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New Directions in Science and Thought in the Sixteenth and Seventeenth Centuries

The Scientific Revolution

New Departures

THE SIXTEENTH AND SEVENTEENTH CENTURIES witnessed a sweeping change in the scientific view of the universe. An earth-centered picture of the universe gave way to one in which the earth was only another planet orbiting about the sun. The sun itself became one of millions of stars. This transformation of humankind's perception of its place in the larger scheme of things led to a vast rethinking of moral and religious matters as well as of scientific theory. At the same time, the new scientific concepts and the methods of their construction became so impressive that subsequent knowledge in the Western world has been deemed correct only as it has approximated knowledge as defined by science. Perhaps no single intellectual development proved to be more significant for the future of European and Western civilization.

The process by which this new view of the universe and of scientific knowledge came to be established is normally termed the *Scientific Revolution*. However, care must be taken in the use of this metaphor. The word *revolution* normally denotes fairly rapid changes in the political world, involving large numbers of people. The Scientific Revolution was not rapid, nor did it involve more than a few hundred human beings. It was a complex movement with many false starts and many brilliant people with wrong as well as useful ideas. It took place in the studies and the crude laboratories of thinkers in Poland, Italy, Bohemia, France, and Great Britain. It stemmed from two major tendencies. The first, as illustrated by Nicolaus Copernicus, was the imposition of important small changes on existing models of thought. The second, as embodied by Francis Bacon, was the desire to pose new kinds of questions and to use new methods of investigation. In both cases, scientific thought changed the current and traditional opinions in other fields.

Nicolaus Copernicus

Copernicus (1473–1543) was a Polish astronomer who enjoyed a very high reputation throughout his life. He had been educated in Italy and corresponded with other astronomers throughout Europe. However, he had not been known for strikingly original or unorthodox thought. In 1543, the year of his death, Coper-

Copernicus Ascribes Movement to the Earth

Copernicus published *De Revolutionibus Orbium Caelestium (On the Revolutions of the Heavenly Spheres)* in 1543. In his preface, which was addressed to Pope Paul III, he explained what had led him to think that the earth moved around the sun and what he thought were some of the scientific consequences of the new theory. The reader should note how important Copernicus considered the opinions of the ancient writers who had also ascribed motion to the earth. This is a good example of the manner in which familiarity with the ancients gave many Renaissance writers the self-confidence to criticize medieval ideas.

I may well presume, most Holy Father, that certain people, as soon as they hear that in this book about the Revolutions of the Spheres of the Universe I ascribe movement to the earthly globe, will cry out that, holding such views, I should at once be hissed off the stage. . . .

So I should like your Holiness to know that I was induced to think of a method of computing the motions of the spheres by nothing else than the knowledge that the Mathematicians [who had previously considered the problem] are inconsistent in these investigations.

For, first, the mathematicians are so unsure of the movements of the Sun and Moon that they cannot even explain or observe the constant length of the seasonal year. Secondly, in determining the motions of these and of the other five planets, they use neither the same principles and hypotheses nor the same demonstrations of the apparent motions and revolutions. . . . Nor have they been able thereby to discern or deduce the principal thing—namely the shape of the Universe and the unchangeable symmetry of its parts. . . .

I pondered long upon this uncertainty of mathematical tradition in establishing the motions of the system of the spheres. At last I began to chafe that philosophers could by no means agree on any one certain theory of the mechanism of the Universe, wrought for us by a supremely good and orderly Creator. . . . I therefore took pains to read again the works of all the philosophers on whom I could lay hand to seek out whether any of them had ever supposed that the motions of the spheres were other than those demanded by the [Ptolemaic] mathematical schools. I found first in Cicero that Hicetas [of Syracuse, fifth century B.C.] had realized that the Earth moved. Afterwards I found in Plutarch that certain others had held the like opinion. . . .

Thus assuming motions, which in my work I ascribe to the Earth, by long and frequent observations I have at last discovered that, if the motions of the rest of the planets be brought into relation with the circulation of the Earth and be reckoned in proportion to the circles of each planet, not only do their phenomena presently ensue, but the orders and magnitudes of all stars and spheres, nay the heavens themselves, become so bound together that nothing in any part thereof could be moved from its place without producing confusion of all the other parts of the Universe as a whole.

As quoted in Thomas S. Kuhn, *The Copernican Revolution: Planetary Astronomy in the Development of Western Thought* (New York: Vintage Books, 1959), pp. 137–139, 141–142.

nicus published *On the Revolutions of the Heavenly Spheres.* Because he died near the time of publication, the fortunes of his work are not the story of one person's crusade for progressive science. Copernicus's book was "a revolution-making rather than a revolutionary text."[1] What Copernicus did was to provide an intellectual springboard for a complete criticism of the then-dominant view of the position of the earth in the universe.

At the time of Copernicus the standard explanation of the earth and the heavens was that associated with Ptolemy and his work entitled the *Almagest* (A.D. 150). There was not just one Ptolemaic system; rather, several versions had been developed over the centuries by commentators on the original book. Most of these systems assumed that the earth was the

[1]Thomas S. Kuhn, *The Copernican Revolution: Planetary Astronomy in the Development of Western Thought* (New York: Vintage, 1959), p. 135.

center of the universe. Above the earth lay a series of crystalline spheres, one of which contained the moon, another the sun, and still others the planets and the stars. This was the astronomy found in such works as Dante's *Divine Comedy*. At the outer regions of these spheres lay the realm of God and the angels. Aristotelian physics provided the intellectual underpinnings of the Ptolemaic systems. The earth had to be the center because of its heaviness. The stars and the other heavenly bodies had to be enclosed in the crystalline spheres so that they could move. Nothing could move unless something was actually moving it. The state of rest was natural; motion was the condition that required explanation.

Numerous problems were associated with this system, and these had long been recognized. The most important was the observed motions of the planets. Planets could be seen moving in noncircular patterns around the earth. At certain times the planets actually appeared to be going backward. The Ptolemaic systems explained these strange motions primarily through *epicycles*. An epicycle is an orbit upon an orbit, like a spinning jewel on a ring. The planets were said to make a second revolution in an orbit tangent to their primary orbit around the earth. Other intellectual but nonobservational difficulties related to the immense speed at which the spheres had to move around the earth. To say the least, the Ptolemaic systems were cluttered. However, they were effective explanations as long as one assumed Aristotelian physics and the Christian belief that the earth rested at the center of the created universe.

Copernicus's *On the Revolutions of the Heavenly Spheres* challenged this picture in the most conservative manner possible. It suggested that if the earth were assumed to move about the sun in a circle, many of the difficulties with the Ptolemaic systems would disappear or become simpler. Although not wholly eliminated, the number of epicycles would be somewhat fewer. The motive behind this shift away from the earth-centered universe was to find a solu-

Two seventeenth-century armillary spheres, astronomical devices composed of rings that represent the orbits of important celestial bodies. The top one was built on the Copernican model, the bottom sphere reflects the much more complicated Ptolemaic universe. [*Museum of the History of Science, Oxford, England*]

tion to the problems of planetary motion. By allowing the earth to move around the sun, Copernicus was able to construct a more mathematically elegant basis for astronomy. He had been discontented with the traditional system because it was mathematically clumsy and inconsistent. The primary appeal of his new system was its mathematical aesthetics: with the sun at the center of the universe, mathematical astronomy would make more sense. A change in the conception of the position of the earth meant that the planets were actually moving in circular orbits and only seemed to be doing otherwise because of the position of the observers on earth.

Except for the modification in the position of the earth, most of the other parts of Copernicus's book were Ptolemaic. The path of the planets remained circular. Genuine epicycles still existed in the heavens. His system was no more accurate than the existing ones for predicting the location of the planets. He had used no new evidence. The major impact of his work was to provide another way of confronting some of the difficulties inherent in Ptolemaic astronomy. This work did not immediately replace the old astronomy, but it did allow other people who were also discontented with the Ptolemaic systems to think in new directions.

Copernicus's concern about mathematics provided an example of the single most important factor in the developing new science. The key to the future development of the Copernican revolution lay in the fusion of mathematical astronomy with further empirical data and observation, and mathematics became the model to which the new scientific thought would conform. The new empirical evidence helped to persuade the learned public.

Tycho Brahe and Johannes Kepler

The next major step toward the conception of a sun-centered system was taken by Tycho Brahe (1546–1601). He actually spent most of his life opposing Copernicus and advocating a different kind of earth-centered system. He suggested that the moon and the sun revolved around the earth and that the other planets revolved around the sun. However, in attacking Copernicus, he gave the latter's ideas more publicity. More important, this Danish astronomer's major weapon against Copernican astronomy was a series of new naked-eye astronomical observations. Brahe constructed the most accurate tables of observations that had been drawn up for centuries.

When Brahe died, these tables came into the possession of Johannes Kepler (1571–1630), a German astronomer. Kepler was a convinced Copernican, but his reasons for taking that position were not scientific. Kepler was deeply influenced by Renaissance Neoplatonism and its honoring of the sun. These Neoplatonists were also determined to discover mathematical harmonies in those numbers that would support a sun-centered universe. After much work Kepler discovered that to keep the sun at the center of things, he must abandon the Copernican concept of circular orbits. The mathematical relationships that emerged from a consideration of Brahe's observations suggested that the orbits of the planets were elliptical. Kepler published his findings in 1609 in a book entitled *On the Motion of Mars*. He had solved the problem of planetary orbits by using Copernicus's sun-centered universe and Brahe's empirical data.

Kepler had, however, also defined a new problem. None of the available theories could explain why the planetary orbits were elliptical. That solution awaited the work of Sir Isaac Newton.

Galileo Galilei

From Copernicus to Brahe to Kepler there had been little new information about the heavens that might not have been known to Ptolemy. However, in the same year that Kepler published his volume on Mars, an Italian scientist named Galileo Galilei (1564–1642) first turned a telescope on the heavens. Through that recently invented instrument he saw stars where none had been known to exist, mountains on the moon, spots moving across the sun, and moons orbiting Jupiter. The heavens were far more complex than anyone had formerly suspected. None of these discoveries proved that the earth orbited the sun, but they did suggest the complete inadequacy of the Ptolemaic system. It simply could not accommodate itself to all of these new phenomena. Some of Galileo's colleagues at the university of Padua were so unnerved that they refused to look through the telescope. Galileo publicized his findings and arguments for the Copernican system in numerous works, the most famous of which was his *Dialogues on the Two Chief Systems of the World* (1632). This book brought down on him the condemnation of the

Galileo Discusses the Relationship of Science and the Bible

The religious authorities were often critical of the discoveries and theories of sixteenth- and seventeenth-century science. For many years religious and scientific writers debated the implications of the Copernican theory in the reading of the Bible. For years before his condemnation by the Roman Catholic church in 1633, Galileo had contended that scientific theory and religious piety were compatible. In his *Letter to the Grand Duchess Christiana* (of Tuscany) written in 1615, Galileo argued that God had revealed truth in both the Bible and physical nature and that the truth of physical nature did not contradict the Bible if the latter were properly understood.

