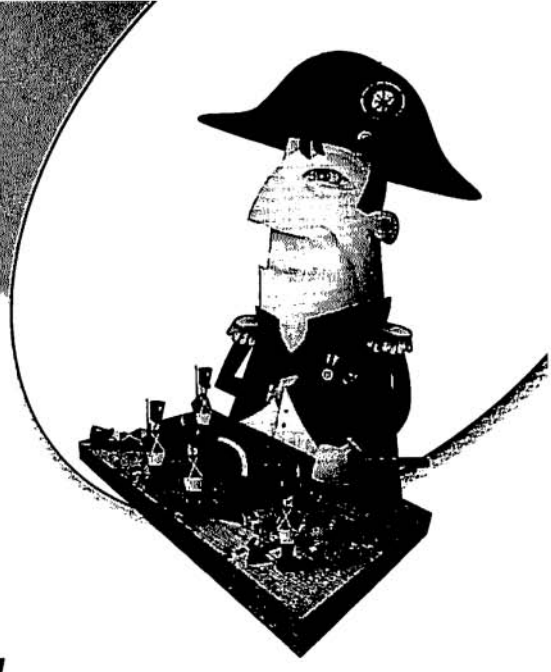

chapter 8

The Scientific Revolution and the Enlightenment, 1543–1789

The Scientific Revolution and the Enlightenment came about as direct, although not immediate, results of the Renaissance and Reformation. During the Renaissance, many ancient Greek and Latin texts came to light and were seriously studied for the first time in centuries. Scholars learned of ancient discoveries in mathematics, astronomy, and philosophy that had been suppressed or dismissed by the Church. The Renaissance also encouraged individual scholars to question the Church's teachings. The perfection of the printing press made the widespread dissemination of old and new knowledge possible. Finally, the Reformation loosened the stranglehold on thought that Christianity had maintained for centuries.

During the Scientific Revolution, direct observations of nature gave people a new way of understanding the world. The Church saw the Scientific Revolution as a threat for two reasons: it changed *what* people thought and, more important, *how* they thought. The increase in human knowledge of the work-

ings of the universe that occurred during the Scientific Revolution was the product of experimentation—of scientists making observations, taking notes, studying their data, and developing theories and conclusions based on what they perceived with their five senses. The Church was naturally hostile to a process that threatened its own supremacy over what people thought. Church officials did not want to change the centuries-old system in which their own scholars and teachers interpreted the world in accordance with their faith, and insisted that the people accept this interpretation rather than thinking about the matter for themselves.

The great thinkers—called *philosophes*—of the Enlightenment applied this same scientific process of critical thinking to social and political problems. They believed in the perfectibility of humanity and society; their goal was a peaceful, prosperous world in which ignorance, greed, and tyranny had no place. For nearly a century, the *philosophes* wrote, argued, debated, and taught that all people were born free and equal, and that individuals should be able to make their way in the world as reasonable beings with a right to decide how and where they wished to live. In the end, they brought about, at least in part, the new world they had imagined; their teachings led directly to major revolutions in British North America and in France.

CHAPTER 8 OBJECTIVES

- Explain the causes of the Scientific Revolution.
- Identify the major achievements and discoveries of the Scientific Revolution.
- Define the Enlightenment and its major causes and effects.
- Identify the major figures of the Scientific Revolution and the Enlightenment and match each person to his or her accomplishments in science, mathematics, literature, and philosophy.

Chapter 8 Time Line

- **1543** Copernicus argues in *De Revolutionibus* that planets move around the sun
- **1577** Tycho Brahe proves that comets are astral bodies
- **1609** Johannes Kepler discovers that planets move in elliptical orbits

- **1610** Galileo observes moons of Jupiter
- **1633** Roman Inquisition forces Galileo to recant
- **1637** Descartes publishes work on analytic geometry
- **1654** Christiaan Huygens invents the pendulum clock
- **1687** Newton publishes *Principia Mathematica*
- **1748** Montesquieu publishes *L'Esprit des lois*
- **1759** Voltaire publishes *Candide*
- **1762** Rousseau publishes *Contract social*
- **1776** American Revolution begins
- **1789** French Revolution

The Scientific Revolution

The ancients, first in the Middle East and then in Classical Greece and Rome, had made great strides in mathematics and the sciences. However, during the Christian era, any scientific teachings that conflicted with the Bible were rigorously suppressed and denounced as heresy.

