region increased. The Japanese rulers came to see Western culture and Christianity as a threat to their traditional values and civilization and grew hostile toward Europeans. In 1637 they expelled all Japanese Christians from the country. Two years later Japan also forced the remaining Portuguese to leave. (*See also* **Exploration; Magellan, Ferdinand.**)

Astrology

See *Magic and Astrology.*

Astronomy

Astronomy, the scientific study of bodies in space, underwent a revolution during the Renaissance. Three great astronomers—Nicolaus COPERNICUS, Johannes KEPLER, and Galileo GALILEI—challenged the old notion that Earth was the center of the universe by showing that Earth and the other planets revolve around the Sun. Other Renaissance thinkers developed the concepts of infinity and of a universe containing many worlds.

Since ancient times, people had learned astronomy alongside astrology and cosmology. Astrology is the study of the influences of the heavens on earthly events. Renaissance astrologers believed that they could predict the future by observing the stars. Cosmology is the study of the nature and structure of the universe. It is linked to theology* and PHILOSOPHY. The ideas of philosophers, such as the ancient Greek thinker ARISTOTLE, affected Renaissance views of the universe as much as the observations of scientists did. Aristotle believed that the world was changing and imperfect, but that the heavens were unchanging and pure. PTOLEMY, the leading astronomer of the ancient world, thought that the study of heavenly motion should encourage people to think about its cause, which was God. Because they saw astronomy as being linked to faith, some Renaissance thinkers were very slow to change the ideas about the universe that they had inherited from Ptolemy.

* **theology** study of the nature of God and of religion

From Ptolemy to Copernicus. Ptolemy had described his view of the universe in a book called *Almagest*. Renaissance scholars translated and commented on this text in the 1400s. Ptolemy's model of the universe was geocentric, or earth-centered. In it, the Sun and planets revolved around Earth. Most Renaissance scholars accepted this theory.

Copernicus, the greatest astronomer of the first half of the 1500s, had a new vision of the universe. In *On the Revolutions of the Heavenly Spheres* (1543), Copernicus described a heliocentric, or sun-centered, universe. In this model, the planets, including Earth, circled the Sun. Copernicus believed that this entire system existed within a sphere of unmoving stars. He used ancient, medieval*, and Renaissance astronomical works to defend his ideas. He combined these sources with his own observations of the sky to create a complex mathematical theory of the movements of the heavens.

* **medieval** referring to the Middle Ages, a period than began around A.D. 400 and ended around 1400 in Italy and 1500 in the rest of Europe

Reactions to Copernicus. Most professional astronomers during the second half of the 1500s had high regard for Copernicus. However, they refused to believe in his heliocentric model.

See color plate 1, vol. 4

The greatest astronomer of this period was Tycho BRAHE. He possessed great skills as an observer and a maker of scientific instruments. Brahe presented a system called geoheliocentrism, in which the planets circled the Sun, which in turn circled an unmoving Earth. This theory enabled him to take advantage of some of Copernicus's discoveries. At the same time, Brahe rejected the disturbing notion that Earth was not the central and most important body of the universe.

Johannes Kepler (1571–1630) and Galileo Galilei (1564–1642) supported the heliocentric view. Kepler used mathematical principles to explain how planets move in a sun-centered system. He was also the first to describe gravity as a force that attracts all bodies in the universe to each other. Galileo used the telescope—a new invention—to study the heavens in greater detail than had ever been possible before. His observations led him to question established ideas about the universe. He saw that heavenly bodies were not perfect and unchanging when he found mountains and valleys on the Moon's surface. He realized that not everything in the heavens revolved around Earth when he discovered moons orbiting Jupiter. He carefully watched the phases of Venus (the cycle of changes in its appearance) and argued that they would not be visible in an earth-centered universe.

Galileo published his discoveries and theories in *Dialogue Concerning the Two Chief World Systems* in 1632. The book described Copernicus's view of a universe centered on the Sun as a physical reality, rather than simply a theory. By publishing this claim, Galileo disobeyed a papal* order. In response, the Roman Catholic Church banned his book and placed Galileo under house arrest for life.