The reason produced for condemning the opinion that the earth moves and the sun stands still is that in many places in the Bible one may read that the sun moves and the earth stands still.

. . .

With regard to this argument, I think in the first place that it is very pious to say and prudent to affirm that the holy Bible can never speak untruth—whenever its true meaning is understood. But I believe nobody will deny that it is often very abstruse, and may say things which are quite different from what its bare words signify. . . .

This being granted, I think that in discussions of physical problems we ought to begin not from the authority of scriptural passages, but from sense-experiences and necessary demonstrations; for the holy Bible and the phenomena of nature proceed alike from the divine Word, the former as the dictate of the Holy Ghost and the latter as the observant executrix of God's commands. It is necessary for the Bible, in order to be accommodated to the understanding of every man, to speak many things which appear to differ from the absolute truth so far as the bare meaning of the words is concerned. But Nature, on the other hand, is inexorable and immutable; she never transgresses the laws imposed upon her, or cares a whit whether her abstruse reasons and methods of operation are understandable to men. For that reason it appears that nothing physical which sense-experience sets before our eyes, or which necessary demonstrations prove to us, ought to be called in question (much less condemned) upon the testimony of biblical passages which may have some different meaning beneath their words. For the Bible is not chained in every expression to conditions as strict as those which govern all physical effects; nor is God any less excellently revealed in Nature's actions than in the sacred statements of the Bible. . . .

From this I do not mean to infer that we need not have an extraordinary esteem for the passages of holy Scripture. On the contrary, having arrived at any certainties in physics, we ought to utilize these as the most appropriate aids in the true exposition of the Bible and in the investigation of those meanings which are necessarily contained therein for these must be concordant with demonstrated truths. I should judge the authority of the Bible was designed to persuade men of those articles and propositions which, surpassing all human reasoning, could not be made credible by science, or by any other means than through the very mouth of the Holy Spirit.

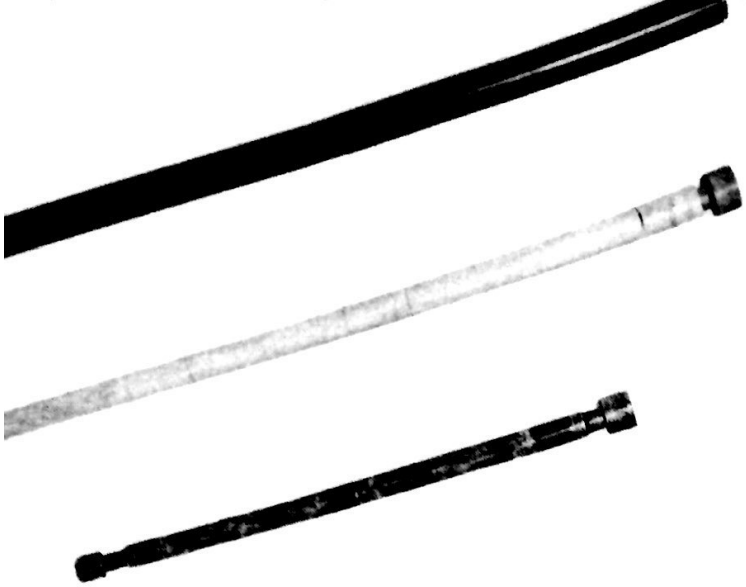
. . .

But I do not feel obliged to believe that the same God who has endowed us with senses, reason, and intellect has intended to forgo their use and by some other means to give us knowledge which we can attain by them.

Discoveries and Opinions of Galileo, trans. and ed. by Stillman Drake (Garden City, N.Y.: Doubleday Anchor Books, 1957), pp. 181–183.

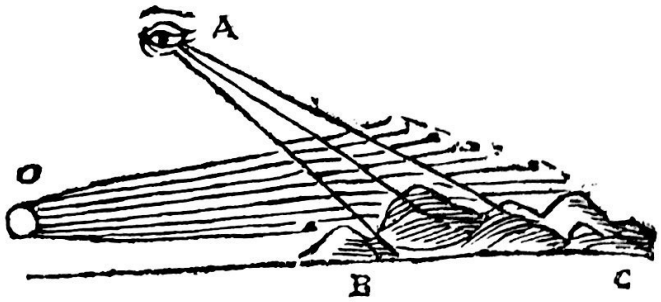
Roman Catholic church. He was compelled to recant his opinions. However, he is reputed to have muttered after the recantation, "*E pur si muove*" ("It [the earth] still moves").

Galileo's discoveries and his popularization of the Copernican system were of secondary importance in his life work. His most important achievement was to articulate the concept of a universe totally subject to mathematical laws. More than any other writer of the cen-



LEFT-*Telescopes built by Galileo. His astronomical observations had revolutionary intellectual and theological implications.* [*Science Museum, London*]

BELOW-*Galileo's drawing of his method for measuring the heights of lunar mountains* (1611). [*Ann Ronan Picture Library and E.P. Goldschmidt and Co., Ltd.*]



tury he argued that nature in its most minute details displayed mathematical regularity. He once wrote:

> Philosophy is written in that great book which ever lies before our eyes—I mean the universe—but we cannot understand it if we do not first learn the language and grasp the symbols in which it is written. This book is written in the mathematical language, and the symbols are triangles, circles, and other geometrical figures, without whose help it is impossible to comprehend a single word of it; without which one wanders through a dark labyrinth.[2]

The universe was rational; however, its rationality was not that of Scholastic logic but of mathematics. Copernicus had thought that the heavens conformed to mathematical regularity; Galileo saw this regularity throughout all physical nature. He believed that the smallest atom behaved with the same mathematical precision as the largest heavenly sphere.

Galileo's thought meant that a world of quantity was replacing one of qualities. Mathematical quantities and relationships would henceforth increasingly be used to describe nature. Color, beauty, taste, and the like would be reduced to numerical relationships. And eventually social relationships would be envisioned in a mathematical model. Nature was cold, rational, mathematical, and mechanistic. What was real and lasting in the world was what was mathematically measurable. Few intellectual shifts have wrought such momentous changes for Western civilization.

[2]Quoted in E. A. Burtt, *The Metaphysical Foundations of Modern Physical Science* (Garden City, N.Y.: Anchor-Doubleday, 1954), p. 75.

René Descartes

No writer of the seventeenth century more fully adopted the geometric spirit of contemporary mathematics than René Descartes (1596–1650). He was a gifted mathematician who invented analytic geometry, and he was the author of major works on numerous scientific topics. However, his most important contribution was to scientific method. He wanted to proceed by deduction rather than by empirical observation and induction.

In 1637 Descartes published a *Discourse on Method* in which he attempted to provide a basis for all thinking founded on a mathematical model. He published the work in French rather than in Latin because he wanted it to have wide circulation and application. He began by saying that he would doubt everything except those propositions about which he could have clear and distinct ideas. This approach rejected all forms of intellectual authority except the conviction of his own reason. He concluded that he could not doubt his own act of thinking and his own existence. From this base he proceeded to deduce the existence of God. The presence of God was important to Descartes because God was the guarantor of the correctness of clear and distinct ideas. Because God was not a deceiver, the ideas of God-given reason could not be false.

Descartes believed that this powerful human reason could fully comprehend the world. He divided existing things into mind and body. Thinking was the characteristic of the mind, extension of the body. Within the material

René Descartes (1596–1650). *Descartes believed that because the material world operated according to mathematical laws it could therefore be understood by the exercise of human reasoning.* [*Giraudon*]

world, mathematical laws reigned supreme. These could be grasped by the human reason. Because the laws were mathematical, they could be deduced from each other and constituted a complete system. The world of extension was the world of the scientist, whereas the mind was related to theology and philosophy. In the material world there was no room for spirits, divinity, or anything nonmaterial. Descartes had separated mind from body in order to banish the former from the realm of scientific speculation. He wanted to resurrect the speculative use of reason, but in a limited manner. It was to be applied only to the mechanical and mathematical realm of matter.

Descartes's emphasis on deduction and rational speculation exercised broad influence. Well into the eighteenth century European thinkers appealed to Descartes's method, which moved from broad intellectual generalizations to specific phenomena. The method then attempted to see how the phenomena could be interpreted so as to mesh with the generalization. However, that method was eventually overcome by the force of scientific induction, whereby the observer or scientist began with observations of empirical data and then attempted to draw generalizations from those observations. The major champion of the inductive method during the early seventeenth century had been Francis Bacon.

Francis Bacon

Bacon (1561–1626) was an Englishman of almost universal accomplishment. He was a lawyer, a high royal official, and the author of histories, moral essays, and philosophical discourses. Traditionally he has been regarded as the father of empiricism and of experimentation in science. Much of this reputation is unearned. Bacon was not a scientist except in the most amateur fashion. His accomplishment was setting a tone and helping to create a climate in which other scientists worked. In books such as *The Advancement of Learning* (1605), the *Novum Organum* (1620), and the *New Atlantis* (1627), Bacon attacked the Scholastic belief that most truth had already been discovered and only required explanation, as well as the Scholastic reverence for intellectual authority in general. He believed that Scholastic thinkers paid too much attention to tradition and to knowledge achieved by the ancients. He urged contemporaries to strike out on their own in search of a new understanding of nature. He wanted seventeenth-century

Sir Francis Bacon, Viscount St. Albans (1561–1626). *By teaching that knowledge should proceed inductively, Bacon became a major champion of the scientific method.* [*National Portrait Gallery, London*]

Europeans to have confidence in themselves and their own abilities rather than in the people and methods of the past. Bacon was one of the first major European writers to champion the desirability of innovation and change.

