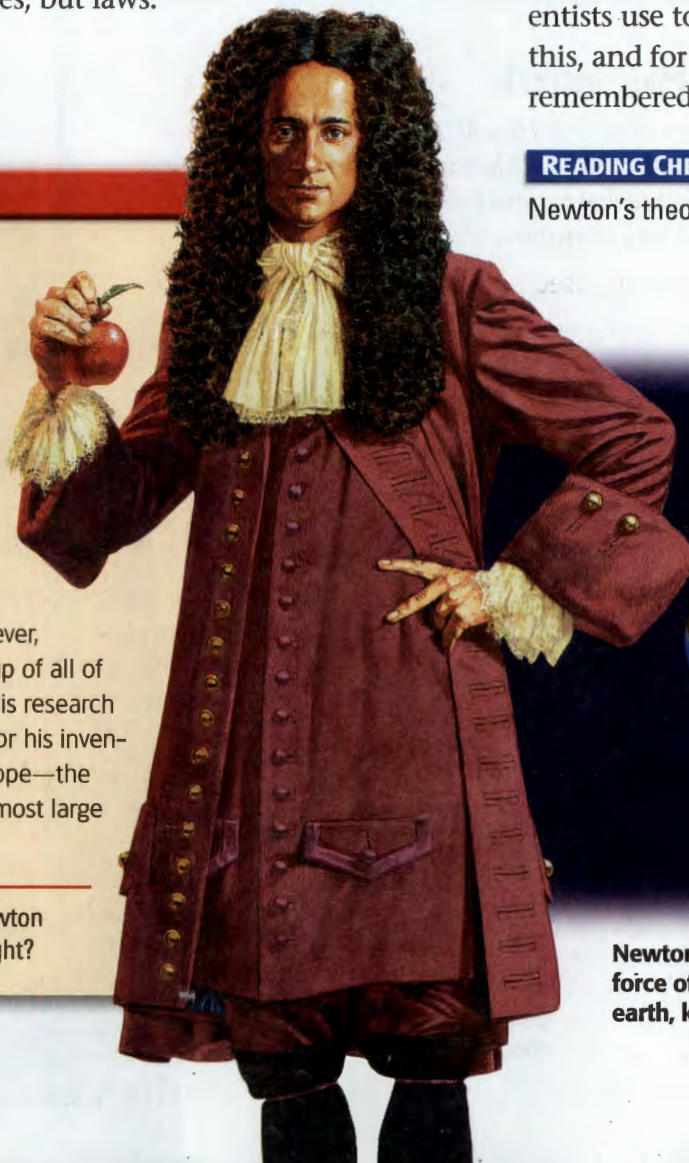
BIOGRAPHY

Sir Isaac Newton

1642–1727

Sir Isaac Newton was interested in learning about the nature of light, so he conducted a series of experiments. In Newton's time, most people assumed that light was white. Newton proved, however, that light is actually made up of all of the colors of the rainbow. His research on light became the basis for his invention of the reflecting telescope—the type of telescope found in most large observatories today.

Summarizing What did Newton prove about the nature of light?



READING CHECK Summarizing Why are Newton's theories called laws?



Newton's discoveries explained how the force of gravity pulls the moon toward the earth, keeping it in orbit around our planet.

New Inventions

During the Scientific Revolution, scientists invented new and better instruments. These helped them study the natural world.

Around 1590, a Dutch lens maker named Zacharias Janssen invented a simple microscope. The first person to use a microscope as a scientific instrument, though, was the Dutch scientist Antoni van Leeuwenhoek (LAY-ven-hook) in the mid-1600s. Examining a drop of pond water with his microscope, he saw tiny plants and animals not visible to the naked eye.

In 1593, Galileo invented the thermometer. Thermometers are used to measure temperature. About 50 years later an Italian doctor developed a more accurate model than Galileo's.

The telescope was probably invented by a Dutch lens maker in 1608. The next year, Galileo built a much-improved telescope that he used to make his important astronomical discoveries.

In 1643, the Italian scientist Evangelista Torricelli invented the barometer. **A barometer is a scientific instrument that measures air pressure.** Barometers are used to help forecast the weather.

These instruments—the microscope, the thermometer, the telescope, and the barometer—are very common today. In fact, you have probably used at least one of them yourself. But when they were invented, they were dramatic advances in technology. They gave scientists the tools they needed to make more accurate observations of the world and to conduct experiments. They were the tools of the Scientific Revolution.



This early microscope was made around 1675. The lens is protected by cardboard and leather and slides up and down.