* **papal** referring to the office and authority of the pope

Contributions from Theology. Modern views of the universe grew out of the findings of Copernicus, Kepler, and Galileo. However, they also reflect the ideas of Renaissance theologians.

Medieval models of the universe had claimed that the universe had boundaries. Cardinal Nicolas Cusanus (1401–1464) argued that the universe was boundless. He also believed that it had no single center and that it contained many inhabited worlds. In the late 1500s, Italian philosopher Giordano BRUNO took up Cusanus's ideas. Bruno was the first to claim that the Sun was a star and that the stars were suns. He was burned at the stake in 1600. Some Renaissance astronomers, including Copernicus, continued to see the universe as limited in size. However, by the end of the 1600s, the idea of an infinite universe with many solar systems had become common. (*See also* **Magic and Astrology.**)

Augsburg

Augsburg, one of the most important cities of Renaissance Germany, was located along a major trade route from Italy. It became a thriving center for both commerce and the arts. Augsburg was also one of the

* **treatise** long, detailed essay

with 590 editions of his works published there between 1500 and 1600. During the Renaissance, Galen's treatises* had a strong impact on Italian universities. They helped to influence the movement known as medical humanism, which aimed to practice medicine in the manner of the ancient physicians.

From Galen's writings, many Italian scholars learned how to dissect and describe different structures of the body. Interest in Galen's work helped to raise the status of anatomy from a minor part of medical education to an important field of study. As the study of anatomy expanded, scholars began to find flaws in Galen's work. Belgian anatomist Andreas VESALIUS revealed many errors in Galen's descriptions of human anatomy. However, he continued to support many of Galen's methods and medical ideas. (*See also* **Anatomy; Classical Scholarship; Medicine.**)

Galilei, Galileo

1564–1642
Italian scientist

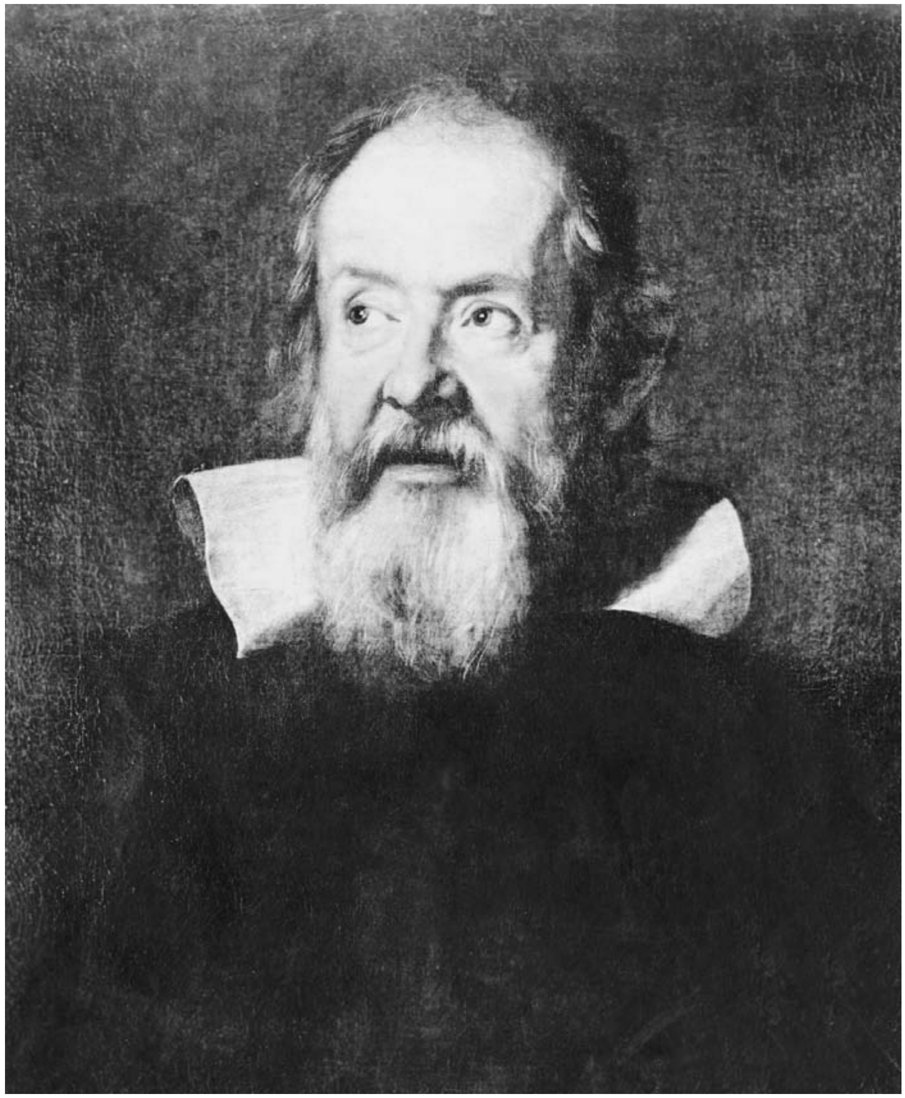
Galileo Galilei of Italy was the foremost scientist of the Renaissance. He made important contributions to the field of mechanics (the study of force and motion) and to the development of the SCIENTIFIC METHOD. He is chiefly remembered, however, for his work in ASTRONOMY. Galileo, as he is known, did much to promote the heliocentric view of the universe, which holds that the Earth revolves around the Sun. This idea met with opposition from the Roman Catholic Church and from some other scientists, who saw it as conflicting with the Bible and with earlier ideas on the nature of the universe. Galileo spent his final years under house arrest, but his ideas spread, influenced other thinkers, and became part of the foundation of modern science.