During the Middle Ages, scientists theorized without having the means of testing their ideas by experimentation. By the seventeenth century this was no longer the case. The invention of the telescope, for example, made it possible to see the heavens up close and observe how the planets moved through space. By the same token, printing had spread throughout Europe beginning in the 1400s, so it was much easier to publicize and share new knowledge than it had been in medieval times. It made possible a true scientific community of scholars who knew one another, corresponded, and shared and discussed their ideas.

The era is known as the Scientific Revolution for two reasons. The first is the major discoveries in astronomy, physics, and mathematics that took place at this time. The second is a shift in thinking that was both the cause and the result of the Scientific Revolution. In the past, people had believed that what happened in the universe was the result of divine whims that were beyond human understanding; now they saw the universe as a machine that worked according to fixed laws that human beings could discover and understand. However, the Scientific Revolution did not do away with human faith in God;

rather, it suggested that God had created the universe and set it in motion according to the laws the scientists had observed. God was considered similar to a watchmaker, who designed and built a watch, wound it up, and left it to run on its own.

As new discoveries followed one another, science became the hobby of many people of leisure. These rich people, including monarchs such as Catherine the Great of Russia, helped the Scientific Revolution in two ways. First, their interest in science and mechanics lent an air of respectability to experimentation and discovery. Second, they were reliable sources of patronage and sponsorship, providing financial support, influence with the powerful, and welcome interest and enthusiasm to many scholars.

Major Figures of the Scientific Revolution

The Scientific Revolution was an international phenomenon; scholars from all over Europe took part in it. This chapter describes the most important figures of the era.

Copernicus

Nicolaus Copernicus was born in 1473 in Torun, Poland. He learned astronomy from the books he read as a student in Italy. Books of the time agreed that the Earth was at the center of the universe and that the other heavenly bodies, including the sun, traveled around it. In ancient times, both Ptolemy and Aristotle had arrived at this view by observing the heavens. Despite Aristotle's status as a pagan from the Classical era, the Church fathers had always accepted his view of astronomy because it allowed them to teach that humankind, God's supreme creation, had its proper place in the center of the universe.

Copernicus, however, came to believe that Aristotle and Ptolemy were wrong. He suggested that the sun, not the Earth, was at the center of the universe, with the planets orbiting it. It seemed to Copernicus that since the Earth and its moon were spherical, the orbits of the planets should be circular; however, he realized that from the point of view of the Earth, the orbits could not be perfect circles. In 1543, Copernicus published his thoughts and discoveries in a book called *De Revolutionibus*, known in English as *On the Revolutions of the Heavenly Spheres*. He died the same year.

Brahe

The next great European astronomer was Tycho Brahe. Born in 1546 to a noble family in what was then Danish territory, Brahe was fortunate in having as his patron a king who provided him with a fully fitted observatory. This enabled him to conduct direct experiments in astronomy—the first in Europe for many centuries. While Copernicus' theories had been more or less guesses, Brahe's observations told him that while the sun and moon traveled around the Earth, the other planets orbited the sun. Like Copernicus, he could not understand why the planets' apparently circular orbits were not regular.

Kepler

Brahe's assistant, the brilliant Johannes Kepler, took discoveries of the heavens one step further. Born in 1571 in the free city of Weil der Stadt, Kepler used mathematics and direct observation to show that the orbits of the planets were ellipses, not circles. As soon as he replaced the idea of circles with that of ellipses, the orbital paths became regular. Kepler also proved that the planets orbited the sun at different speeds. His greatest work was *On the Motion of Mars*, published in 1609; it soon appeared on the Holy Office's *Index of Forbidden Books*.