Bacon believed that human knowledge should produce useful results. In particular, knowledge of nature should be brought to the aid of the human condition. Those goals required the modification or abandonment of Scholastic modes of learning and thinking. Bacon contended, "The [Scholastic] logic now in use serves more to fix and give stability to the errors which have their foundation in commonly received notions than to help the search after truth."[3] Scholastic philosophers could not escape from their syllogisms to examine the foundations of their thought and intellectual presuppositions. Bacon urged that philoso-

[3]Quoted in Franklin Baumer, *Main Currents of Western Thought*, 4th ed. (New Haven, Conn.: Yale, 1978), p. 281.

Bacon Attacks the Idols that Harm Human Understanding

Francis Bacon wanted the men and women of his era to have the courage to change the way in which they thought about physical nature. In this famous passage from the *Novum Organum* (1620) Bacon attempted to explain why people had such difficulty in asking new questions and seeking new answers. His observations may still be relevant to the manner in which people form and hold their opinions in our own day.

The idols and false notions which are now in possession of the human understanding, and have taken deep root therein, not only so beset men's minds that truth can hardly find entrance, but even after entrance is obtained, they will again in the very instauration of the sciences meet and trouble us, unless men being forewarned of the danger fortify themselves as far as may be against their assaults.

There are four classes of Idols which beset men's minds. To these for distinction's sake I have assigned names,—calling the first class Idols of the Tribe; *the second,* Idols of the Cave; *the third,* Idols of the Marketplace; *the fourth,* Idols of the Theatre.

. . . . . .

The Idols of the Tribe have their foundation in human nature itself; and in the tribe or race of men. For it is a false assertion that the sense of man is the measure of things. On the contrary, all perceptions as well as the sense as of the mind are according to the measure of the individual and not according to the measure of the universe. And the human understanding is like a false mirror, which, receiving rays irregularly, distorts and discolours the nature of things by mingling its own nature with it.

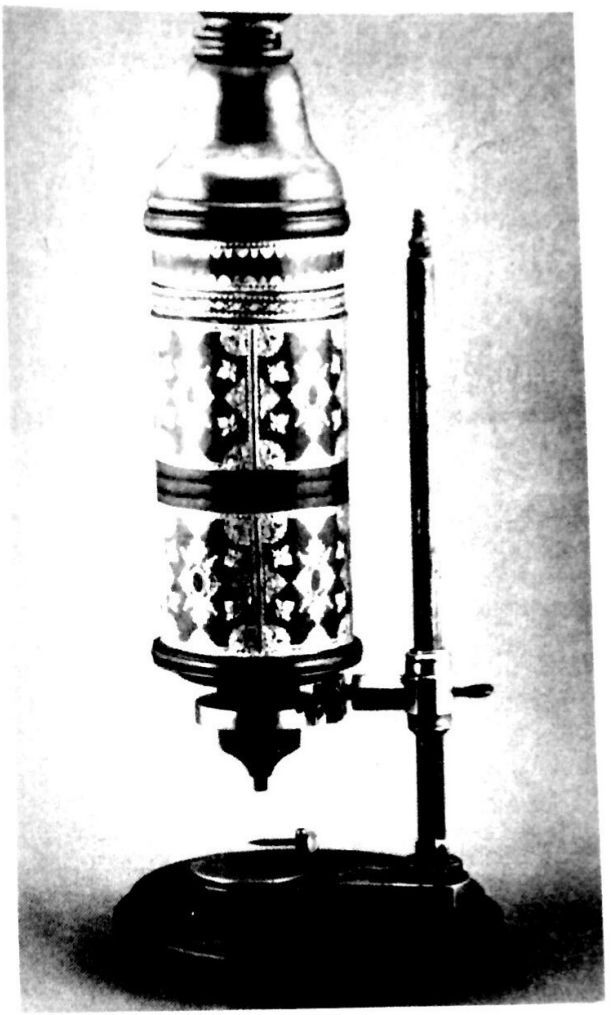
The Idols of the Cave are the idols of the individual man. For every one (besides the errors common to human nature in general) has a cave or den of his own, which refracts and discolours the light of nature; owing either to his own proper and peculiar nature; or to his education and conversation with others; or to the reading of books, and the authority of those whom he esteems and admires. . . .

There are also Idols formed by the intercourse and association of men with each other, which I call Idols of the Marketplace, on account of the commerce and consort of men there. For it is by discourse that men associate; and words are imposed according to the apprehension of the vulgar. And therefore the ill and unfit choice of words wonderfully obstructs the understanding.

. . .

Lastly, there are Idols which have immigrated into men's minds from the various dogmas of philosophies, and also from wrong laws of demonstration. These I call Idols of the Theatre; because in my judgment all the received systems are but so many stage plays, representing worlds of their own creation after an unreal and scenic fashion.

Francis Bacon, *Essays, Advancement of Learning, New Atlantis, and Other Pieces*, ed. by Richard Foster Jones (New York: Odyssey, 1937), pp. 278–280.



The microscope was the telescope's companion as a major optical invention of the seventeenth century. Several people, including Galileo, had a hand in its development, but the greatest progress was made by the Dutchman Anton von Leeuwenhoek (1632–1723) and the Englishman Robert Hooke (1635–1703). Hooke designed this microscope in 1670. [IBM Gallery of Science and Art]

BELOW-*Another optical aid: spectacles. Spectacles date from at least the fourteenth century and were becoming common during the later 1500s. Here we see a spectacle pedlar selling his wares. Spectacles were selected by trial and error, not made to prescription. [The Mansell Collection]*

phers and investigators of nature examine the evidence of their senses before constructing logical speculations. In a famous passage he divided all philosophers into "men of experiment and men of dogmas." He observed:

> The men of experiment are like the ant, they only collect and use; the reasoners resemble spiders, who make cobwebs out of their own substance. But the bee takes a middle course: it gathers its material from the flowers of the garden and of the field, but transforms and digests it by a power of its own. Not unlike this is the true business of philosophy.[4]

By directing scientists toward an examination of empirical evidence, Bacon hoped that they would achieve new knowledge and thus new capabilities for humankind.

Bacon compared himself with Columbus plotting a new route to intellectual discovery. The comparison is significant, because it displays the consciousness of a changing world that appears so often in writers of the late sixteenth and early seventeenth centuries. They were rejecting the past not from simple hatred but rather from a firm understanding that the world was much more complicated than their medieval forebears had thought.

Neither Europe nor European thought could remain self-contained. There were not only new worlds on the globe but also new worlds of the mind. Most of the people in Bacon's day, including the intellectuals, thought that the best era of human history lay in antiquity. Bacon dissented vigorously from that point of view. He looked to a future of material improvement achieved through the empirical examination of nature. His own theory of induction from empirical evidence was quite

[4]Quoted in ibid., p. 288.

Major Works of the Scientific Revolution

On the Revolutions of the Heavenly Spheres (Copernicus)	1543
The Advancement of Learning (Bacon)	1605
On the Motion of Mars (Kepler)	1609
Novum Organum (Bacon)	1620
Dialogues on the Two Chief Systems of the World (Galileo)	1632
Discourse on Method (Descartes)	1637
Principia Mathematica (Newton)	1687

Sir Isaac Newton, discoverer of the mathematical and physical laws governing the force of gravity. Newton believed that religion and science were compatible and mutually supportive. To study nature was to gain a better understanding of the Creator. [*New York Public Library Picture Collection*]

unsystematic, but his insistence on appeal to experience influenced others whose methods were more productive. His great achievement was persuading increasing numbers of thinkers that scientific thought must conform to empirical experience.

Bacon gave science a progressionist bias. Science was to have a practical purpose and the goal of human improvement. Some scientific investigation does possess this character. Much pure research does not. However, Bacon linked in the public mind the concepts of science and material progress. This was a powerful idea and has continued to influence Western civilization to the present day. It has made science and those who can appeal to the authority of science major forces for change and innovation. Thus, though not making any major scientific contribution himself, Bacon directed investigators of nature to a new method and a new purpose.

Isaac Newton

Isaac Newton (1642–1727) drew on the work of his predecessors and his own brilliance to solve the major remaining problem of planetary motion and to establish a basis for physics that endured more than two centuries. The question that continued to perplex seventeenth-century scientists who accepted the theories of Copernicus, Kepler, and Galileo was how the planets and other heavenly bodies moved in an orderly fashion. The Ptolemaic and Aristotelian answer had been the crystalline spheres and a universe arranged in the order of the heaviness of its parts. Numerous unsatisfactory theories had been set forth to deal with the question.

In 1687 Newton published *The Mathematical Principles of Natural Philosophy*, better known by its Latin title of *Principia Mathematica*. Much of the research and thinking for this great work had taken place more than fifteen years earlier. Newton was heavily indebted to the work of Galileo and particularly to the latter's view that inertia could exist in either a state of motion or a state of rest. Galileo's mathematical bias permeated Newton's thought. Newton reasoned that the planets and all other physical objects in the universe moved through mutual attraction. Every object in the universe affected every other object through gravity. The attraction of gravity explained why the planets moved in an orderly rather than a chaotic manner. He had found that "the force of gravity towards the whole planet did arise from and was compounded of the forces of gravity towards all its parts, and towards every one part was in the inverse proportion of the squares of the distances from the part."[5] Newton demonstrated this relationship mathematically. He made no attempt to explain the nature of gravity itself.

[5]Quoted in A. Rupert Hall, *From Galileo to Newton, 1630–1720* (London: Fontana, 1970), p. 300.

Newton was a great mathematical genius, but he also upheld the importance of empirical data and observation. He believed, in good Baconian fashion, that one must observe phenomena before attempting to explain them. The final test of any theory or hypothesis for him was whether it described what could actually be observed. He was a great opponent of Descartes's rationalism, which he believed included insufficient guards against error. As Newton's own theory of universal gravitation became increasingly accepted, the Baconian bias also became more fully popularized.

With the work of Newton the natural universe became a realm of law and regularity.

Newton Sets Forth Rules of Reasoning in Philosophy

Philosophy was the term that seventeenth-century writers used to describe the new science. In this passage from his *Principia Mathematica* (1687) Isaac Newton laid down what he regarded as the fundamental rules for scientific reasoning. The reader should notice the importance he placed on experimental evidence and his desire to find rules or regularities that exist throughout the natural order.

Rule I. We are to admit no more causes of natural things than such as are both true and sufficient to explain their appearances.

To this purpose the philosophers say that Nature does nothing in vain, and more is in vain when less will serve; for Nature is pleased with simplicity, and affects not the pomp of superfluous causes.