READING CHECK Comparing

How are the microscope and the telescope similar?

SUMMARY AND PREVIEW The work of Copernicus, Brahe, Kepler, Galileo, and Newton was central to the Scientific Revolution. In the next section, you will learn more about the effects of these scientists' accomplishments on society then and now.

Section 2 Assessment

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Online Quiz

KEYWORD: SQ7 HP13

Reviewing Ideas, Terms, and People HSS 7.10.2 Critical Thinking

- a. **Recall** What event caused Europeans to doubt the ideas of ancient Greek authorities?

b. **Explain** How did the doubting of Greek authorities help usher in the Scientific Revolution?
- a. **Identify** Who was **Galileo**?

b. **Summarize** How did **Copernicus** and **Kepler** change people's view of the universe?
- a. **Identify** For what laws is **Isaac Newton** most famous?

b. **Evaluate** Why do you think Newton is considered the greatest figure of the Scientific Revolution?
- Define** What is a **barometer**?

- Comparing and Contrasting** Draw a diagram like the one below. Describe each individual's view of how the universe is organized.

Scientist	Ptolemy	Copernicus	Kepler
View			

FOCUS ON SPEAKING

- Noting Galileo's Achievements** Now that you've read about Galileo, make a list of some of his major achievements. Then look back at your definition of science from Section 1. How do Galileo's achievements match the basic goals of science?

Science and Society

What You Will Learn...

Main Ideas

1. The ideas of Francis Bacon and René Descartes helped to clarify the scientific method.
2. Science influenced new ideas about government.
3. Science and religion developed a sometimes uneasy relationship.

The Big Idea

The Scientific Revolution led to the establishment of science as a method of learning, new ideas about government, and conflict with religious authorities.

Key Terms and People

Francis Bacon, *p. 364*

René Descartes, *p. 365*

scientific method, *p. 365*

hypothesis, *p. 366*



HSS 7.10.3 Understand the scientific method advanced by Bacon and Descartes, the influence of new scientific rationalism on the growth of democratic ideas, and the coexistence of science with traditional religious beliefs.

If YOU were there...

You are a scientist conducting an experiment about falling objects. You stand at the base of a tall tower, watching as two of your assistants drop balls from the top. The balls are the same size, but one is made of iron and one of wood. The iron ball is much heavier, so you think that it will hit the ground first. But to your surprise, the two balls appear to hit the ground at the same time! You begin to think that all items will fall at the same speed.

How could you test your new theory?

BUILDING BACKGROUND The great scientists of the Scientific Revolution were pioneers. Even as they made great discoveries, scientists like the one described here had to find ways to explain what they had learned and how it could affect society.

Bacon, Descartes, and the Scientific Method

The Scientific Revolution led to a dramatic change in the way people learned about the world. The new, scientific way of gaining knowledge had far-reaching effects. In fact, the Scientific Revolution still affects us today.

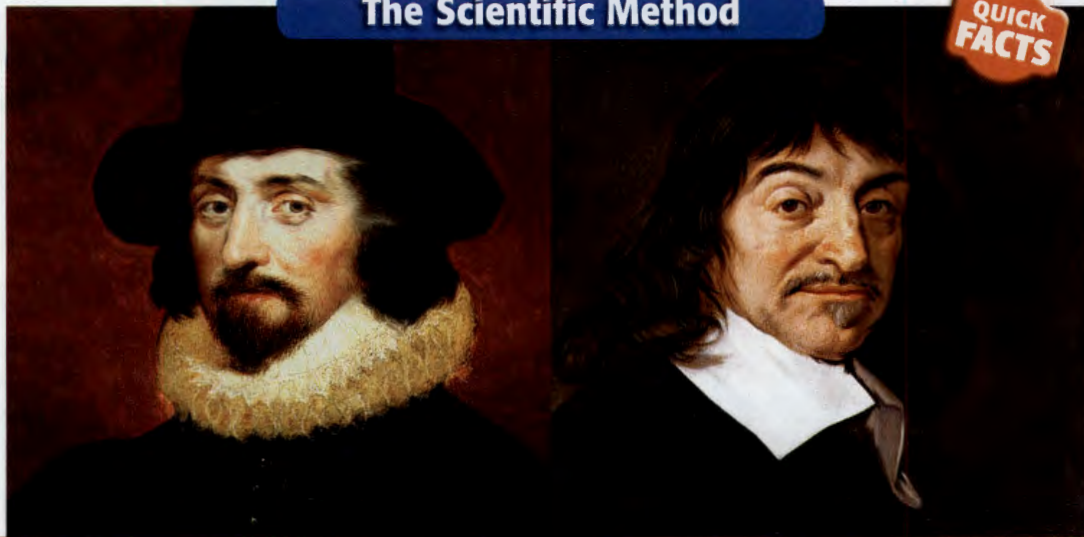
The first effect of the Scientific Revolution was the establishment of science as the most effective way for learning about the natural world. Two individuals played a leading role in gaining this acceptance of science.

