Module 22

The Scientific Revolution

Essential Question

How did the scientific advances of the 16th to 18th centuries change society?

About the Photo: Powerful telescopes such as this one are used by astronomers to study the skies.

Explore ONLINE!

HISTORY

VIDEOS, including...

- Issac Newton: The Gravity of Genius
- Newton's Laws
- The Telescope

- Document-Based Investigations
- Graphic Organizers
- Interactive Games
- Image with Hotspots: Ptolemy's Map
- Animation: Models of the Solar System
- Image with Hotspots: The Monk and the Mathematician

In this module, you will learn about the discoveries and inventions of the Scientific Revolution. The Scientific Revolution laid the foundations for modern science.

What You Will Learn...

Timeline of Events 1525–1725

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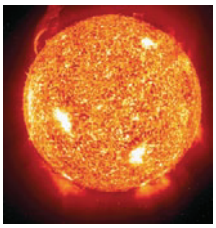
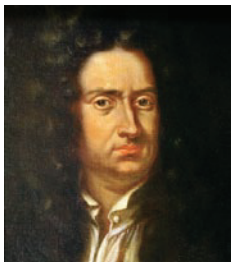
Module Events		World Events
	1525	
		1533 Francisco Pizarro conquers the Incas.
1543 Copernicus publishes his theory of the sun-centered solar system.		
	1575	
c. 1590 Zacharias Janssen invents the microscope.		
1609 Galileo uses his telescope to study planets.		
		1620 The *Mayflower* sets sail for North America.
	1625	
		1631 Construction begins on the Taj Mahal in India.
	1675	
1687 Sir Isaac Newton publishes *Principia Mathematica.*		
		1690 John Locke argues that people have certain natural rights.
	1725	





Reading Social Studies

THEME FOCUS:

Science and Technology, Society and Culture

This module discusses the advances in science and technology made during the Scientific Revolution. As you read this module you will learn about the work of scientists such as Nicolaus Copernicus, Galileo, and Isaac Newton—scientists whose ideas continue to have an impact today. They and other scientists of this period have greatly influenced society and culture, not just in Europe but around the world. Think how much different our lives would be without science!

READING FOCUS:

Recognize Fallacies in Reasoning

As part of evaluating a historical argument, you can judge whether the reasoning is sound. A fallacy is a false or mistaken idea.

Recognize Fallacies As you identify a main idea, judge its soundness. Look for cause-and-effect relationships that support the idea. Decide whether you think the argument is logical.

Notice how a reader explained the logical reasoning behind the main idea in the following paragraph.

> Three key factors changed how people understood the natural world leading up to and during the Scientific Revolution. First, explorers discovered a new continent that was not on the maps created by ancient Greek philosophers. People began questioning the accuracy of Greek authorities. Second, astronomers' observations changed how people understood the universe. Their observations of how the planets moved challenged the belief that the earth was the center of the universe. Finally, new inventions allowed scientists to make more accurate observations and conduct experiments. This led to more discoveries about how the natural world works.

People questioned previous knowledge based on the discovery of a new continent. This supports the main idea that the way people understood the natural world changed.

If observations challenged how people previously understood the universe, it would make sense that the way people understood the natural world changed.

Here's the third reason why the way people understood the natural world changed: inventions led to more accurate knowledge about the world. It makes sense that how people understood the natural world changed during the Scientific Revolution.

You Try It!

Galileo's ideas about the universe conflicted with those of the Church.

↓

Galileo was not a devout Catholic.

Tycho Brahe established an observatory and carefully recorded his observations of the stars

↓

because he wanted to keep accurate astronomical records.

Sir Isaac Newton, one of the greatest scientists in history, was English.

↓

Therefore, all scientists are from England.

1. Is the first conclusion a fallacy of reason? What reasonable conclusions can you draw from the statement?
2. Do you think the second conclusion is logical or illogical? What makes you think so?
3. Is the third conclusion reasonable? Why or why not?

As you read this module, notice how the authors use logical reasoning to support their main ideas.