Astronomy took a giant leap forward with the discovery of the telescope, first patented in the Netherlands in 1608–1609. Scientists had realized during the 1300s that a glass lens could magnify an object seen through it; they had been using this knowledge ever since to manufacture eyeglasses and magnifying glasses. However, these were only intended to improve people's vision for everyday purposes such as reading. No one had thought to apply the same idea to achieving a close-up view of such faraway objects as the stars.

Galileo

Mathematics and engineering professor Galileo Galilei of Pisa was the first to make extensive use of the telescope to study the planets. With this new invention—at that time no more than a plain narrow tube a little over a yard long, with concave and convex lenses inside—he was able to see things in the heavens that had simply not been visible to his predecessors.

Looking through his telescope in 1610, Galileo realized immediately that Jupiter had its own moons in orbit around it, just as the Earth had a moon. This

discovery alone proved that Earth was not the center of the universe around which all other objects orbited. When Galileo published his new knowledge of the heavens, Kepler and most of Europe's intellectuals, including the Jesuit astronomers, eagerly accepted them.

Through his telescope, Galileo saw the rings around Saturn, although he did not understand what they were. He observed that, contrary to Aristotle's assertion that all heavenly bodies were perfect, smooth spheres, the surface of the Earth's moon was craggy and irregular. Since the Church had accepted Aristotle's theory of the universe, this meant that Galileo was well on his way to making an enemy of one of Europe's most powerful institutions.

In 1632, Galileo published *Dialogue on the Two Great Systems of the World.* Written in the form of an imaginary dialogue between Copernicus and Ptolemy, this work discussed theories about planetary orbits and tides. A lifelong and devout Catholic, Galileo dedicated the *Dialogue* to Pope Urban VIII. It was clear that he anticipated no trouble from the Church because of his writing; he had carefully refrained from discussing certain forbidden topics, such as the work of Kepler.

To Galileo's surprise, Urban VIII summoned him to Rome to appear before the Inquisition on the charge of defying the Holy Office's policy against writing about Copernican theory. Galileo produced documentary proof of his assertion that he was permitted to write speculatively about Copernican astronomy. Despite this evidence, the Inquisition refused to face the public mockery that would have resulted from making a mistake over a figure so internationally famous as Galileo. The Holy Office therefore sentenced Galileo to deny the validity of his own discoveries, then placed him under custody of the liberal archbishop of Siena, who encouraged him to continue working and writing. In effect, Galileo remained under house arrest until his death in 1642. He was free to study, experiment, and write, although it proved difficult (though not impossible) to find publishers in the face of a Holy Office ban on anything he might produce.

Within the next few years Galileo's works spread throughout Europe in various translations and editions. His last book, *The Two New Sciences,* discussed the structure of matter, the strength of materials, and the laws governing natural motion. He discovered the laws of falling bodies and the mathematical formula we use to describe acceleration.

Defending his own writings in his later personal correspondence, Galileo argued that God had given human beings the ability to observe and reason. What people could see and understand with their five senses must be the

truth; for instance, that planets moved around the sun. He argued that if this appeared to conflict with the scriptures, then human understanding of the scriptures must be at fault.

Newton

The year of Galileo's death saw the birth of Isaac Newton in rural Lincolnshire, England. Newton attended Cambridge University and studied the works of Galileo and Kepler. Newton revolutionized scientific thinking in Europe with his discovery of the principle of gravity—the single, constant force in the universe that attracted objects to one another. Newton realized that it was gravity that attracted the planets to the sun and the moons to the planets; gravity was what kept each body in a regular orbit at a constant distance from the larger mass around which it revolved. Newton's work explained how gravity could be calculated mathematically; he was the first scientist to apply calculus to astronomy.