Francis Bacon

Francis Bacon was an English philosopher who had read the works of the great scientists of the Scientific Revolution. He was extremely impressed with what he read. He noted how these scientists, using observations, facts, experiments, and theories, were revealing the truth about how nature worked.

The Scientific Method

QUICK
FACTS



Francis Bacon (1561–1626)

- Scientists should observe the world and gather data, or information, about it.
- Scientists can conduct experiments to gather data.
- Scientists can develop theories to explain their data and then test them through more experiments.

René Descartes (1596–1650)

- Doubt everything until it can be proven with reason.
- The natural world operates like a machine and follows basic physical laws.
- Individual existence is the one acceptable truth. "I think, therefore I am."

The Scientific Method

The ideas of Bacon and Descartes led to the scientific method—a method for gathering and testing ideas about the world.

Bacon argued that science should be pursued in a systematic fashion. He even tried to get the king of England to provide money for scientific research. If science were pursued consistently and logically, Bacon wrote, then human knowledge would continually advance over the years. In 1605, Bacon published his ideas in a book titled *The Advancement of Learning*.

René Descartes

Another thinker who made great contributions to the establishment of science was the French philosopher **René Descartes** (ruh-NAY day-CART).

Descartes believed that nothing should be accepted as true if it wasn't proven to be true. This differed from the belief that

most European scholars had been supporting for generations. They believed knowledge begins with faith; Descartes said it begins with doubt.

Descartes didn't just mean that observations and experiments were needed for this proof. These things, he said, took place in the material world, and people might be tricked by their senses. Instead, Descartes emphasized that people must use clear thinking and reason to establish proof.

The Scientific Method

Today scientists use a **procedure** called the scientific method when doing their research. **The scientific method is a step-by-step method for performing experiments and other scientific research.**

ACADEMIC VOCABULARY

procedure
a series of steps taken to accomplish a task

Science in School

If you have performed an experiment in science class, then you've seen the scientific method at work. Here, students are performing an experiment to learn about falling objects.

Students and scientists still use the scientific method because it helps them rationally solve problems. They conduct experiments to test their hypotheses. If their experiments don't produce the results they expect, they change their hypotheses and start over. Only after getting the same results time after time do scientists consider their findings conclusive.

ANALYSIS SKILL ANALYZING INFORMATION

How does the scientific method help scientists solve problems?



The scientific method combines Bacon's idea of a systematic scientific process, Descartes's insistence on proof and clear reasoning, and the work of other scientists. Using the scientific method, scientists have learned more about the universe in the few hundred years since the Scientific Revolution than in all of the thousands of years that came before. Because of this, the basics of the scientific method—observation and experimentation—are considered the main **principles** of modern science.

There are six basic steps in the scientific method:

1. Stating the problem. The problem is often a question that begins with *why*. For example, Copernicus's problem today would be stated, "Why do the planets move as they do?"
2. Gathering information. This can involve reading what other scientists have written and making observations.
3. Forming a hypothesis. A **hypothesis** is a solution that the scientist proposes to solve the problem. A hypothesis differs

from a theory in that a hypothesis has not yet been tested.

4. Testing the hypothesis by performing experiments.
5. Recording and analyzing data gathered from the experiments.
6. Drawing conclusions from the data collected.

After scientists have concluded their experiments, they typically publish their results. This sharing of ideas is very important for two reasons.

First, publishing results lets other scientists try to reproduce the experiments. By reproducing experiments, scientists can determine whether the results are the same. If they are, they can be reasonably sure that the results are accurate.

Second, publishing results spreads scientific knowledge. New scientific knowledge builds on previous knowledge. Sir Isaac Newton once wrote, "If I have seen further it is by standing on the shoulders of Giants."

READING CHECK Sequencing What are the steps in the scientific method?

ACADEMIC VOCABULARY

principles basic beliefs, rules, or laws

Science and Government

Some of the most important effects of the Scientific Revolution had nothing to do with science at all. When philosophers began applying scientific thought to other areas of human life, they came up with some startling new ideas.