Key Terms and People

Lesson 1

Scientific Revolution
science
theories
Ptolemy
rationalists
alchemy

Lesson 2

Nicolaus Copernicus
Tycho Brahe
Johannes Kepler
Galileo Galilei
Sir Isaac Newton
barometer

Lesson 3

Francis Bacon
René Descartes
scientific method
hypothesis

A New View of the World

The Big Idea

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

Main Ideas

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

Key Terms and People

Scientific Revolution
science
theories
Ptolemy
rationalists
alchemy

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 the 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?

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 such authorities as 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 developing 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.

Reading Check
Find Main Ideas
What was the Scientific Revolution?

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.

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

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.

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

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

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 look 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.

Religion's Role in Promoting 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.

The Catholic Church encouraged learning, as well. It helped pay for scientific research and sent priests to study at universities. The Church supported the teaching of math and science.

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.

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
Analyze Effects
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. In the next lesson, you will read about specific events of the Scientific Revolution.

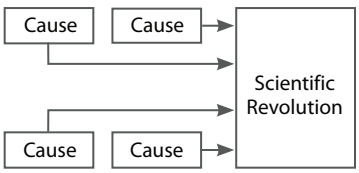
Lesson 1 Assessment

Review Ideas, Terms, and People

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



Discoveries and Inventions

The Big Idea

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

Main Ideas

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

Key Terms and People

Nicolaus Copernicus
Tycho Brahe
Johannes Kepler
Galileo Galilei
Sir Isaac Newton
barometer

Reading Check
Analyze Effects
How did the European discovery of America affect the Scientific Revolution?

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?

Discovery Leads to Doubt

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

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. These observations that conflicted with the Greek scholars' writings helped lead to 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.

Changing Views of the Universe

The diagram shows the sun at the center of the universe. Before Copernicus, most people believed that the sun revolved around Earth, as in this drawing.

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 Earth was the center of the universe and that the sun and other planets orbited, or circled around, 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 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

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.

Evaluate

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

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 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.

Quick Facts

Kepler's Discoveries

- 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.

Kepler demonstrated that planets move in elliptical orbits.

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

DOCUMENT-BASED INVESTIGATION Historical Source

Galileo Discovers Moons of Jupiter

In 1610, Galileo (1564–1642) wrote a book about his discovery of four moons that orbit Jupiter. At that time, many people believed that humans were at the center of the universe. Galileo's discovery challenged this belief. After explaining how he determined that the moons revolved around Jupiter, he explained its importance.

Galileo points out that his discovery should help convince people who believe Earth orbits the sun, but not that the moon orbits Earth.

Galileo argues that his observation proves it's possible for the moon to revolve around Earth while Earth also orbits the sun.

"We have a notable and splendid argument to remove the scruples [doubts] of those who can tolerate [believe] the revolution of the planets round the Sun in the Copernican system, yet are so disturbed by the motion of one Moon about the Earth, while both accomplish an orbit of a year's length about the Sun, that they consider that this theory of the constitution of the universe must be upset as impossible; for now we have not one planet only revolving about another, while both traverse [follow] a vast orbit about the Sun, but our sense of sight presents to us four satellites [stars] circling about Jupiter, like the Moon about the Earth, while the whole system travels over a mighty orbit about the Sun in the space of twelve years."

—Galileo Galilei, in *The Sidereal Messenger of Galileo Galilei and a Part of the Preface to Kepler's Dioptrics*, translated by E.S. Carlos

Analyze Historical Sources
Why did Galileo believe this discovery helped prove that Earth orbited the sun?

Reading Check
Summarize What were two major achievements in astronomy?

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.