* **classical** in the tradition of ancient Greece and Rome

Early Career. Galileo was born in Pisa, Italy. Eight years later his family moved to Florence, where Galileo received a classical* education at a nearby monastery. In 1581 Galileo enrolled as a medical student at Pisa's university, where he studied under several leading mathematicians of the day. After four years, Galileo left the university without a degree and began teaching mathematics privately in Florence. A few years later he became a professor of mathematics in Pisa. During his years there, Galileo wrote several volumes of notes on scientific subjects. One volume, which focused on topics such as gravity and bodies in motion, discussed a series of experiments that Galileo had performed in an effort to develop a set of laws of motion.

The death of Galileo's father in 1591 placed heavy financial burdens on the young scientist, who took a position at the University of Padua to improve his salary. He spent the next 18 years in Venice, a period that Galileo later described as the happiest of his life. During this time the scientist produced works on mechanics and kept notes and sketches of experiments he performed with pendulums, objects rolling on slanted surfaces, and thrown or falling objects.

A New Look at the Universe. During his early career, Galileo taught astronomy according to the theories of the ancient scholar PTOLEMY. For



The most important scientist of the Renaissance, Galileo Galilei was known mainly for his work in the field of astronomy. His theories about the motion of the Earth brought him under attack from the Catholic Church.

centuries astronomers had relied on Ptolemy's model of the universe, which used an elaborate mathematical system to explain how the Sun, the Moon, and all the planets revolved around the Earth. A 1543 work by astronomer Nicolaus COPERNICUS, however, had presented a bold new view of the heavens, in which Earth and all the other planets revolved around the Sun. Galileo would come to be the leading champion of this new theory.

In 1609 Galileo heard that scientists in Holland had invented a new device called the telescope, which made it possible to view distant objects in greater detail than ever before. Galileo perfected the telescope for the study of heavenly bodies and turned his eyes toward the skies. He made startling discoveries, including new stars invisible to the naked eye, mountains on the surface of the Moon, and satellites orbiting the planet Jupiter. The following year he published these discoveries in a book called *Sidereal* Messenger*, which quickly made him the most famous astronomer in Europe. Galileo's discoveries earned him the

*** sidereal** relating to the stars

* **patronage** support or financial sponsorship

patronage* of Cosimo II de' MEDICI, the grand duke of Tuscany (the region surrounding Florence). The scientist moved to Florence to serve as "mathematician and philosopher" to the grand duke. He also visited Rome, where he enjoyed the praise of fellow scientists.