The Power of Reason

By the end of the Scientific Revolution, one thing had become clear to many European thinkers: human reason, or logical thought, was a powerful tool. After all, scientists using reason had made many discoveries about the universe in a relatively short time.

Since reason had proven itself as a way to learn some of nature's great secrets, might reason also be used to solve the problems facing people? Philosophers decided to use reason when they considered society's problems like poverty and war, or what type of government is best.

This use of reason to consider the problems of society led philosophers to look at the world in a new way. They thought they could use reason to determine how to improve society.

Democratic Ideas

One way in which scientists thought they could improve society was by changing its government. Scientists' use of reason and logic during the Scientific Revolution helped pave the way for the beginnings of democratic thought in Europe.

As scientists like Sir Isaac Newton studied the world, they discovered laws that governed nature. In time, some scientists began to think that there must be laws that governed human behavior as well. Once people learned what these laws were, the scientists argued, they could improve their lives and their societies.

But the idea that people's lives were governed by laws had a deeper meaning as well. If all people were governed by the same laws, then it stood to reason that all people must be equal. This idea of the equality of all people was a fundamental step in the development of democratic ideas in Europe.

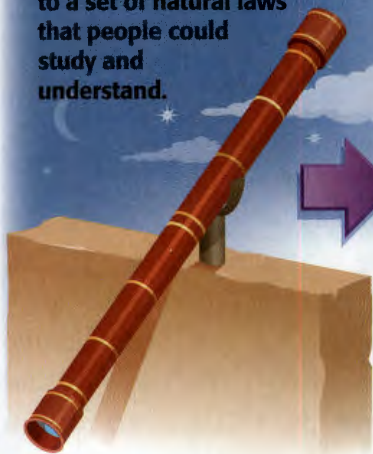
READING CHECK Identifying Cause and Effect

How did the growth of science help lead to the growth of democratic ideas?

Rationalism and Democracy

QUICK FACTS

Scientists believed that the world operated according to a set of natural laws that people could study and understand.



Political thinkers believed that natural laws could also explain the behavior of people. They wanted to use their understanding of human behavior to improve society.



These beliefs led people to call for personal freedom, individual rights, and equality—basic ideas of democracy.



Science and Religion

The Roman Catholic Church was a powerful force in Europe during the time of the Scientific Revolution. The birth and growth of science led to conflicts between scientists and the Church.

Reason for Conflict

There were two related parts to the conflict between science and the Church. The first was that the new science was putting forth ideas that contradicted Church teachings. For example, Copernicus's idea that the earth orbited the sun contradicted the Church teaching that the earth was at the center of the universe.

A second part of the conflict was related to the first. When people contradicted the Church's teachings, they weakened the Church. Church officials were afraid that questioning even one Church teaching might lead to more and more questions about the Church. People might even start

to doubt key elements of the faith. Church officials feared this would undermine the Church's influence.

The Trial of Galileo

The conflict between science and the Church was illustrated by a trial. Galileo published a book that supported the view that the planets orbit the sun. For this, he was put on trial by the Inquisition, a Church court that investigated people who questioned Church authority.

Catholic officials insisted that Galileo publicly reject his findings and accept Catholic teachings that the earth was the center of the universe and did not move. Under threat of torture, Galileo agreed. Still, legend has it that as Galileo left his trial, he muttered, "And yet it does move."

Although he is remembered for opposing this Church teaching, Galileo was a devout Catholic. He believed that experimentation was a search for an understanding of God's creation.

FOCUS ON READING

What sentences point to a contrast between scientific and religious ideas?

touches your life every day. Therefore, the Scientific Revolution ranks as one of the most influential events in history.

READING CHECK Analyzing Why were science and the Catholic Church at odds during the Scientific Revolution?

SUMMARY AND PREVIEW The scientific method became the standard method for all scientific study. New philosophies based on scientific thinking would later influence government. However, scientific teachings would sometimes conflict with religious teachings. In the next unit, you will turn your attention away from Europe and learn about the early civilizations of the Americas.



The painting at left shows Galileo defending himself before Church officials. Still, Galileo and other scientists were deeply religious, like the Italian monk and mathematician above.

Knowledge and Belief

Many of the scientists you have been reading about held views similar to Galileo's. For the scientists of the Scientific Revolution, science and traditional religious beliefs could exist at the same time.

Nicolaus Copernicus served as a Church official. Sir Isaac Newton saw a close connection between science and religion. For example, Newton believed that all forces in nature were actions directed by God.