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
- synthesized his observations with others' to formulate theories
- identified four laws that described how the physical world worked

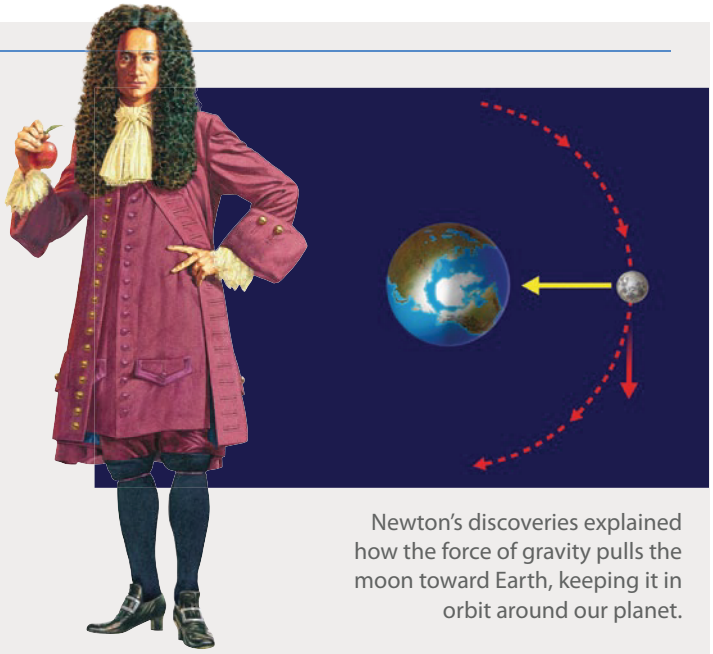
One of Newton's laws is called the law of gravity. You may know that gravity is the force that attracts objects to each other. It's the force that makes a dropped apple fall to the ground and that keeps the planets in orbit around the sun.

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.

Summarize
What did Newton prove about the nature of light?



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

Newton's three other laws are called the laws of motion. They describe how objects move in space. You may have heard of one of them, which he explained in *Principia Mathematica*: "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.

His discoveries were remarkable, but he did not make them by himself. Newton learned from other scientists and built upon their knowledge. In his correspondence with another scientist, he wrote, "If I have seen further, it is by standing on the shoulders of giants."

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.

Reading Check
Summarize
What do Newton's laws describe?

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

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

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.

Reading Check
Compare
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 lesson, you will learn more about the effects of these scientists' accomplishments on society then and now.

Lesson 2 Assessment

Reviewing Ideas, Terms, and People

1. **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?
2. **a. Identify** Who was Galileo?
   b. Summarize How did Copernicus and Kepler change people's view of the universe?
3. **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?
4. **Define** What is a barometer?

Critical Thinking

5. **Compare and Contrast** Draw a diagram like the one below. Describe each individual's view of how the universe is organized.

Scientist	Ptolemy	Copernicus	Kepler
View			

Science and Society

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.

Main Ideas

- The ideas of Francis Bacon and René Descartes helped clarify the scientific method.
- Science influenced new ideas about government.
- As scientists developed a better understanding of the human body, medical treatments also changed.
- Science and religion developed a sometimes uneasy relationship.

Key Terms and People

Francis Bacon
René Descartes
scientific method
hypothesis

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 idea?

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 to learn 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.

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*.

Link to Today

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.

Analyze Information
How does the scientific method help scientists solve problems?

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 isn'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.

Academic Vocabulary
procedure a series of steps taken to accomplish a task

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.

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.

Academic Vocabulary
principles basic beliefs, rules, or laws

Quick Facts

The Scientific Method

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

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."

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.
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. If not, a new hypothesis can be formed and tested.

Second, publishing results spreads scientific knowledge. This opens up the exchange of ideas. Sir Isaac Newton did not just publish his work, but also exchanged many letters with other scientists.

Reading Check
Summarize What are the steps in the scientific method?

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 proved to be 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 there must be laws that governed human behavior as well. Once people learned

Quick Facts

Rationalism and Democracy

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.

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
Analyze Effects How did the growth of science lead to the growth of democratic ideas?

Advances in Medicine

Before the Scientific Revolution, doctors approached medical treatment very differently from how they do today. Their understanding of the human body was not based on scientific observations. They believed health depended on keeping the body in balance. So, for example, if a patient had a cold, a doctor might place hot cups on the skin to restore the balance.