Although Galileo had taught the theories of Ptolemy in Padua, his own observations and calculations convinced him that the Earth actually traveled around the Sun. He discussed this view with other scholars and referred to it in some of his writings. Although Galileo tried to argue that his evidence of the Earth's motion did not necessarily contradict the Bible, pressure against him began to mount. In early 1616 the church ordered Galileo not to "hold, teach, or defend" the view that the Earth moves and the Sun does not. Galileo agreed and avoided arrest. A few days later the church added Copernicus's revolutionary work to the INDEX OF PROHIBITED BOOKS.

In 1623 a new pope, Urban VIII, took office. At first, Urban VIII was sympathetic to Galileo, and most scholars believe that he granted the scientist some sort of permission to resume his studies of the Copernican system. By 1630 Galileo had finished his great work *Dialogue Concerning the Two Chief World Systems*. In this piece he compared the evidence for the systems of Ptolemy and Copernicus and came down heavily in favor of the Copernicans—in the process making those who held to the Ptolemaic system look rather foolish. Galileo argued that the Earth is similar to heavenly bodies in its motion and material. He disputed earlier proofs that the Earth is at rest and claimed that Earth was probably a planet that revolved around the Sun.

Trial and Later Years. To get a church censor to approve the publication of the *Dialogue,* Galileo added a statement to the text claiming that he meant it as a mathematical exercise only, not a proof of a moving Earth or a stationary Sun. Despite this precaution, the book's publication in 1632 landed Galileo in deeper trouble than he could have imagined. Pope Urban VIII was furious, possibly feeling that Galileo had broken an earlier promise to write on the topic without taking sides. The pope also thought that Galileo had ridiculed his own answer to the problem of the two world systems, which was that human intellect could not solve it. The church banned all further publication and sales of the *Dialogue*. It then summoned Galileo to Rome to be tried for teaching a theory that the church had condemned as contrary to Scripture.

A committee of ten cardinals tried Galileo. They found that he had taught and defended the opinions of Copernicus, although they could not be certain that he actually believed them—a more serious charge. To bring the matter to a close, the head of the committee offered to let Galileo plead that he had become carried away while writing and had defended the Copernican theory without meaning to do so. Galileo agreed to this position, but the pope was not satisfied. He made Galileo swear that he did not believe in the Earth's motion and that his former teachings were wrong. The church then pardoned Galileo, but confined him to his home and forbade him to write any more on Copernicanism.

During his forced retirement, Galileo continued his research into the science of mechanics. He published his results in 1638 under the title

Righting a Wrong

Centuries after Galileo's death, the Roman Catholic Church admitted that it had been wrong to put him on trial and ban his work. The process began in 1820, when the church withdrew its condemnation of the Copernican system. Fifteen years later it removed Galileo's *Dialogue* from its list of forbidden books. In 1981 Pope John Paul II established a special commission to reexamine Galileo's trial. Its report, released in 1992, officially declared that religious authorities had misunderstood Galileo's teachings.

The Two New Sciences—the manuscript had been smuggled to Holland for printing. After 11 years of quiet house arrest, the leading scientist of his age died peacefully at his villa* at Arcetri. He was buried in the church of Santa Croce in Florence, where his remains lie near those of such other celebrated Renaissance figures as the artist MICHELANGELO BUONARROTI and the author Niccolò MACHIAVELLI. (*See also* **Sciences, Physical; Scientific Instruments.**)

* **villa** luxurious country home and the land surrounding it

Gama, Vasco da

ca. 1469–1524
Portuguese explorer

Vasco da Gama made one of the most important voyages of exploration in the Renaissance. Unlike Christopher COLUMBUS, he did not discover new lands unknown to Europeans. Instead, da Gama pioneered a new route to Asia, a place known to Europeans but very difficult to reach. By sailing around Africa to India, da Gama opened the door to trade, conquest, and a Portuguese empire in East Africa and Asia.