Bacon, too, was a religious man. He wrote that knowledge "is a rich storehouse for the glory of the Creator." Unlike Newton, Bacon stressed the separation of reason and faith. He argued that religious leaders shouldn't try to explain scientific matters. In turn, he said that scientific thinkers shouldn't try to interpret religious matters.

Despite the conflicts, science developed rapidly after the Scientific Revolution. Scientists made—and continue to make—countless discoveries. Scientific knowledge has changed human life dramatically and

Section 3 Assessment

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Online Quiz

KEYWORD: SQ7 HP13

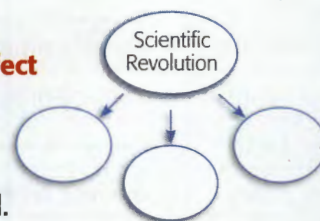
Reviewing Ideas, Terms, and People HSS 7.10.3

- a. Define** What is the scientific method?
b. Explain Why did Francis Bacon want the king to fund scientific research?
- a. Identify** What type of government began to develop using ideas from the Scientific Revolution?
b. Draw Conclusions Why did political philosophers begin to make greater use of reason in their work?
- a. Recall** Why did the Inquisition put Galileo on trial?
b. Summarize What caused conflict between science and the Roman Catholic Church?

Critical Thinking

4. Understanding Cause and Effect

Copy the diagram. Identify effects of the Scientific Revolution. Add as many arrows and circles as you need.



FOCUS ON SPEAKING

- Planning Your Defense** In this section, you read about the Church's objections to Galileo's ideas. How might you argue against those objections? Look back over your notes from the previous two sections to get some ideas.

Social Studies Skills

Analysis

Critical Thinking

Participation

Study

Analyzing Tables

Understand the Skill

Like graphs, tables present numerical data. The data are usually listed side by side for easy reference and comparison. A table is especially useful for organizing several different categories of data. Since the data in each row or column are related, you can easily compare numbers and see relationships.

Learn the Skill

Follow these guidelines to read and analyze a table.

- 1 Read the table's title to determine its subject. All the data presented in the table will be related in some way to this subject.
- 2 Identify the data. Note the headings and labels of the table's columns and rows. This will tell you how the data are organized. A table may also contain notes in parentheses. These explain the units in which the data should be read.

- 3 Study the information. Note the numbers in each row and column. Read across rows and down columns.
- 4 Use critical thinking skills to compare and contrast numbers, identify cause-and-effect relationships, and note statistical trends. Form hypotheses and draw conclusions.

Practice and Apply the Skill

The table below provides information on planets in the solar system. Interpret the table to answer the following questions.

1. Which planets were unknown to Kepler, Galileo, and other scientists of the 1500s and 1600s?
2. What relationship does the table show between the length of a planet's year and its distance from the sun?
3. Why did Pluto remain undiscovered for so long?

Planets of the Solar System

Planet	When discovered	Diameter (in miles)	Minimum distance from Earth (in millions of miles)	Distance from Sun (in millions of miles)	Length of year (in Earth years)
Mercury	ancient times	3,024	57	36	0.24
Venus	ancient times	7,504	26	67	0.62
Earth	—————	7,909	—————	93	1.00
Mars	ancient times	4,212	49	141	1.88
Jupiter	ancient times	88,534	390	482	11.86
Saturn	prehistoric times	74,400	792	885	29.46
Uranus	1781	32,488	1,687	1,780	84.01
Neptune	1846	31,279	2,695	2,788	164.80
Pluto	1930	1,364	3,573	3,666	247.70

Visual Summary

Use the visual summary below to help you review the main ideas of the chapter.

QUICK FACTS



Reviewing Vocabulary, Terms, and People

Complete each sentence by filling in the blank with the correct term from the chapter.

1. In science, a logical explanation for observed facts is called a(n) _____.
2. Greek _____ used logic and reason to explain what they observed in nature.
3. The first scientist to argue that the planets orbited the sun was _____.
4. _____ put forth important theories in his book, *Principia Mathematica*.
5. The _____ is a set of steps that scientists follow.
6. One important invention of the Scientific Revolution was the _____, an instrument that measures air pressure.
7. _____ believed that nothing should be accepted as true if it wasn't proven to be true.

Comprehension and Critical Thinking

SECTION 1 (Pages 354–357) HSS 7.10.1

8. **a. Recall** When did the Scientific Revolution occur?
8. **b. Analyze** How did Muslim scholars contribute to the Scientific Revolution?
8. **c. Evaluate** Do you agree or disagree with the statement that the Scientific Revolution was the single most important event in the intellectual history of humankind? Why?