During the Scientific Revolution, the field of medicine changed thanks to the scientific method. People began to question the accepted wisdom about medicine and the human body. William Harvey was one physician who realized there was much to learn.

Harvey conducted experiments to learn how the human circulatory system worked. He asked many questions and concluded that previous beliefs about the circulatory system were wrong. Because of Harvey's discoveries and others, doctors changed the way they treated patients.

The Scientific Revolution also led to other medical discoveries. Van Leeuwenhoek's innovative use of the microscope allowed scientists to see things inside the human body that had not been visible before. They were also able to use microscopes to analyze cells.

Reading Check
Analyze Effects How did the Scientific Revolution influence medical discoveries?

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 Earth orbited the sun contradicted the Church teaching that 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 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.

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

Science and Religion

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

try to explain scientific matters. In turn, he said that scientific thinkers shouldn't try to interpret religious matters.

Reading Check
Draw Conclusions
Why were science and the Catholic Church at odds during the Scientific Revolution?

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

Summary 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.

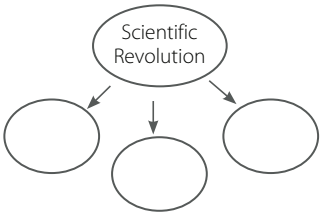
Lesson 3 Assessment

Reviewing Ideas, Terms, and People

1. **a. Define** What is the scientific method?
   b. Explain Why did Francis Bacon want the king to fund scientific research?
2. **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?
3. **a. Explain** How did doctors practice medicine before the Scientific Revolution?
   b. Draw Conclusions Why did doctors change the way they practiced medicine?
4. **a. Recall** Why did the Inquisition put Galileo on trial?
   b. Summarize What caused conflict between science and the Roman Catholic Church?

Critical Thinking

5. **Understand Cause and Effect** Copy the diagram. Identify effects of the Scientific Revolution. Add as many arrows and circles as you need.



Social Studies Skills

Analyze Tables

Define 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 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 do you think Neptune remained 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	ancient 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

Module 22 Assessment

Review Vocabulary, Terms, and People

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

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 isn't proven to be true.

Comprehension and Critical Thinking

Lesson 1

8. a. **Recall** When did the Scientific Revolution occur?
   b. **Analyze** How did Muslim scholars contribute to the Scientific Revolution?
   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?

Lesson 2

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

Lesson 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"?

Module 22 Assessment, continued

Review Themes

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

Reading Skills

Recognize Logical Fallacies in Reasoning *Use the Reading Skills taught in the module to answer the questions about the reading selection below.*

During the Scientific Revolution, scientists invented new and better instruments. In 1593, Galileo invented the thermometer. The telescope was probably invented by a Dutch lens maker in 1608. In 1609, Galileo built a much-improved telescope and made important astronomical discoveries. In 1643, the Italian scientist Evangelista Torricelli invented the barometer, a scientific instrument that measures air pressure.

13. Which of the following is an example of a false conclusion drawn from the selection above?
    - **a.** New inventions helped scientists better observe and understand the natural world.
    - **b.** The most important instruments ever were invented during the Scientific Revolution.
    - **c.** During the sixteenth and seventeenth centuries, scientists invented new instruments.
    - **d.** Though he did not invent the telescope, Galileo greatly improved it.

Social Studies Skills

Analyze Tables *Use the Social Studies Skills taught in this module to answer the questions about the table below. The table shows data collected during Hurricane Frances in 2004. Scientists measure the strength of a hurricane on a scale from 1 to 5, with 5 being the strongest.*

Date and time	Wind speed (mph)	Air pressure (mb)	Strength
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

14. What happened to the air pressure as the hurricane got weaker?
15. On which days did the air pressure of the hurricane measure 950 mb or greater?

Focus On Speaking

16. **Give a Speech** Prepare a speech to defend Galileo. Begin with an introduction. Then present your main points in support of his discoveries, 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.

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