Da Gama's career as an explorer began in 1497, when the Portuguese king Manuel I named him captain of a fleet of four ships and sent him to find a route across the Indian Ocean to India. The voyage built on years of Portuguese exploration along Africa's coasts, including the voyage of Bartolomeu Dias nine years earlier around the Cape of Good Hope on the southern tip of Africa.

Da Gama headed south from Portugal, paused at the Cape Verde Islands off western Africa, and then moved out into the Atlantic. Although his exact route is unknown, da Gama sailed through the open ocean rather than inching his way along the coast. After 90 days at sea out of sight of land, the fleet arrived 100 miles north of the Cape of Good Hope. Da Gama rounded the cape in November 1497 and proceeded north along the eastern coast of Africa.

See color plate 2, vol. 4

After stopping at several ports, da Gama found an Indian sailor to guide him across the Indian Ocean. In May 1498 the Portuguese reached the Indian port of Calicut, where they spent more than three months trying to trade for spices and gems. Despite the hostility of Muslim traders and the local Hindu ruler, da Gama obtained a cargo of cinnamon and pepper. In 1499 he returned to Portugal. In some ways he had been less than successful, having wrecked two of his four ships and lost two-thirds of his crew. Yet he had proved that the sea route to India existed.

King Manuel rewarded da Gama and promptly sent larger fleets along the new route. Da Gama made his second voyage to India in 1502 and another in 1524, this time as the viceroy* of India. (*See also* **Exploration; Portugal; Travel and Tourism.**)

* **viceroy** someone who rules a territory on behalf of a king

Gardens

The gardens of the Renaissance were art forms that, like the other arts of the era, took inspiration from the ancient world. The Renaissance garden emerged in Italy during the 1450s and reached a peak in the late 1500s with grand garden complexes featuring terraces and fountains. The style that developed in Italy influenced garden design throughout Europe.

Isaac Newton, Sir

Encyclopedia of World Biography, December 12, 1998
Born: December 25, 1642 in Woolsthorpe, England
Died: March 20, 1727 in Kensington, England
Nationality: English
Occupation: Physicist

Sir Isaac Newton (1642-1727) was an English scientist and mathematician. He made major contributions in mathematics and theoretical and experimental physics and achieved a remarkable synthesis of the work of his predecessors on the laws of motion, especially the law of universal gravitation.

Isaac Newton was born on Christmas Day, 1642, at Woolsthorpe, a hamlet in southwestern Lincolnshire. In his early years Lincolnshire was a battle-ground of the civil wars, in which the challenging of authority in government and religion was dividing England's population. Also of significance for his early development were circumstances within his family. He was born after the death of his father, and in his third year his mother married the rector of a neighboring parish, leaving Isaac at Woolsthorpe in the care of his grandmother.

After a rudimentary education in local schools, he was sent at the age of 12 to the King's School in Grantham, where he lived in the home of an apothecary named Clark. It was from Clark's stepdaughter that Newton's biographer William Stukeley learned many years later of the boy's interest in her father's chemical library and laboratory and of the windmill run by a live mouse, the floating lanterns, sundials, and other mechanical contrivances Newton built to amuse her. Although she married someone else and he never married, she was the one person for whom Newton seems to have had a romantic attachment.

At birth Newton was heir to the modest estate which, when he came of age, he was expected to manage. But during a trial period midway in his course at King's School, it became apparent that farming was not his métier. In 1661, at the age of 19, he entered Trinity College, Cambridge. There the questioning of long-accepted beliefs was beginning to be apparent in new attitudes toward man's environment, expressed in the attention given to mathematics and science.

After receiving his bachelor's degree in 1665, apparently without special distinction, Newton stayed on for his master's; but an epidemic of the plague caused the university to close. Newton was back at Woolsthorpe for 18 months in 1666 and 1667. During this brief period he performed the basic experiments and apparently did the fundamental thinking for all his subsequent work on gravitation and optics and developed for his own use his system of calculus. The story that the idea of universal gravitation was suggested to him by the falling of an apple seems to be authentic: Stukeley reports that he heard it from Newton himself.