SECTION 2 (Pages 358–363) HSS 7.10.2

9. **a. Describe** What was Nicolaus Copernicus's theory about the planets and the sun?
9. **b. Compare and Contrast** How were Copernicus's and Kepler's theories about the movement of the planets similar? How were they different?
9. **c. Elaborate** Choose one invention from the Scientific Revolution and explain how it affects your life.

SECTION 3 (Pages 364–369) HSS 7.10.3

- 10. a. Describe** How did the Scientific Revolution help inspire democratic ideas?
- b. Analyze** Why did many scientists believe science and religion could exist at the same time?
- c. Elaborate** What did Sir Isaac Newton mean when he wrote, “If I have seen further it is by standing on the shoulders of Giants”?

Social Studies Skills

Understanding Tables An invention from the Scientific Revolution—the barometer—is used to record air pressure during a hurricane. Scientists measure the strength of a hurricane on a scale from 1–5, with 5 being the strongest. Study the data in the table below about Hurricane Frances in 2004. Use the table to answer the questions that follow.

Date and Time	Wind speed (mph)	Air pressure (mb)	Category
9/1 12:00 noon	120	937	4
9/2 12:00 noon	125	939	4
9/3 12:00 noon	110	957	3
9/4 12:00 noon	90	960	2
9/5 11:00 am	80	963	1

- 11.** What happened to the air pressure as the hurricane got weaker?
- 12.** On what days did the air pressure of the hurricane measure 950 mb or greater?

Using the Internet

go.hrw.com

KEYWORD: SQ7 WH13

- 13. Activity: Researching Scientists and Their Discoveries** Imagine a time when the basic understanding of the universe was yet to be revealed and statements like “The sun revolves around the earth” were considered true. Amazing discoveries were made during the Scientific Revolution. Enter the activity keyword. Then create a chart of important scientists of that time, their key discoveries or inventions, the way in which each discovery influenced society, and how information about the discoveries has evolved over the years.

Reviewing Themes

- 14. Science and Technology** How do you know the earth orbits the sun? Did you gain that knowledge using methods similar to those used before or during the Scientific Revolution? Explain your answer.
- 15. Society and Culture** How did the birth of science lead to the growth of democratic ideas?

Reading Skills

Understanding Comparison and Contrast Read the paragraph below and answer the questions that follow.

Two scientists who played a vital role in the Scientific Revolution were Nicolaus Copernicus and Johannes Kepler. Copernicus, who was Polish, lived from 1473 to 1543. Kepler, who was German, lived from 1571 to 1630. Both men were astronomers. Copernicus’s great contribution was his theory that the planets all orbit the sun. Kepler’s great contribution was his theory that the orbits of the planets are elliptical, rather than circular. Both of these theories overturned ideas that people had believed for more than 1,400 years.

- 16.** Compare the lives of Copernicus and Kepler by identifying three similarities they had.
- 17.** Contrast the lives of Copernicus and Kepler by identifying three differences between them.

FOCUS ON SPEAKING

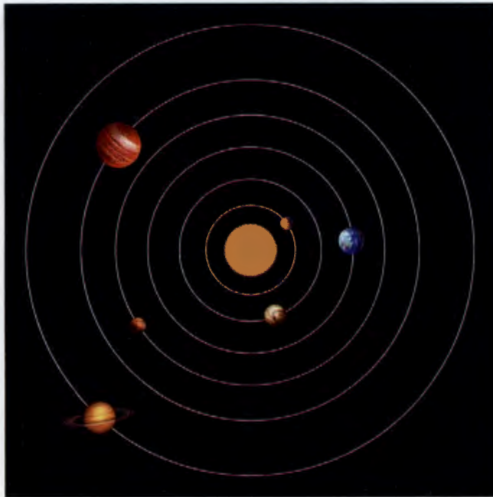
- 18. Giving Your Speech** Prepare your speech for defending your client. Begin with an introduction. Then present your main points in support of your claim, supporting your points with reasons or evidence. Try to anticipate the other side’s points and address them in your speech. End your speech with a conclusion.

Write sentences describing each of your points. These notes will help you remember what you want to say in your speech. When you give your speech, be sure to make eye contact with your audience, use a pleasant tone of voice, and speak with confidence.

Standards Assessment

DIRECTIONS: Read each question, and write the letter of the best response.