Rule II. Therefore to the same natural effects we must, as far as possible, assign the same causes.

As to respiration in a man and in a beast; the descent of stones in Europe and in America; the light of our culinary fire and of the sun; the reflection of light in the earth, and in the planets.

Rule III. The qualities of bodies, which admit neither intension nor remission of degrees, and which are found to belong to all bodies within the reach of our experiments, are to be esteemed the universal qualities of all bodies whatsoever.

For since the qualities of bodies are only known to us by experiments, we are to hold for universal all such as universally agree with experiments and such as are not liable to diminution can never be quite taken away. We are certainly not to relinquish the evidence of experiments for the sake of dreams and vain fictions of our own devising. . . . We no other way know the extension of bodies than by our senses, nor do these reach it in all bodies; but because we perceive extension in all that are sensible, therefore we ascribe it universally to all others also. That abundance of bodies are hard, we learn by experience; and because the hardness of the whole arises from the hardness of the parts, we therefore justly infer the hardness of the undivided particles not only of the bodies we feel but of all others. That bodies are impenetrable, we gather not from reason, but from sensation. . . .

Lastly, if it universally appears, by experiments and astronomical observations, that all bodies about the earth gravitate towards the earth, and that in proportion to the quantity of matter which they severally contain; . . . we must, in consequence of this rule, universally allow that all bodies whatsoever are endowed with a principle of universal gravitation. . . .

Rule IV. In experimental philosophy we are to look upon propositions collected by general induction from phaenomena as accurately or very nearly true, notwithstanding any contrary hypotheses that may be imagined, till such time as other phaenomena occur, by which they may either be made more accurate, or liable to exceptions.

This rule must follow, that the argument of induction may not be evaded by hypotheses.

Introduction to Contemporary Civilization in the West, 3rd ed., Vol. 1 (New York: Columbia University Press, 1960), pp. 850–852.

Spirits and divinities were no longer necessary to explain its operation. Thus the Scientific Revolution liberated human beings from the fear of a chaotic or haphazard universe. Most of the scientists were very devout people. They saw the new picture of physical nature as suggesting a new picture of God. The Creator of this rational, lawful nature must also be rational. To study nature was to come to a better understanding of that Creator. Science and religious faith were not only compatible but mutually supporting. As Newton wrote, "The main Business of Natural Philosophy is to argue from Phaenomena without feigning Hypothesis, and to deduce Causes from Effects, till we come to the very first Cause, which certainly is not mechanical."[6]

This reconciliation of faith and science allowed the new physics and astronomy to spread rapidly. At the very time when Europeans were finally tiring of the wars of religion, the new science provided the basis for a view of God that might lead away from irrational disputes and wars over religious doctrine. Faith in a rational God encouraged faith in the rationality of human beings and in their capacity to improve their lot once liberated from the traditions of the past. The Scientific Revolution provided the great model for the desirability of change and of criticism of inherited views. Yet at the same time the new science caused some people to feel that the mystery had been driven from the universe and that the rational Creator was less loving and less near to humankind than the God of earlier ages.

Writers and Philosophers

The end of the sixteenth century saw weariness with religious strife and incipient unbelief as many no longer embraced either old Catholic or new Protestant absolutes. Intellectually as well as politically the seventeenth century was a period of transition, one already well prepared for by the thinkers of the Renaissance, who had reacted strongly against medieval intellectual traditions, especially those informed by Aristotle and Scholasticism.

Even as they sought to find a purer culture before the Middle Ages in pagan and Christian antiquity, however, Humanists and Protestants continued to share much of the medieval vision of a unified Christendom. Few wanted to embrace the secular values and preoccupations of the growing scientific movement, which found its models in mathematics and the natural sciences, rather than in the example and authority of antiquity. Some strongly condemned the work of Copernicus, Kepler, and Galileo, whose theories seemed to fly in the face of commonsense experience as well as to question hallowed tradition.

The thinkers of the Renaissance and the Reformation nonetheless paved the way for the new science and philosophy, both by their attacks on tradition and by their own failure to implement radical reforms. The Humanist revival of ancient skepticism proved an effective foundation for attacks on traditional views of authority and rationality in both religion and science. Already such thinkers as the Italian Pico della Mirandola (1463–1494), the German Cornelius Agrippa of Nettisheim (1486–1535), and the Frenchman François Rabelais (1494–1553) had questioned the ability of reason to obtain certitude. Sebastian Castellio (1515–1563), Michel de Montaigne (1533–1592), and Pierre Charron (1541–1603) had been as much repelled by the new Calvinist religion as John Calvin had been by medieval religion. It was in the wake of such criticism that René Descartes developed a more modest, yet surer, definition of rationality as the tool of the new scientific philosophy.

The writers and philosophers of the seventeenth century were aware that they lived in a period of transition. Some embraced the new science wholeheartedly (Hobbes and Locke), some tried to straddle the two ages (Cervantes, Shakespeare, and Milton), and still others ignored or opposed the new developments that seemed mortally to threaten traditional values (Pascal and Bunyan). As a group these thinkers helped to make the transition from medieval to modern times by clarifying the intellectual issues involved. In literature, religious thought, and political theory, they established the national landmarks and struck the new directions in Western thought.

Miguel de Cervantes Saavedra (1547–1616)

Spanish literature of the sixteenth and seventeenth centuries reflects the peculiar religious and political history of Spain in this period. Spain was dominated by the Catholic church. Since the joint reign of Ferdinand and Isabella (1479–1504) the church had received

[6]Quoted in Baumer, p. 323.

the unqualified support of reigning political power. Although there was religious reform in Spain, a Protestant Reformation never occurred, thanks largely to the entrenched power of the church and the Inquisition.

The second influence was the aggressive piety of Spanish rulers. The intertwining of Catholic piety and Spanish political power underlay the third major influence on Spanish literature: preoccupation with medieval chivalric virtues—in particular, questions of honor and loyalty. The novels and plays of the period almost invariably focus on a special decision involving a character's reputation as his honor or loyalty is tested. In this regard Spanish literature may be said to have remained more Catholic and medieval than that of England and France, where major Protestant movements had occurred. Two of the most important Spanish writers in this period became priests (Lope de Vega and Pedro Calderón de la Barca), and the one generally acknowledged to be the greatest Spanish writer of all time, Cervantes, was preoccupied in his work with the strengths and weaknesses of religious idealism.

Cervantes was born in Alcalá, the son of a nomadic physician. Having received only a smattering of formal education, he educated himself by insatiable reading in vernacular literature and immersion in the "school of life." As a young man he worked in Rome for a Spanish cardinal. In 1570 he became a soldier and was decorated for gallantry in the Battle of Lepanto (1571). While he was returning to Spain in 1575, his ship was captured by pirates, and Cervantes spent five years as a slave in Algiers. On his release and return to Spain, he held many odd jobs, among them that of a tax collector. He was several times imprisoned for padding his accounts. He began to write his most famous work, *Don Quixote*, in 1603, while languishing in prison.

The first part of *Don Quixote* appeared in 1605. If, as many argue, the intent of this work was to satirize the chivalric romances so popular in Spain, Cervantes nonetheless failed to conceal his deep affection for the character he created as an object of ridicule, Don Quixote. The work is satire only on the surface and has remained as much an object of study by philosophers and theologians as by students of Spanish literature. Don Quixote, a none-too-stable middle-aged man, was presented by Cervantes as one driven mad by reading too many chivalric romances. He finally comes to believe that he is an aspirant to knighthood and must prove by brave deeds his worthiness of knightly rank. To this end he acquires a rusty suit of armor, mounts an aged steed (named Rozinante), and chooses for his inspiration a quite unworthy peasant girl, Dulcinea, whom he fancies to be a noble lady to whom he can, with honor, dedicate his life.

The author of Don Quixote, *Miguel de Cervantes Saavedra* (1547–1616), *generally acknowledged to be the greatest Spanish writer.* [*Library of Congress*]

Don Quixote's foil in the story—Sancho Panza, a clever, worldly-wise peasant who serves as his squire—is an equally fascinating character. Sancho Panza watches with bemused skepticism, but also with genuine sympathy, as his lord does battle with a windmill (which he mistakes for a dragon) and repeatedly makes a fool of himself as he gallops across the countryside. The story ends tragi-

cally with Don Quixote's humiliating defeat by a well-meaning friend, who, disguised as a knight, bests Don Quixote in combat and forces him to renounce his quest for knighthood. The humiliated Don Quixote does not, however, come to his senses as a result. He returns sadly to his village to die a shamed and broken-hearted old man.

Throughout *Don Quixote* Cervantes juxtaposed the down-to-earth realism of Sancho Panza with the old-fashioned religious idealism of Don Quixote. The reader perceives that Cervantes admired the one as much as the other and meant to portray both as representing attitudes necessary for a happy life. If they are to be truly happy, men and women need dreams, even impossible ones, just as much as they need a sense of reality.

Don Quixote as imagined by the nineteenth-century French artist Honoré Daumier (1808–1879). *Cervantes' novel has delighted readers for four centuries.* [*Giraudon*]

William Shakespeare (1564–1616)

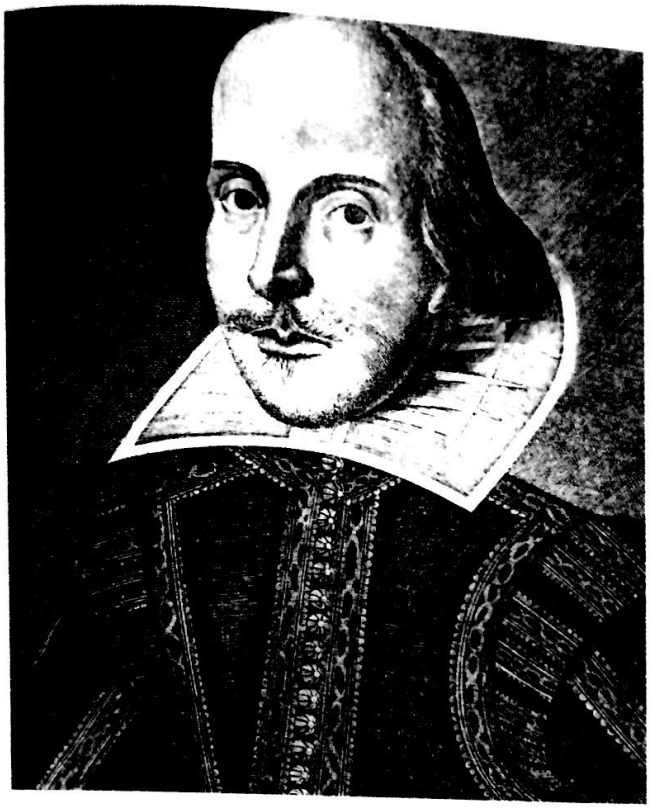
Shakespeare, the greatest playwright in the English language, was born in Stratford-on-Avon, where he lived almost all of his life except for the years when he wrote in London. There is much less factual knowledge about him than one would expect of such an important figure. Shakespeare married in 1582 at the early age of eighteen, and he and his wife, Anne Hathaway, had three children (two were twins) by 1585. He apparently worked as a schoolteacher for a time and in this capacity acquired his broad knowledge of Renaissance learning and literature. The argument of some scholars that he was an untutored natural genius is highly questionable. His own learning and his enthusiasm for the education of his day are manifest in the many learned allusions that appear in his plays.