Returning to Cambridge in 1667, Newton quickly completed the requirements for his master's degree and then entered upon a period of elaboration of the work begun at Woolsthorpe. His mathematics professor, Isaac Barrow, was the first to recognize Newton's unusual ability, and when, in 1669, Barrow resigned to devote himself to theology, he recommended Newton as his successor. Newton became Lucasian professor of mathematics at 27 and stayed at Trinity in that capacity for 27 years.

Experiments in Optics

Newton's main interest at the time of his appointment was optics, and for several years the lectures required of him by the professorship were devoted to this subject. In a letter of 1672 to the secretary of the Royal Society, he says that in 1666 he had bought a prism "to try therewith the celebrated phenomena of colours." He continues, "In order thereto having darkened the room and made a small hole in my window-shuts to let in a convenient quantity of the Suns light, I placed my prism at its entrance, that it might be thereby refracted to the opposite wall." He had been surprised to see the various colors appear on the wall in an oblong arrangement (the vertical being the greater dimension), "which according to the received laws of refraction should have been circular." Proceeding from this experiment through several stages to the "crucial" one, in which he had isolated a single ray and found it unchanging in color and refrangibility, he had drawn the revolutionary conclusion that "Light itself is a heterogeneous mixture of differently refrangible rays."

These experiments had grown out of Newton's interest in improving the effectiveness of telescopes, and his discoveries about the nature and composition of light had led him to believe that greater accuracy could not be achieved in instruments based on the refractive principle. He had turned, consequently, to suggestions for a reflecting telescope made by earlier investigators but never tested in an actual instrument. Being manually dexterous, he built several models in which the image was viewed in a concave mirror through an eyepiece in the side of the tube. In 1672 he sent one of these to the Royal Society.

Newton felt honored when the members were favorably impressed by the efficiency of his small reflecting telescope and when on the basis of it they elected him to their membership. But when this warm reception induced him to send the society a paper describing his experiments on light and his conclusions drawn from them, the results were almost disastrous for him and for posterity. The paper was published in the society's *Philosophical Transactions ,* and the reactions of English and Continental scientists, led by Robert Hooke and Christiaan Huygens, ranged from skepticism to bitter opposition to conclusions which seemed to invalidate the prevalent wave theory of light.

At first Newton patiently answered objections with further explanations, but when these produced only more negative responses, he finally became irritated and vowed he would never publish again, even threatening to give up scientific investigation altogether. Several years later, and only through the tireless efforts of the astronomer Edmund Halley, Newton was persuaded to put together the results of his work on the laws of motion, which became the great *Principia*.

His Major Work

Newton's *magnum opus, Philosophiae naturalis principia mathematica,* to give it its full title, was completed in 18 months--a prodigious accomplishment. It was first published in Latin in 1687, when Newton was 45. Its appearance established him as the leading scientist of his time, not only in England but in the entire Western world.

In the *Principia* Newton demonstrated for the first time that celestial bodies follow the laws of dynamics and, formulating the law of universal gravitation, gave mathematical solutions to most of the problems concerning motion which had engaged the attention of earlier and contemporary scientists. Book 1 treats the motion of bodies in purely mathematical terms. Book 2 deals with motion in resistant mediums, that is, in physical reality. In Book 3, Newton describes a cosmos based on the laws he has established. He demonstrates the use of these laws in determining the density of the earth, the masses of the sun and of planets having satellites, and the trajectory of a comet; and he explains the variations in the moon's motion, the precession of the equinoxes, the variation in gravitational acceleration with latitude, and the motion of the tides. What seems to have been an early version of book 3, published posthumously as *The System of the World,* contains Newton's calculation, with illustrative diagram, of the manner in which, according to the law of centripetal force, a projectile could be made to go into orbit around the earth.