The importance of Newton's discovery of the principle of gravity cannot be underestimated. It revolutionized European thinking, proving once and for all that the people could understand the way their own world worked. Before Newton, Europeans had understood the universe as operating by divine whims that they could not hope to understand; after Newton, they understood it as operating by fixed, comprehensible laws. For the first time, an understanding of the world could be based on human reason and experience, not on faith.

Like Galileo and those who had gone before him, Newton believed that his scientific theories were perfectly compatible with Church teaching. In his view, the law of gravity was a divine creation, and he was doing honor to God by revealing his divine plan. Unfortunately, the Church could not accept this view; as it had always done, it reacted to independent intellectual endeavor with suspicion and hostility. In a sense, the Church was right to recognize the threat posed by scientific discovery. Since science proved that the Church had been teaching an inaccurate and false theory of the structure of the universe, *all* Church teaching was called into question. The Scientific Revolution permanently weakened the place the Church held in popular regard.

The Enlightenment (The Age of Reason)

In the wake of the Scientific Revolution came the Enlightenment, a period of intellectual achievement that lasted for approximately a century, from the Eng-

lish Revolution in 1689 to the French Revolution in 1789. The Enlightenment is also called the Age of Reason. This movement was a natural consequence of the Scientific Revolution, which had introduced a new thought process to the West. During the Age of Reason, intellectuals applied that new way of thinking to social and political questions. They argued against political and religious tyranny, against a fixed hierarchy of social ranks, against censorship, and against chattel slavery. They argued for freedom—freedom of individual thought, freedom of the press and the arts, freedom to have a say in one's own government, and freedom to rise in the world according to merit rather than the accident of birth and rank.

The Enlightenment was centered in France—specifically in Paris—for a variety of reasons. First, France was the dominant power in Europe because of its victory in the Thirty Years' War (see Chapter 5). Second, French was the common language of educated Europeans in the eighteenth century, just as Latin had been during the Renaissance. Third, the establishment of the French academies of arts, sciences, and letters had given a degree of official approval and sponsorship to intellectuals, although this was also true in other nations, and censorship still operated in France. Enlightenment thinkers viewed Britain as the ideal society; although it had many problems yet to overcome, Britain was a constitutional monarchy with a relatively representative government and relative religious tolerance, and therefore a haven from tyranny. Last and not least, France had a central geographical location on the European continent; the less restrictive conditions in Britain might make it appear a natural center for an intellectual movement, but it was an island on the other side of the English Channel.

The thinkers of the Enlightenment were men (and some women) of all European nations: Britain, Germany, France, Poland, and Italy. They achieved fame in various fields: there were poets, playwrights, political thinkers, nonfiction writers, scientists, novelists, philosophers, and economists. They were collectively known as *philosophes*—a French word that can perhaps best be translated as "critical thinkers." What united the *philosophes* as one group was this critical way of thinking—the habit of applying the same reasoning process to the problems and questions of their age. They came to a variety of conclusions—there were in fact some fierce disagreements among them—but all used the same method to arrive at them.

The Enlightenment marked a break with the past in two major ways. First, the Middle Ages and the period that followed had generally been a time of

pessimism, or at best resignation. Many medieval Church officials and even scholars had believed the world would end in 1500; people made the best of life on earth only in the hope of achieving something better after death. By contrast, the Enlightenment was an era of optimism, in which the great intellectuals believed in the perfectibility of humankind. The *philosophes* believed that reasoning and knowledge could solve the problems of society, if properly applied. They believed that a world of peace, prosperity, and earthly happiness could truly be achieved. Their ideas about political theory were based on notions of individual liberty, which they and their followers expressed in the French Declaration of the Rights of Man (see Chapter 9) and the American Declaration of Independence and Bill of Rights.

Second, human society had always accepted that human beings were God's creation; people had always dedicated their endeavors to the glory of God and had prayed for God's assistance when going into battle or danger. This attitude even persisted during the Scientific Revolution. During the Enlightenment, the *philosophes* began openly questioning the relevance, if not the existence, of God. They focused on human achievement as the product of a particular individual's merit, and honored that person rather than God.