Shakespeare enjoyed the life of a country gentleman. There is none of the Puritan distress over worldliness in his work. He took the new commercialism and the bawdy pleasures of the Elizabethan Age in stride and with amusement. The few allusions to the Puritans that exist in his works appear to be more critical than complimentary. In matters of politics, as in those of religion, he was very much a man of his time and not inclined to offend his queen.

That Shakespeare was interested in politics is apparent from his history plays and the references to contemporary political events that fill all his plays. He seems to have viewed government simply, however, through the character of the individual ruler, whether Richard III or Elizabeth Tudor, not in terms of ideal systems or social goals. By modern standards he was a political conservative, accepting the social rankings and the power structure of his day and demonstrating unquestioned patriotism.

Shakespeare knew the theater as one who participated in every phase of its life—as a playwright, an actor, and a part owner of a theater. He was a member and principal dramatist of a famous company of actors known as the King's Men. During the tenure of Edmund Tilney, who was Queen Elizabeth's Master of Revels during the greater part of Shakespeare's active period (1590–1610), many of Shakespeare's plays were performed at court. The queen enthusiastically patronized plays and pageants.

Elizabethan drama was already a distinctive form when Shakespeare began writing. Unlike



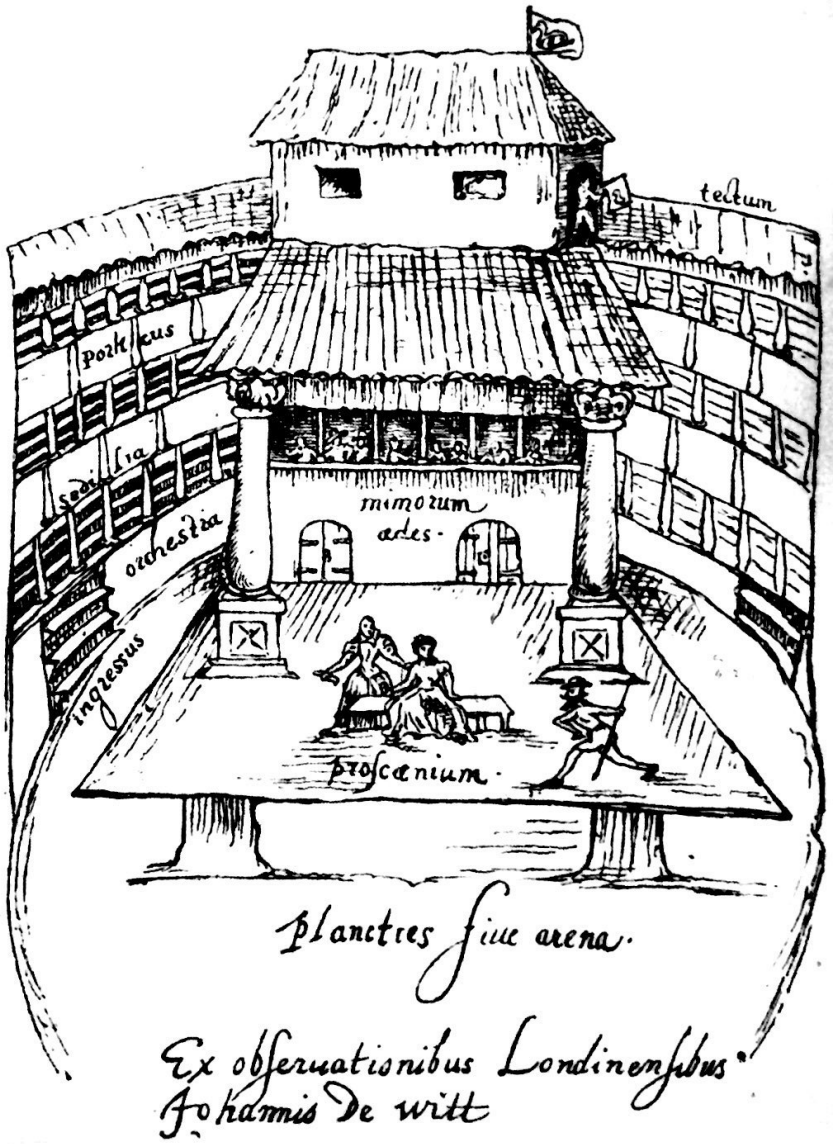
The English dramatist and poet, William Shakespeare. This engraving by Martin Droeshout appears on the title page of the collected edition of his plays published in 1623 *and is probably as close as we shall come to knowing what he looked like.* [*New York Public Library*]

French drama of the seventeenth century, which was dominated by the court and classical models, English drama developed in the sixteenth and seventeenth centuries as a blending of many extant forms, ranging from classical comedies and tragedies to the medieval morality play and contemporary Italian short stories. In Shakespeare's own library one could find Holinshed's and other English chronicles; the works of Plutarch, Ovid, and Vergil, among other Latin authors; Arthurian romances and popular songs and fables; the writings of Montaigne and Rabelais; and the major English poets and prose writers.

Two contemporaries, Thomas Kyd and Christopher Marlowe, especially influenced Shakespeare's tragedies. Kyd (1558–1594) was the author of the first dramatic version of *Hamlet* and a master at weaving together motive and plot. The tragedies of Marlowe (1564–1593) set a model for character, poetry, and style that only Shakespeare among the English playwrights of the period surpassed. Shakespeare's work was an original synthesis of the best past and current achievements. He mastered the psychology of human motivation and passion and had a unique talent for psychological penetration.

Shakespeare wrote histories, comedies, and tragedies. *Richard III* (1593), a very early play, stands out among the examples of the first genre, although some historians have criticized as historically inaccurate his patriotic depiction of Richard, the foe of Henry Tudor, as an unprincipled villain. Shakespeare's comedies, although not attaining the heights of his tragedies, surpass in originality his history plays. Save for *The Tempest* (1611), his last play, the

This 1596 *sketch of the interior of the Swan Theater in London by Johannis de Witt, a Dutch visitor, is the only known contemporary view of an Elizabethan playhouse. In this kind of setting the plays of Marlowe, Shakespeare, Jonson, and their fellows were first seen.* [*University Library, Utrecht*]



comedies most familiar to modern readers were written between 1598 and 1602: *Much Ado About Nothing* (1598–1599), *As You Like It* (1598–1600), and *Twelfth Night* (1602).

The tragedies are considered his unique achievement. Four of these were written within a three-year period: *Hamlet* (1603), *Othello* (1604), *King Lear* (1605), and *Macbeth* (1606). The most original of the tragedies, *Romeo and Juliet* (1597), transformed an old popular story into a moving drama of "star-cross'd lovers." Both Romeo and Juliet, denied a marriage by their factious families, die tragic deaths. Romeo, finding Juliet and thinking her dead after she has taken a sleeping potion, poisons himself. Juliet, awakening to find Romeo dead, stabs herself to death with his dagger.

Throughout his lifetime and ever since, Shakespeare has been immensely popular with both the playgoer and the play reader. As Ben Jonson, a contemporary classical dramatist who created his own school of poets, aptly put it in a tribute affixed to the First Folio edition of Shakespeare's plays (1623): "He was not of an age, but for all time."

The English writer and poet John Milton in an engraving by William Faithorne—one of the few authentic contemporary likenesses of him. [*Library of Congress*]

John Milton (1608–1674)

John Milton was the son of a devout Puritan father. Educated at Saint Paul's School and then at Christ's College of Cambridge University, he became a careful student of Christian and pagan classics. In 1638 he traveled to Italy, where he found in the lingering Renaissance a very congenial intellectual atmosphere. The Phlegraean Fields near Naples, a volcanic region, later became the model for hell in *Paradise Lost,* and it is suspected by some scholars that the Villa d'Este provided the model for paradise in *Paradise Regained.* Milton remained throughout his life a man more at home in the Italian Renaissance, with its high ideals and universal vision, than in the strife-torn England of the seventeenth century.

A man of deep inner conviction and principle, Milton believed that standing a test of character was the most important thing in an individual's life. This belief informed his own personal life and is the subject of much of his literary work. An early poem, *Lycidas,* was a pastoral elegy dealing with one who lived well but not long, Edward King, a close college friend who tragically drowned. In 1639 Milton joined the Puritan struggle against Charles I and Archbishop Laud. Employing his literary talents as a pamphleteer, he defended the presbyterian form of church government against the episcopacy and supported other Puritan reforms. After a month-long unsuccessful marriage in 1642 (a marriage later reconciled), he wrote several tracts in defense of the right to divorce. These writings became a factor in Parliament's passage of a censorship law in 1643, against which Milton wrote an eloquent defense of the freedom of the press, *Areopagitica* (1644).

Until the upheavals of the civil war moderated his views, Milton believed that government should have the least possible control over the private lives of individuals. When Parliament divided into Presbyterians and Independents, he took the side of the latter, who wanted to dissolve the national church altogether in favor of the local autonomy of individual congregations. He also defended the execution of Charles I in a tract on the *Tenure of Kings and Magistrates.* After his intense labor on this tract his eyesight failed. Milton was totally blind when he wrote his acclaimed masterpieces.

Paradise Lost, completed in 1665 and published in 1667, is a study of the destructive qualities of pride and the redeeming possibilities of humility. It elaborates in traditional Christian language and concept the revolt of

Satan in heaven and the fall of Adam on earth. The motives of Satan and all who rebel against God intrigued Milton. His proud but tragic Satan, one of the great figures of all literature, represents the absolute corruption of potential greatness.