In the years after Newton's election to the Royal Society, the thinking of his colleagues and of scholars generally had been developing along lines similar to those which his had taken, and they were more receptive to his explanations of the behavior of bodies moving according to the laws of motion than they had been to his theories about the nature of light. Yet the *Principia* presented a stumbling block: its extremely condensed mathematical form made it difficult for even the most acute minds to follow. Those who did understand it saw that it needed simplification and interpretation. As a result, in the 40 years from 1687 to Newton's death the *Principia* was the basis of numerous books and articles. These included a few peevish attacks, but by far the greater number were explanations and elaborations of what had subtly evolved in the minds of his contemporaries from "Mr. Newton's theories" to the "Newtonian philosophy."

London Years

The publication of the *Principia* was the climax of Newton's professional life. It was followed by a period of depression and lack of interest in scientific matters. He became interested in university politics and was elected a representative of the university in Parliament. Later he asked friends in London to help him obtain a government appointment. The result was that in 1696, at the age of 54, he left Cambridge to become warden and then master of the Mint. The position was intended to be something of a sinecure, but he took it just as seriously as he had his scientific pursuits and made changes in the English monetary system that were effective for 150 years.

Newton's London life lasted as long as his Lucasian professorship. During that time he received many honors, including the first knighthood conferred for scientific achievement and election to life presidency of the Royal Society. In 1704, when Huygens and Hooke were no longer living, he published the *Opticks,* mainly a compilation of earlier research, and subsequently revised it three times; he supervised the two revisions of the *Principia;* he engaged in the regrettable controversy with G. W. von Leibniz over the invention of the calculus; he carried on a correspondence with scientists all over Great Britain and Europe; he continued his study and investigation in various fields; and, until his very last years, he conscientiously performed his duties at the Mint.

His "Opticks"

In the interval between publication of the *Principia* in 1687 and the appearance of the *Opticks* in 1704, the trend was away from the use of Latin for all scholarly writing. The *Opticks* was written and originally published in English (a Latin translation appeared 2 years later) and was consequently accessible to a wide range of readers in England. The reputation which the *Principia* had established for its author of course prepared the way for acceptance of his second published work. Furthermore, its content and manner of presentation made the *Opticks* more approachable. It was essentially an account of experiments performed by Newton himself and his conclusions drawn from them, and it had greater appeal for the experimental temper of the educated public of the time than the more theoretical and mathematical *Principia*.

Of great interest for scientists generally were the queries with which Newton concluded the text of the *Opticks*--for example, "Do not Bodies act upon Light at a distance, and by their action bend its rays?" These queries (16 in the first edition, subsequently increased to 31) constitute a unique expression of Newton's philosophy; posing them as negative questions made it possible for him to suggest ideas which he could not support by experimental evidence or mathematical proof but which gave stimulus and direction to further research for many generations of scientists. "Of the Species and Magnitude of Curvilinear Figures," two treatises included with the original edition of the *Opticks,* was the first purely mathematical work Newton had published.

Mathematical Works

Newton's mathematical genius had been stimulated in his early years at Cambridge by his work under Barrow, which included a thorough grounding in Greek mathematics as well as in the recent work of René Descartes and of John Wallis. During his undergraduate years Newton had discovered what is known as the binomial theorem; invention of the calculus had followed; mathematical questions had been treated at length in correspondence with scientists in England and abroad; and his contributions to optics and celestial mechanics could be said to be his mathematical formulation of their principles.

But it was not until the controversy over the discovery of the calculus that Newton published mathematical work as such. The controversy, begun in 1699, when Fatio de Duillier made the first accusation of plagiarism against

Leibniz, continued sporadically for nearly 20 years, not completely subsiding even with Leibniz's death in 1716.