Major Thinkers of the Enlightenment

The *philosophes* of the Enlightenment were such a large and varied group that this book can only cover a few of the most prominent.

Montesquieu

Charles-Louis Secondat, Baron de Montesquieu, was born in 1689 in the Gironde region of southwestern France. His two most famous works are the *Persian Letters* (1721) and *L'Esprit des lois*, or *The Spirit of Laws* (1748).

Many scholars consider the *Persian Letters* as the book that began the Enlightenment. It is in the form of a collection of letters written by two fictional Persian travelers in Europe. The travelers observe and comment on French society, government, and customs, and also discuss conditions at the Persian court they have left behind. Montesquieu used this format to make some pointed, although veiled, criticisms of the despotism that prevailed at this time in France. He scoffed at the vanity and pride that the hereditary nobles took in their social position, noting that it came not from intelligence or virtue but from the accident of birth. Montesquieu published the *Persian Letters*

anonymously in the Netherlands, a common course for authors to pursue at that time if they thought their ideas would stir up trouble with the authorities. The book was a great success, going through several editions in a single year.

The Spirit of Laws is a work of serious political theory; unlike *Persian Letters*, it does not make its points under the guise of fiction. This was the first book to advocate a balanced government made of different branches—executive, legislative, and judicial—each of which had some power over the others. Montesquieu believed this was the best way to avoid the autocracy that he felt was corrupt and harmful to society. The work also examined the roles of major social institutions such as the Church, which lost no time placing it on the *Index of Forbidden Books*. However, it was widely read and highly influential; fifty years after the book's appearance, the government of the United States was organized along the lines suggested by Montesquieu.

Voltaire

Born in Paris in 1694, François-Marie Arouet was educated by the Jesuits and determined early on to pursue a career in writing. Around 1718, he coined the pen name "Voltaire," by which he was known for the rest of his long and productive life.

One of Voltaire's most important concerns was freedom of religion. During a three-year stay in England in the 1720s, he observed what he considered an ideal society, one that supported its artists and men of letters while allowing its citizens to worship as they saw fit. By praising England enthusiastically in his *Letters on England* (1733), Voltaire implied severe criticism of the very different conditions in France; as a consequence, the book was banned in his own country. Voltaire was twice imprisoned in the Bastille for his writings; after the second prison term, he moved to the Swiss border area, where it would be easy to flee if the state pursued him in the future.

Voltaire published throughout his lifetime, both fiction and nonfiction, and kept up a voluminous correspondence with all the great thinkers of his age. His best-known work is the short novel *Candide* (1759), which lampoons many of the worst aspects of European society: government, military life, and religion. The novel concludes that "one must cultivate one's garden"—in other words, what is most important is to use one's intellectual and philosophical skills to solve real, practical problems in a realistic and practical way.

Voltaire lived to the great age of eighty-four, not quite long enough to witness the French Revolution (see Chapter 9) but long enough to see himself crowned as the elder statesman of the Enlightenment.

Rousseau

Jean-Jacques Rousseau, born in 1712 in Geneva, Switzerland, was in many ways the odd man out among the *philosophes*. As his thinking developed over time, he quarreled violently with almost all of them. Concentrating on man's emotional side rather than his reasoning powers, Rousseau believed passionately in the importance of each person as a unique individual. His works insist that the emotional makeup of a person is just as important as the intellectual; therefore, he has often been considered the father of the Romantic movement in the arts (see Chapter 11).

In *The Social Contract* (1762), Rousseau described his ideal society. He believed that social structure was inherently evil because, as he could see for himself, it created false ideas of inequality. He saw people born into one social rank, and thus condemned to stay in it regardless of natural merits or faults. Rousseau believed that without an imposed social structure, human beings would follow their nature and would relate to one another in benevolence rather than self-interest. This notion of the "noble savage" seemed ludicrous to many of the other *philosophes*, who believed that education was the key to a better society.