1



The pioneering work of which early scientist produced this understanding of the solar system?

- A Francis Bacon
- B Nicolaus Copernicus
- C Antoni van Leeuwenhoek
- D Isaac Newton

2 The fundamental principles of the modern scientific method are

- A logic and mathematical theories.
- B common beliefs of science and religion.
- C very detailed record keeping.
- D observation and experimentation.

3 The basis of the Scientific Revolution of the 1500s and 1600s is found *mainly* in the

- A writings of early Catholic popes and monks.
- B inventions of the ancient Chinese.
- C sponsorship of scientists by powerful European kings.
- D work of ancient Greeks and Muslim scholars.

4 Sir Isaac Newton is one of the most important participants in the Scientific Revolution because of his

- A observation that objects in the universe follow orderly laws.
- B first use of the telescope to study the solar system and the universe.
- C application of the scientific method to learn about the organs of the human body.
- D invention of the microscope and use of it to discover the existence of bacteria.

5 The two Europeans generally credited with developing the modern scientific method are

- A Galileo Galilei and Sir Isaac Newton.
- B Sir Isaac Newton and Francis Bacon.
- C Francis Bacon and René Descartes.
- D René Descartes and Sir Isaac Newton.

Connecting with Past Learnings

6 In Grade 6 you learned about the interest that many ancient civilizations had in astronomy. Which European scientist would have been *least* interested in the ancients' work?

- A Tycho Brahe
- B Galileo Galilei
- C Antoni van Leeuwenhoek
- D Johannes Kepler

7 The event you learned about earlier in this course that was *most* responsible for the Scientific Revolution was

- A the Renaissance.
- B the fall of Rome.
- C the development of feudalism.
- D the Crusades.

Assignment

Collect information and write an informative report on a topic related to the Renaissance or to the Reformation. Use one of these topics, or choose your own topic:

- The importance of Florence to the Renaissance
- Martin Luther's contributions to the Reformation

TIP Choosing a Point of View

Your audience should find your report informative and believable. One part of being believable is writing your report from the third-person point of view. That means you never bring yourself or your own opinions into the report. Watch for the pronouns *I*, *me*, and *we*. If you are using those words, you are bringing your own opinion into the report.

A Social Studies Report

You play many roles when you write a research report. As a detective, you track down information about a subject. As a judge, you determine what information is credible. As a reporter, you write clearly about what you have learned. In the process, you can reach a deeper understanding of history.

1. Prewrite

Choosing a Topic

Here are two keys to choosing a good topic for research:

- You find the topic interesting.
- You can find several sources of information on it.

A good topic is broad enough that you can find information, but narrow enough to cover in detail. You can narrow a topic by looking at a small part of it and breaking that part into even smaller parts.

Renaissance → Renaissance Artists → Leonardo's Achievements

Developing a Research Question

Starting with a question helps focus your research. For example, here is a question on the topic "The Achievements of Leonardo da Vinci": *How did Leonardo's achievements reflect the ideas of the Renaissance?* The answer to your question becomes your thesis, or big idea.

Finding Historical Information

Look for answers to your research question in at least three sources of historical information besides your textbook. For each source, write down the kinds of information shown below. To help with taking notes, put a circled number next to each source.

① **Encyclopedia article:**
 "Article Title." Name of Encyclopedia. Edition or year published.

② **Book:** Author. Title.
 City of Publication:
 Publisher, Year published.

③ **Magazine or newspaper article:** "Title of Article."
Publication name.
 Date: page number(s).

④ **Internet site:** Author (if known). "Document title."
Web Site. Date of electronic publication. Date information was accessed (url).



ELA Writing 7.2.3 Write research reports.

Taking Notes

As you read your sources, carefully write down facts, details, and quotations related to your research question. Take these types of notes:

Paraphrases The source's ideas in your own words

Summaries The source's main points in your own words

Direct quotations The source's exact words inside quotation marks

Next to each note, write the number of the source and the number of the page that contains the information.

Organizing Your Ideas and Information

How can you organize your research information? Here are two good ways:

- Chronological order (the order that events occurred)
- Order of importance (usually least to most important)

Use one of these orders to organize your notes in an outline. Here is a partial outline of the main body of a paper about Leonardo da Vinci.

Big Idea: Because of his many talents and interests, Leonardo da Vinci embodied the spirit of the Renaissance.