In *Paradise Lost* Milton aspired to give England a lasting epic like that given Greece in Homer's *Iliad* and ancient Rome in Vergil's *Aeneid*. In choosing biblical subject matter, he revealed the influence of contemporary theology. Milton tended to agree with the Arminians, who, unlike the extreme Calvinists, did not believe that all worldly events, including the Fall of Man, were immutably fixed in the eternal decree of God. Milton shared the Arminian belief that human beings must take responsibility for their fate and that human efforts to improve character could, with God's grace, bring salvation.

Perhaps his own blindness, joined with the hope of making the best of a failed religious revolution, inclined Milton to sympathize with those who urged people to make the most of what they had, even in the face of seemingly sure defeat. That is a manifest concern of his last works, *Samson Agonistes*, which recounts the biblical story of Samson, and *Paradise Regained*, the story of Christ's temptation in the wilderness, both published in 1671.

John Bunyan (1628–1688)

Bunyan was the English author of two classics of sectarian Puritan spirituality: *Grace Abounding* (1666) and *The Pilgrim's Progress* (1678). A Bedford tinker, his works speak especially for the seventeenth-century working people and popular religious culture. Bunyan received only the most basic education before taking up his father's craft. He was drafted into Oliver Cromwell's revolutionary army in 1644 and served for two years, although without seeing actual combat. The visionary fervor of the New Model Army and the imagery of warfare abound in Bunyan's work.

After the restoration of the monarchy in 1660, Bunyan went to prison for his fiery preaching and remained there for twelve years. Had he been willing to agree to give up preaching, he might have been released much sooner. But Puritans considered the compromise of one's beliefs a tragic flaw, and Bunyan steadfastly refused all such suggestions.

During this period of imprisonment Bunyan wrote his famous autobiography, *Grace Abounding*. It is both a very personal statement and a model for the faithful. Like *The Pilgrim's Progress*, Bunyan's later masterpiece, *Grace Abounding* expresses Puritan piety at its most fervent. Puritans believed that individuals could do absolutely nothing to save themselves, and this made them extremely restless and introspective. The individual believer could only trust that God had placed her or him among the elect and try each day to live a life that reflected such a favored status. So long as men and women struggled successfully against the flesh and the world, they had presumptive evidence that they were among God's elect. To falter or to become complacent in the face of temptation was to cast doubt on one's faith and salvation and even to raise the specter of eternal damnation.

This anxious questing for salvation was the subject of *The Pilgrim's Progress*, a work unique in its contribution to Western religious symbolism and imagery. The story of the journey of Christian and his friends Hopeful and Faithful to the Celestial City, it teaches that one must deny spouse, children, and all earthly security and go in search of "Life, life, eternal life." During the long journey, the travelers must resist the temptations of Worldly-Wiseman and Vanity Fair, pass through the Slough of Despond, and endure a long dark night in Doubting Castle, their faith being tested at every turn. Bunyan later wrote a work tracing the progress of Christian's opposite, *The Life and Death of Mr. Badman* (1680), the story of a man so addicted to the bad habits of Restoration society, of which Bunyan strongly disapproved, that he journeyed steadfastly not to heaven but to hell.

Major Works of Seventeenth-Century Literature and Philosophy

King Lear (Shakespeare)	
Don Quixote, Part I (Cervantes)	
Leviathan (Hobbes)	
Provincial Letters (Pascal)	1656-
Paradise Lost (Milton)	
Ethics (Spinoza)	
The Pilgrim's Progress (Bunyan)	
Treatises of Government (Locke)	
An Essay Concerning Human Understanding (Locke)	

The loss of national unity during the Puritan struggle against the Stuart monarchy and the Anglican church took its toll on English literature and drama during the seventeenth century. In 1642 the Puritans had closed the theaters of London. They were reopened after the Restoration of Charles II in 1660, and drama revived following the long Puritan interregnum.

Literary thought thereafter became less experimental and adopted proven classical forms, as a new movement to subject reality to the strict rules of reason began. During the so-called Augustan Age, from John Dryden (1631–1700) to Alexander Pope (1688–1744), writers turned away from the universal ideals and the transcendental concerns of the Elizabethans and the Puritan divines. As in France, where the French comedy writer Molière (1622–1673) is the outstanding example, English writers tried to please the royal court and aristocracy by turning to more earthy and popular topics.

Blaise Pascal (1623–1662)

Pascal, a French mathematician and a physical scientist widely acclaimed by his contemporaries, surrendered all his wealth to pursue an austere, self-disciplined life. Torn between the continuing dogmatism and the new skepticism of the seventeenth century, he aspired to write a work that would refute both the Jesuits, whose casuistry (i.e., arguments designed to

Pascal Meditates on Human Beings As Thinking Creatures

Pascal was both a religious and a scientific writer. Unlike other scientific thinkers of the seventeenth century, he was not overly optimistic about the ability of science to improve the human condition. Pascal believed that science and philosophy would instead help human beings to understand their situation better. In these passages from his *Pensées (Thoughts)*, he discussed the uniqueness of human beings as the creatures who alone in all the universe are capable of thinking.

339

I can well conceive a man without hands, feet, head (for it is only experience which teaches us that the head is more necessary than feet). But I cannot conceive man without thought; he would be a stone or a brute.

344

Reason commands us far more imperiously than a master; for in disobeying the one we are unfortunate, and in disobeying the other we are fools.

346

Thought constitutes the greatness of man.

347

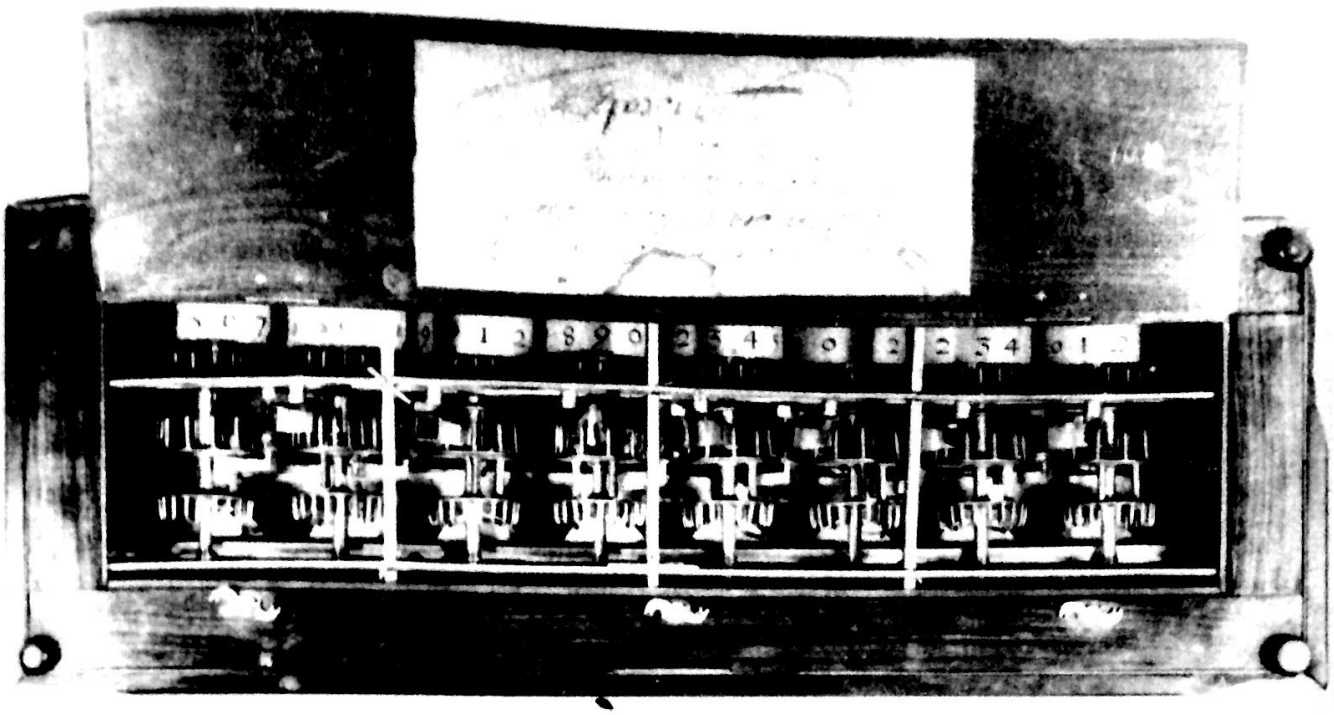
Man is but a reed, the most feeble thing in nature; but he is a thinking reed. The entire universe need not arm itself to crush him. A vapour, a drop of water suffices to kill him. But, if the universe were to crush him, man would still be more noble than that which killed him, because he knows that he dies and the advantage which the universe has over him; the universe knows nothing of this.

All our dignity consists, then, in thought. By it we must elevate ourselves, and not by space and time which we cannot fill. Let us endeavour, then, to think well; this is the principle of morality.

348

A thinking reed—*It is not from space that I must seek my dignity, but from the government of my thought. I shall have no more if I possess worlds. By space the universe encompasses and swallows me up like an atom; by thought I comprehend the world.*

Blaise Pascal, *Pensées and The Provincial Letters* (New York: Modern Library, 1941), pp. 115–116.



Pascal invented this adding machine, the ancestor of all mechanical calculators, about 1644. *It has eight wheels with ten cogs each, corresponding to the numbers 0–9. The wheels move forward for addition, backward for subtraction.* [*Musee des Techniques, Paris*]

minimize and even excuse sinful acts) he considered a distortion of Christian teaching, and the skeptics of his age, who either denied religion altogether (atheists) or accepted it only as it conformed to reason (deists). Such a definitive work was never realized, and his views on these matters exist only in piecemeal form. He wrote against the Jesuits in his *Provincial Letters* (1656–1657), and he left behind a provocative collection of reflections on humankind and religion that was published posthumously under the title *Pensées*.

Pascal allied himself with the Jansenists, seventeenth-century Catholic opponents of the Jesuits. His sister was a member of the Jansenist community of Port-Royal near Paris. The Jansenists shared with the Calvinists Saint Augustine's belief in human beings' total sinfulness, their eternal predestination by God, and their complete dependence on faith and grace for knowledge of God and salvation.