Diderot

Denis Diderot was born in 1713 in the town of Langres in northeastern France. Like Voltaire, he received a good education under the Jesuits. He was able to turn his hand to any number of intellectual tasks, including editing, translating, and writing both fiction and nonfiction.

Diderot's most important contribution to the legacy of the Enlightenment is the *Encyclopédie*. The project came about when he accepted a commission to translate *Chambers' Cyclopedia* into French. Diderot decided to publish his own encyclopedia, which grew over time to seventeen volumes of text (published 1751–1765) and eleven volumes of engraved illustrations, completed in 1773. Until 1758, mathematician Jean Baptiste d'Alembert worked with Diderot as coeditor; when D'Alembert withdrew, succumbing to pressure from powerful vested interests who did not want to see the work published, Diderot carried on alone.

As its name suggests, the *Encyclopédie* was an attempt to sum up all human knowledge in one place. It included articles by all the greatest thinkers and writers of the age (including Voltaire, Rousseau, and Diderot himself) on a

variety of topics: science, technology, crafts, mathematics, art, religion, music, and history. The purpose of the *Encyclopédie* was to enlighten the ignorant—to provide ordinary people with information that everyone, as a sentient being in the world, should know. The *philosophes* believed strongly in the value of education; they saw ignorance as their enemy. They believed that educating the common people was one of the most basic and important ways to improve society.

QUIZ

1. **The Scientific Revolution and the Enlightenment share which of the following?**
   A. the approval and support of the Church
   B. the design of new systems of government
   C. the process of critical thinking and experimentation
   D. the invention of new solutions to major social problems

2. **_____ is an important historical figure because he realized that the planets moved in regular elliptical orbits around the sun.**
   A. Tycho Brahe
   B. Nicolaus Copernicus
   C. Galileo Galilei
   D. Johannes Kepler

3. **One important reason France was the center of the Enlightenment was that**
   A. it was the largest centrally located nation in Europe.
   B. it had a more despotic government than any other European nation.
   C. its people spoke the language common to all educated people of the time.
   D. it did not allow censorship of the press.

4. **What argument did Galileo make in support of his discoveries about the planets when the Church refused to accept them?**
   A. that what could be observed by the human eye must be the truth
   B. that Church fathers had no right to make pronouncements about astronomy
   C. that other intellectuals and scientists agreed with his findings
   D. that he had used the finest scientific instruments of the day

5. **Church officials were hostile to the discoveries of the Scientific Revolution because**
   A. the discoveries were not the result of proper experimentation and study.
   B. the scientists who made the discoveries were all Protestants.
   C. they objected to the scientists' expressed disbelief in God.
   D. these discoveries contradicted and disproved what the Church had always taught.

6. **The term *philosophe* is best translated as _____**
   A. scholar.
   B. critical thinker.
   C. student.
   D. intellectual.

7. **Which statement is true of all the *philosophes* of the Enlightenment?**
   A. They were all French.
   B. They all supported and agreed with one another.
   C. They all shared a common way of thinking.
   D. They were all knowledgeable about mathematics and science.

8. **Rousseau has been called the father of the Romantic movement because**
   A. he imagined a government operating under a system of checks and balances.
   B. he believed in the supreme importance of each human being's individual personality and emotions.
   C. he wrote clever satires on the society of his day.
   D. he conceived the idea of a multivolume French encyclopedia of knowledge.

9. **Which best describes the *Encyclopédie*?**
   A. a satire of French government and society
   B. a compendium of historical and scientific facts, dates, and important events
   C. a compilation of information on scientific, mechanical, artistic, and historical topics
   D. an illustrated guide to the lives of France's most famous citizens

10. **Which best describes what the *philosophes* hoped and believed the future might hold for humankind?**
    A. They believed that society might become peaceful, prosperous, and happy.
    B. They believed that the world would end in a great war among all nations.
    C. They believed that there was no possibility that society would ever improve.
    D. They believed that society would succumb to despotism.