The inclusion of the two tracts in the first edition of the *Opticks* was certainly related to the controversy, then in progress, and the appearance of other tracts in 1707 and 1711 under the editorship of younger colleagues suggests Newton's release of this material under pressure from his supporters. These tracts were for the most part revisions of the results of early research long since incorporated in Newton's working equipment. In the second edition of the *Principia,* of 1713, the four "Regulae Philosophandi" and the four-page "Scholium Generale" added to book 3 were apparently also designed to answer critics on the Continent who were expressing their partisanship for Leibniz by attacking any statement of Newton's that could not be confirmed by mathematical proof; the "Scholium" is of special interest in that it gives an insight into Newton's way of thought which the more austere style of the main text precludes.

Other Writings and Research

Two other areas to which Newton devoted much attention were chronology and theology. A shortened form of his *Chronology of Ancient Kingdoms* appeared without his consent in 1725, inducing him to prepare the longer work for publication; it did not actually appear until after his death. In it Newton attempted to correlate Egyptian, Greek, and Hebrew history and mythology and for the first time made use of astronomical references in ancient texts to establish dates of historical events. In his *Observations upon the Prophecies of Daniel and the Apocalypse of St. John,* also posthumously published, his aim was to show that the prophecies of the Old and New Testaments had so far been fulfilled.

Another of Newton's continuing interests was the area in which alchemy was evolving into chemistry. His laboratory assistant during his years at Cambridge wrote of his chemical experiments as being a major occupation of these years, and Newton's manuscripts reflect the importance he attached to this phase of his research. His Mint papers show that he made use of chemical knowledge in connection with the metallic composition of the coinage. Among the vast body of his manuscripts are notes indicating that his *Chronology* and *Prophecy* and also his alchemical work were parts of a larger design that would embrace cosmology, history, and theology in a single synthesis.

The mass of Newton's papers, manuscripts, and correspondence which survives reveals a person with qualities of mind, physique, and personality extraordinarily favorable for the making of a great scientist: tremendous powers of concentration, ability to stand long periods of intense mental exertion, and objectivity uncomplicated by frivolous interests. The many portraits of Newton (he was painted by nearly all the leading artists of his time) range from the fashionable, somewhat idealized, treatment to a more convincing realism. All present the natural dignity, the serious mien, and the large searching eyes mentioned by his contemporaries.

When Newton came to maturity, circumstances were auspiciously combined to make possible a major change in men's ways of thought and endeavor. The uniqueness of Newton's achievement could be said to lie in his exploitation of these unusual circumstances. He alone among his gifted contemporaries fully recognized the implications of recent scientific discoveries. With these as a point of departure, he developed a unified mathematical interpretation of the cosmos, in the expounding of which he demonstrated method and direction for future elaboration. In shifting the emphasis from quality to quantity, from pursuit of answers to the question "Why?" to focus upon "What?" and "How?" he effectively prepared the way for the age of technology. He died on March 20, 1727.

Further Readings

- Newton's writings are available in many editions, several of which contain scholarly introductions and notes of great value. Louis T. More, *Isaac Newton* (1934), is the major biography written in this century, but it lacks the benefit of recent scholarship. Two good newer accounts are Herbert D. Anthony, *Sir Isaac Newton* (1960), a

short but comprehensive and interestingly presented biography, and Frank Manuel, *Isaac Newton* (1968), an illuminating psychological study of Newton.

- A convenient biographical introduction in John David North's brief study, *Isaac Newton* (1968), which relates the highlights of Newton's life and work. A psychologically oriented essay on Newton is in Dunkwart A. Rustow, ed., *Philosophers and Kings: Studies in Leadership* (1970). Among the older works, William Stukeley's *Memoirs of Sir Isaac Newton's Life,* for which he collected material during Newton's last years but which was not published until 1936, is an interesting compilation of anecdotes and observations. Sir David Brewster, *Memoirs of the Life, Writings and Discoveries of Sir Isaac Newton* (1855; repr. 1965), is still a useful biographical source.
- Useful evaluations of Newton's work include Edward N. da C. Andrade, *Isaac Newton* (1954), available in paperback; the chapter on Newton in James G. Crowther, *Founders of British Science* (1960); Arthur E. Bell, *Newtonian Science* (1961); and Alexandre Koyré, *Newtonian Studies* (1965).

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