Pascal believed that reason and science, although attesting to human dignity, remained of no avail in matters of religion. Here only the reasons of the heart and a "leap of faith" could prevail. Pascal saw two essential truths in the Christian religion: that a loving God, worthy of human attainment, exists, and that human beings, because they are corrupted in nature, are utterly unworthy of God. Pascal believed that the atheists and the deists of the age had spurned the lesson of reason. For him rational analysis of the human condition attested humankind's utter mortality and corruption and exposed the weakness of reason itself in resolving the problems of human nature and destiny. Reason should rather drive those who truly heed it to faith and dependence on divine grace.

Pascal made a famous wager with the skeptics. It is a better bet, he argued, to believe that God exists and to stake everything on his promised mercy than not to do so, because if God does exist, everything will be gained by the believer, whereas the loss incurred by having believed in Him should He prove not to exist is by comparison very slight.

Convinced that belief in God improved life psychologically and disciplined it morally, regardless of whether or not God proved in the end to exist, Pascal worked to strengthen traditional religious belief. He urged his contemporaries to seek self-understanding by "learned ignorance" and to discover humankind's

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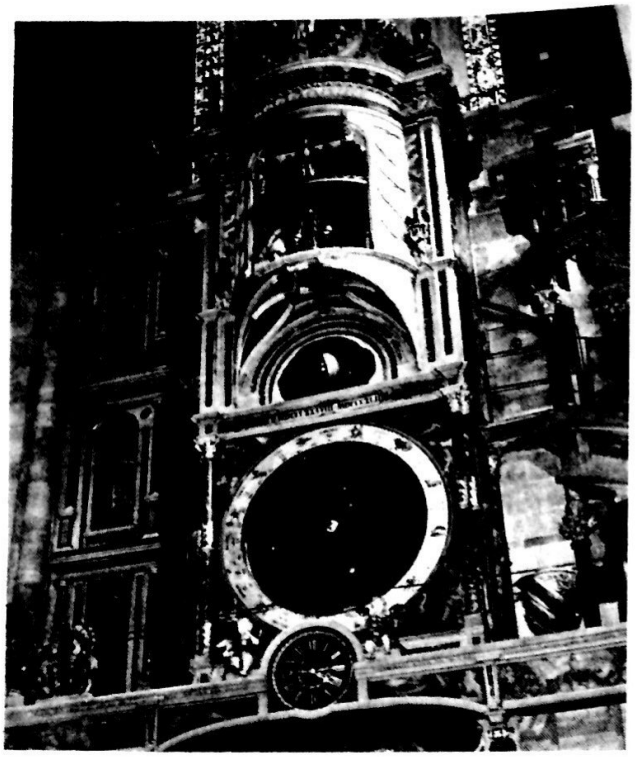

Even before Pascal's day, of course, there was a tradition of elaborate mechanical devices throughout Europe. For example, by 1500, *there were public clocks in practically every town. One of the most famous is the astronomical clock of Strasbourg cathedral in France, which presents a parade of allegorical figures every day at noon.* [*French Government Tourist Office, New York*]

The Glockenspiel, or clock performance, occurring hourly at the Munich city hall, is another ingenious time-keeping device. [*German Information Center, New York*]

greatness by recognizing its misery. Thereby he hoped to counter what he believed to be the false optimism of the new rationalism and science.

Baruch Spinoza (1632–1677)

The most controversial thinker of the seventeenth century was Baruch Spinoza, the son of a Jewish merchant of Amsterdam. Spinoza's philosophy caused his excommunication by his own synagogue in 1656. In 1670 he published his *Treatise on Religious and Political Philosophy*, a work that criticized the dogmatism of Dutch Calvinists and championed freedom of thought. During his lifetime both Jews and Protestants attacked him as an atheist.

Spinoza's most influential writing, the *Ethics*, was published after his death in 1677. Religious leaders universally condemned it for its apparent espousal of pantheism. God and nature were so closely identified by Spinoza that little room seemed left either for divine revelation in Scripture or for the personal immortality of the soul, denials equally repugnant to Jews and to Christians. The *Ethics* was a very complicated work, written in the spirit of the new science as a geometrical system of definitions, axioms, and propositions. Spinoza divided the work into five parts, which dealt with God, the mind, emotions, human bondage, and human freedom.

The most controversial part of the *Ethics* deals with the nature of substance and of God. According to Spinoza, there is but one substance, which is self-caused, free, and infinite, and God is that substance. From this definition it follows that everything that exists is in God and cannot even be conceived of apart from Him. Such a doctrine is not literally pantheistic because God is still seen to be more than the created world that He, as primal substance, embraces. It may perhaps best be described as *panentheism:* the teaching that all that is is within God, yet God remains more than and beyond the natural world. Nonetheless, in Spinoza's view, statements about the natural world are also statements about divine nature. Mind and matter are seen to be extensions of the infinite substance of God; what transpires in the world of humankind and nature is a necessary outpouring of the divine.

Such teaching seemed to portray the world as eternal and human actions as unfree and inevitable. Jews and Christians have traditionally condemned such teachings because they

deny the creation of the world by God in time and destroy any voluntary basis for personal reward and punishment.

Spinoza found enthusiastic supporters, however, in the nineteenth-century German philosopher Georg Wilhelm Friedrich Hegel and in romantic writers of the same century, especially Johann Wolfgang von Goethe and Percy Bysshe Shelley. Modern thinkers who are unable to accept traditional religious language and doctrines have continued to find in the teaching of Spinoza a congenial rational religion.

Thomas Hobbes (1588–1679)

Thomas Hobbes was incontestably the most original political philosopher of the seventeenth century. The son of a clergyman, he was educated at Oxford University. Although he never broke with the Church of England, he came to share basic Calvinist beliefs, especially the low view of human nature and the ideal of a commonwealth based on a covenant, both of which found eloquent expression in Hobbes's political philosophy.

An urbane and much-traveled man, Hobbes enthusiastically supported the new scientific movement. He worked as tutor and secretary to three earls of Devonshire over a fifty-year period. During the 1630s he visited Paris, where he came to know Descartes, and after the outbreak of the Puritan Revolution in 1640, he lived as an exile in Paris until 1651. In 1646 Hobbes became the tutor of the Prince of Wales, the future Charles II, and remained on good terms with him after the restoration of the Stuart monarchy. Hobbes also spent time with Galileo in Italy and took a special interest in the works of William Harvey (1578–1657). Harvey was a physiologist famed for the discovery of how blood circulated through the body; his scientific writings influenced Hobbes's own tracts on bodily motions. Hobbes became an expert in geometry and optics. He was also highly trained in classical languages, and his first published work was a translation of Thucydides' *History of the Peloponnesian War*, the first English translation of this work, which is still reprinted today.

The English Civil War made Hobbes a political philosopher. In 1651 his *Leviathan* appeared. Written as the concluding part of a broad philosophical system that analyzed physical bodies and human nature, the work established Hobbes as a major European thinker. Its subject was the political consequences of human passions and its originality lay in (1) its making natural law, rather than common law (i.e., custom or precedent), the basis of all positive law and (2) its defense of a representative theory of absolute authority against the theory of the divine right of kings. Hobbes maintained that statute law found its justification only as an expression of the law of nature and that political authority came to rulers only by way of the consent of the people.

Hobbes viewed humankind and society in a thoroughly materialistic and mechanical way. Human beings are defined as a collection of material particles in motion. All their psychological processes begin with and are derived from bare sensation, and all their motivations are egoistical, intended to increase pleasure and minimize pain. The human power of reasoning, which Hobbes defined unspectacularly as a process of adding and subtracting the consequences of agreed-upon general names of things, develops only after years of concentrated industry. Human will Hobbes defined as simply "the last appetite before choice."

Despite this mechanistic view of human beings, Hobbes believed they could accomplish much by the reasoned use of science. All was contingent, however, on the correct use of that greatest of all human creations, one compounded of the powers of most people: the commonwealth, in which people are united by their consent in one all-powerful person.

The key to Hobbes's political philosophy is a brilliant myth of the original state of humankind. According to this myth, human beings in the natural state are generally inclined to a "perpetual and restless desire of power after power that ceases only in death."[7] As all people desire and, in the state of nature, have a natural right to everything, their equality breeds enmity, competition, diffidence, and desire for glory begets perpetual quarreling—"a war of every man against every man."[8] As Hobbes put it in a famous summary:

> In such condition there is no place for industry, because the fruit thereof is uncertain; and consequently no culture of the earth; no navigation nor use of the commodities that may be imported by sea; no commodious building; no instruments of moving and removing such things as require much force; no knowledge of the face of the earth; no account of

[7] *Leviathan Parts I and II*, ed. by H. W. Schneider (Indianapolis: Bobbs-Merrill, 1958), p. 86.

[8] Ibid., p. 106.

The famous title-page illustration for Hobbe's Leviathan. *The ruler is pictured as absolute lord of his lands, but note that he incorporates the mass of individuals whose self-interests are best served by their willingness to accept him and cooperate with him.*

time; no arts; no letters; no society; and, which is worst of all, continual fear and danger of violent death; and the life of man solitary, poor, nasty, brutish, and short.[9]

Whereas earlier and later philosophers saw the original human state as a paradise from which humankind had fallen, Hobbes saw it as a corruption from which only society had delivered people. Contrary to the views of Aristotle and Christian thinkers like Thomas Aquinas, in the view of Hobbes human beings are not by nature sociable, political animals; they are self-centered beasts, laws unto themselves, utterly without a master unless one is imposed by force.

According to Hobbes, people escape the impossible state of nature only by entering a social contract that creates a commonwealth tightly ruled by law and order. They are driven to this solution by their fear of death and their desire for "commodious living." The social contract obliges every person, for the sake of peace and self-defense, to agree to set aside personal rights to all things and to be content with as much liberty against others as he or she would allow others against himself or herself. All agree to live according to a secularized version of the golden rule: "Do not that to another which you would not have done to yourself."[10]

Because words and promises are insufficient to guarantee this state, the social contract also establishes the coercive force necessary to com-

[9]Ibid., p. 107.