I. Leonardo's artistic talents

A. Painting

B. Sculpture

C. Architecture

II. Leonardo's other talents

A. Inventor

B. Engineer

C. Town planner

III. Leonardo's interest in learning

A. Nature

B. Technology

TIP

Checking Other

Sources Get a more complete picture of your subject by consulting sources with different opinions. For example, reading both praise and criticism of the Medicis will give you a more balanced view of the family.

2. Write

Here is a framework that can help you as you write a first draft.

A Writer's Framework

Introduction

- Start with a quote or an interesting historical fact.
- State your report's big idea.
- Provide historical background readers need to understand your big idea.

Body

- Present information about at least three sub-points of your big idea.
- Write at least one paragraph for each of these main (or sub-) points.
- Include supporting details, facts, or examples in each paragraph.

Conclusion

- Summarize your main points.
- Restate your big idea in slightly different words.
- You might comment on how the information in your report relates to other historical events.

Studying a Model

Here is a model of a research report. Study it to see how one student developed a paper. The first and last paragraphs are shown in full. The paragraphs in the body of the paper are summarized.

INTRODUCTORY PARAGRAPH

Attention grabber

Statement of Thesis or Big Idea

He may have been the greatest painter of the Renaissance. He was also its greatest sculptor and its greatest architect. In addition, he was a notable inventor, engineer, town planner, and mapmaker. In his spare time, he filled his sketchbook with detailed drawings of plants, animals, and machines. His name was Leonardo da Vinci. Many experts consider him to be the greatest genius in history. With his extraordinary talent and wide-ranging interests, Leonardo da Vinci embodied the spirit of the Renaissance.

Body Paragraphs

In the first paragraph of the body of the research report, the student briefly describes a painting, a sculpture, and a building designed by Leonardo. For each example, the student cites expert opinions about the work's merit.

In the next paragraph, the student discusses Leonardo's non-artistic talents—his inventions and his work as an engineer and town planner. As in the previous paragraph, the student cites expert opinions.

In the last paragraph of the body, the student gives examples of Leonardo's interest in nature and technology. The student also discusses Leonardo's notebooks and quotes expert opinions about the work.

CONCLUDING PARAGRAPH

Summary of Main Points

Statement of Big Idea

General Comment about the Topic

Artist, sculptor, architect, engineer, and observer of nature—Leonardo displayed his genius in a wide variety of fields. A Renaissance person is someone who can do almost anything well. Since Leonardo da Vinci was a genius at almost everything, he embodied the spirit of the Renaissance. He was the ultimate Renaissance person.

Notice that each paragraph uses the same organizational pattern as the entire paper. Each paragraph expresses a main idea, then provides information to support that idea. One difference is that only the last paragraph ends with a concluding statement.

3. Evaluate and Revise

Evaluating and Revising Your Draft

Carefully read your first draft. Ask the questions below to decide which parts of your first draft should be revised.

Evaluating and Revising an Informative Report

- Does the introduction begin with an interesting quotation or fact?
- Does your introduction include a clear statement of your big idea?
- Does your introduction give any needed background information?
- Is the report clearly organized in either chronological order or order of importance?
- Does the body of your report have at least three paragraphs, each developing one point under your big idea?
- Are all facts, details, and examples accurate? Are they clearly related to the ideas they support?
- Does the conclusion summarize the main points?
- Does the conclusion restate the big idea in different words?
- Have you included a list of at least three sources you used?

4. Proofread and Publish

Proofreading

After revising your report, read it carefully before sharing it. Look especially for these things.

- Proper spelling and capitalization of names for people, places, things, and events.
- Correct punctuation marks around direct quotations.

Publishing

Choose one or more of these ideas to publish your report.

- Turn your report into an informative speech and share it with classmates.
- Make a display that includes your report and helpful illustrations. Place it in a hallway display case or the library.
- Submit your report to an online discussion group that focuses on the Renaissance or the Reformation. Ask for feedback.

Practice and Apply

Use the steps and strategies outlined in this workshop to research and write a research report on the Renaissance or the Reformation.

TIP Evaluating Sources

Not all sources of information are equal. Some are not reliable or trustworthy.

You have to be especially careful about Internet sources since anyone can create an Internet site. For example, do not use a Web page created by a 10-year-old to find information about Leonardo's art. Look for a reliable source—an art historian or an art museum.

TIP Identifying Sources

If your teacher asks you to show your sources in the body of your paper, you can use **parenthetical citations**. Enclose the author's last name (or if no author is given, the first major word of the source title) followed by the page number.

Example

Between 1485 and 1490, Leonardo da Vinci created plans for advanced weapons and submarines (Renaissance 1).