[10]Ibid., p. 130.

pel compliance with the covenant. Hobbes believed that the dangers of anarchy were always far greater than those of tyranny and conceived of the ruler as absolute and unlimited in power, once established in office. There is no room in Hobbes's political philosophy for political protest in the name of individual conscience, nor for resistance to legitimate authority by private individuals—features of the *Leviathan* criticized by contemporary Catholics and Puritans alike. To his critics, who lamented the loss of their individual liberty in such a government, Hobbes pointed out the alternative:

> The greatest that in any form of government can possibly happen to the people in general is scarce sensible in respect of the miseries and horrible calamities that accompany a civil war or that dissolute condition of masterless men, without subjection to laws and a coercive power to tie their hands from rapine and revenge.[11]

It is puzzling why Hobbes believed that absolute rulers would be more benevolent and less egoistic than all other people. He simply placed the highest possible value on a strong, efficient ruler who could save human beings from the chaos attendant on the state of nature. In the end it mattered little to Hobbes whether this ruler was Charles I, Oliver Cromwell, or Charles II, each of whom received Hobbes's enthusiastic support, once he was established in power.

John Locke (1632–1704)

Locke has proved to be the most influential political thinker of the seventeenth century. His political philosophy found expression in the Glorious Revolution of 1688–1689. Although he was not as original as Hobbes, his political writings became a major source of the later Enlightenment criticism of absolutism, and they gave inspiration to both the American and the French revolutions.

Locke's sympathies lay with the Puritans and the Parliamentary forces that challenged the Stuart monarchy. His father fought with the Parliamentary army during the English Civil War. Locke read deeply in the works of Francis Bacon, René Descartes, and Isaac Newton and was a close friend of the English physicist and chemist Robert Boyle (1627–1691). Some view Locke as the first philosopher to synthesize the rationalism of Descartes and the experimental science of Bacon, Newton, and Boyle.

Locke was for a brief period strongly influenced by the political views of Hobbes. This influence changed, however, after his association with Anthony Ashley Cooper, the earl of Shaftesbury. In 1667 Locke moved into Shaftesbury's London home and served him as physician, secretary, and traveling companion. A zealous Protestant, Shaftesbury was considered by his contemporaries a radical in both religion and politics. He organized an unsuccessful rebellion against Charles II in 1682. Although Locke had no part in the plot, both he and Shaftesbury were forced to flee to Holland after its failure.

Locke's two most famous works are the *Essay Concerning Human Understanding* (1690), completed during his exile in Holland, and the *Two Treatises of Government* (1690). In the *Essay Concerning Human Understanding* Locke stressed the creative function of the human mind. He believed that the mind at birth was a blank tablet. There are no innate ideas; all knowledge is derived from actual sensual experience. Human ideas are either simple (that is, passive receptions from daily experience) or complex (that is, products of sustained mental exercise). What people know is not the external world in itself but the results of the interaction of the mind with the outside world. Locke also denied the existence of innate moral norms. Moral ideals are the product of humankind's subjection of their self-love to their reason—a freely chosen self-disciplining of natural desires so that conflict in conscience may be avoided and happiness attained. Locke also believed that the teachings of Christianity were identical to what uncorrupted reason taught about the good life. A rational person would therefore always live according to simple Christian precepts. Although Locke firmly denied toleration to Catholics and atheists—both were considered subversive in England—he otherwise sanctioned a variety of Protestant religious practice.

Locke wrote *Two Treatises of Government* during the reign of Charles II. They oppose the argument that rulers are absolute in their power. According to the preface of the published edition, which appeared after the Glorious Revolution, the treatises were written "to justify to the world the people of England, whose love of their just and natural rights, with their resolution to preserve them, saved

[11] Ibid., p. 152.

John Locke Explains the Sources of Human Knowledge

An Essay Concerning Human Understanding (1690) may be the most influential philosophical work ever written in English. Locke's most fundamental idea, which is explicated in the passage below, is that human knowledge is grounded in the experiences of the senses and in the reflection of the mind on those experiences. He rejected any belief in innate ideas. His emphasis on experience led to the wider belief that human beings are creatures of their environment. After Locke, numerous writers argued that human beings could be improved if the environment in which they lived were reformed.

Let us then suppose the mind to be, as we say, white paper void of all characters, without any ideas. *How comes it to be furnished? Whence comes it by that vast store which the busy and boundless fancy of man has painted on it with an almost endless variety? Whence has it all the materials of reason and knowledge? To this I answer, in one word, from* experience; *in that all our knowledge is founded, and from that it ultimately derives itself. Our observation, employed either about* external sensible objects, or about the internal operations of our minds perceived and reflected on by ourselves, is that which supplies our understanding with all the materials of thinking. *These two are the fountains of knowledge, from whence all the ideas we have, or can naturally have, do spring.*

First, our senses, *conversant about particular sensible objects, do* convey into the mind *several distinct* perceptions *of things, according to those various ways wherein those objects do affect them. And thus we come by those* ideas *we have of* yellow, white, heat, cold, soft, hard, bitter, sweet, *and all those which we call sensible qualities. . . . This great source of most of the* ideas *we have, depending wholly upon our senses, and derived by them to the understanding, I call SENSATION.*

Secondly, the other fountain from which experience furnisheth the understanding with ideas *is the* perception of the operations of our own minds *within us, as it is employed about the* ideas *it has got. . . . And such are* perception, thinking, doubting, believing, reasoning, knowing, willing, *and all the different actings of our own minds. . . . I call this REFLECTION, the* ideas *it affords being such only as the mind gets by reflecting on its own operations within itself. . . . These two, I say, viz. external material things as the objects of SENSATION, and the operations of our own minds within as the objects of REFLECTION, are to me the only originals from whence all our* ideas *take their beginnings. . . .*

The understanding seems to me not to have the least glimmering of any ideas *which it doth not receive from one of these two.*

John Locke, *An Essay Concerning Human Understanding,* Vol. 1 (London: Everyman's Library, 1961), pp. 77–78.

the nation when it was on the brink of slavery and ruin."[12] Locke rejected particularly the views of Sir Robert Filmer and Thomas Hobbes.

Filmer had written a work entitled *Patriarcha, or the Natural Power of Kings* (published in 1680), in which the rights of kings over their subjects were compared with the rights of fathers over their children. Locke devoted his entire first treatise to a refutation of Filmer's argument, maintaining not only that the analogy was inappropriate, but that even the right of a father over his children could not be construed as absolute and was subject to a higher natural law. Both fathers and rulers, Locke argued, remain bound to the law of nature, which is the voice of reason, teaching that "all mankind [are] equal and independent, [and] no one ought to harm another in his life,

[12] *The Second Treatise of Government,* ed. by T. P. Peardon (Indianapolis: Bobbs-Merrill, 1952), Preface.

health, liberty, or possessions,"[13] inasmuch as all human beings are the images and property of God. According to Locke, people enter into social contracts, empowering legislatures and monarchs to "umpire" their disputes, precisely in order to preserve their natural rights, not to give rulers an absolute power over them. Rulers are rather "entrusted" with the preservation of the law of nature and transgress it at their peril:

> Whenever that end [namely, the preservation of life, liberty, and property for which power is given to rulers by a commonwealth] is manifestly neglected or opposed, the trust must necessarily be forfeited and the power devolve into the hands of those that gave it, who may place it anew where they think best for their safety and security.[14]

From Locke's point of view, absolute monarchy is "inconsistent" with civil society and can be "no form of civil government at all."

Locke's main differences with Hobbes stemmed from the latter's well-known views on the state of nature. Locke believed that the natural human state was one of perfect freedom and equality. Here all enjoyed, in unregulated fashion, the natural rights of life, liberty, and property. The only thing lacking in the state of nature was a single authority to give judgment when disputes inevitably arose because of the natural freedom and equality possessed by all. Contrary to the view of Hobbes, human beings in their natural state were creatures not of monomaniacal passion but of extreme goodwill and rationality. And they did not surrender their natural rights unconditionally when they entered the social contract; rather, they established a means whereby these rights could be better preserved. The state of warfare that Hobbes believed characterized the state of nature emerged for Locke only when rulers failed in their responsibility to preserve the freedoms of the state of nature and attempted to enslave people by absolute rule, that is, to remove them from their "natural" condition. Only then did the peace, goodwill, mutual assistance, and preservation in which human beings naturally live and socially ought to live come to an end and a state of war emerge.

[13]Ibid., Ch. 2, sects. 4–6, pp. 4–6.

[14]Ibid., Ch. 13, sect. 149, p. 84.

Suggested Readings

V. M. Brittain, *Valiant Pilgrim: The Story of John Bunyan and Puritan England* (1950). Illustrated historical biography.

K. C. Brown, *Hobbes Studies* (1965). A collection of important essays.

Herbert Butterfield, *The Origins of Modern Science 1300–1800* (1949). An authoritative survey.

John Caird, *Spinoza* (1971). Intellectual biography by a philosopher.

Norman F. Cantor (Ed.), *Seventeenth Century Rationalism: Bacon and Descartes* (1969).

Cervantes, *The Portable Cervantes,* ed. and trans. by Samuel Putnam (1969).

Hardin Craig, *Shakespeare: A Historical and Critical Study with Annotated Texts of Twenty-one Plays* (1958).

Maurice Cranston, *Locke* (1961). Brief biographical sketch.

J. Dunn, *The Political Thought of John Locke; An Historical Account of the "Two Treatises of Government"* (1969). An excellent introduction.

Manuel Duran, *Cervantes* (1974). Detailed biography.

Galileo Galilei, *Discoveries and Opinions of Galileo,* ed. and trans. by Stillman Drake (1957).

A. R. Hall, *The Scientific Revolution 1500–1800: The Formation of the Modern Scientific Attitude* (1966). Traces undermining of traditional science and rise of new sciences.

Thomas Hobbes, *Leviathan. Parts I and II,* ed. by H. W. Schneider (1958).

Margaret Jacob, *The Newtonians and the English Revolution* (1976). A controversial book that attempts to relate science and politics.

T. E. Jessop, *Thomas Hobbes* (1960). Brief biographical sketch.

H. Kearney, *Science and Change 1500–1700* (1971). Broad survey.

Alexander Koyre, *From the Closed World to the Infinite Universe* (1957). Treated from perspective of the historian of ideas.

Thomas S. Kuhn, *The Copernican Revolution* (1957). A scholarly treatment.

Peter Laslett, *Locke's Two Treatises of Government,* 2nd ed. (1970). Definitive texts with very important introductions.

John D. North, *Isaac Newton* (1967). Brief biography.

Alan G. R. Smith, *Science and Society* (1973). A readable, well-illustrated history of the Scientific Revolution.

E. M. W. Tillyard, *Milton* (1952). Brief biographical sketch.

Richard S. Westfall, *Never at Rest: A Biography of Isaac Newton* (1981). A new and very important major study.