2

ISAAC NEWTON

1642-1727

Nature and Nature's laws lay hid in night:
God said, Let Newton be! and all was light.

ALEXANDER POPE

Isaac Newton, the greatest and most influential scientist who ever lived, was born in Woolsthorpe, England, on Christmas Day, 1642, the same year that Galileo died. Like Muhammad, he was born after the death of his father. As a child, he showed considerable mechanical aptitude, and was very clever with his hands. Although a bright child, he was inattentive in school and did not attract much attention. When he was a teenager, his mother took him out of school, hoping that he would become a successful farmer. Fortunately, she was persuaded that his principal talents lay elsewhere, and at eighteen, he entered Cambridge University. There, he rapidly absorbed what was then known of science and mathematics, and soon moved on to his own independent research. Between his twenty-first and twenty-seventh years, he laid the foundations for the scientific theories that subsequently revolutionized the world.

The middle of the seventeenth century was a period of great scientific ferment. The invention of the telescope near the begin-

ning of the century had revolutionized the entire study of astronomy. The English philosopher Francis Bacon and the French philosopher René Descartes had both urged scientists throughout Europe to cease relying on the authority of Aristotle and to experiment and observe for themselves. What Bacon and Descartes had preached, the great Galileo had practiced. His astronomical observations, using the newly invented telescope, had revolutionized the study of astronomy, and his mechanical experiments had established what is now known as Newton's first law of motion.

Other great scientists, such as William Harvey, who discovered the circulation of the blood, and Johannes Kepler, who discovered the laws describing the motions of the planets around the sun, were bringing new basic information to the scientific community. Still, pure science was largely a plaything of intellectuals, and as yet there was no proof that when applied to technology, science could revolutionize the whole mode of human life, as Francis Bacon had predicted.

Although Copernicus and Galileo had swept aside some of the misconceptions of ancient science and contributed to a greater understanding of the universe, no set of principles had been formulated that could turn this collection of seemingly unrelated facts into a unified theory with which to make scientific predictions. It was Isaac Newton who supplied that unified theory and set modern science on the course which it has followed ever since.

Newton was always reluctant to publish his results, and although he had formulated the basic ideas behind most of his work by 1669, many of his theories were not made public until much later. The first of his discoveries to be published was his ground-breaking work on the nature of light. In a series of careful experiments, Newton had discovered that ordinary white light is a mixture of all the colors of the rainbow. He had also made a careful analysis of the consequences of the laws of the reflection and refraction of light. Using these laws, he had in 1668 designed and actually built the first reflecting telescope, the type of telescope that is used in most major astronomical obser-

vatories today. These discoveries, together with the results of many other optical experiments which he had performed, were presented by Newton before the British Royal Society when he was twenty-nine years old.

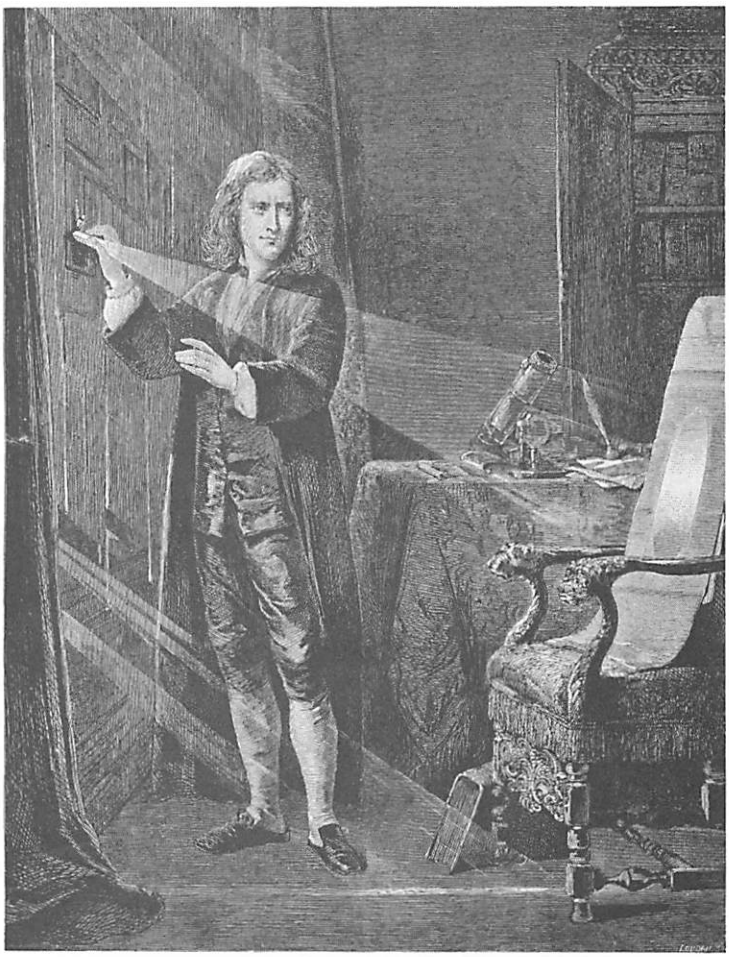
Newton's achievements in optics alone would probably entitle him to a place on this list; however, they are considerably less important than his accomplishments in pure mathematics and mechanics. His major mathematical contribution was his invention of integral calculus, which he probably devised when he was twenty-three or twenty-four years old. That invention, the most important achievement of modern mathematics, is not merely the seed out of which much of modern mathematical theory has grown, it is also the essential tool without which most of the subsequent progess in modern science would have been impossible. Had Newton done nothing else, the invention of integral calculus by itself would have entitled him to a fairly high place on this list.

Newton's most important discoveries, however, were in the field of mechanics, the science of how material objects move. Galileo had discovered the first law of motion, which describes the motion of objects if they are not subjected to any exterior forces. In practice, of course, all objects are subjected to exterior forces, and the most important question in mechanics is how objects move under such circumstances. This problem was solved by Newton in his famous second law of motion, which may rightly be considered the most fundamental law of classical physics. The second law (described mathematically by the equation $\mathbf{F} = ma$) states that the acceleration of an object (i.e., the rate at which its velocity changes) is equal to the net force on the object divided by the object's mass. To those first two laws, Newton added his famous third law of motion (which states that for each action—i.e., physical force—there is an equal and opposite reaction), and the most famous of his scientific laws, the law of universal gravitation. This set of four laws, taken conjointly, form a unified system by means of which virtually all macroscopic mechanical systems, from the swinging of a pendulum to

the motion of the planets in their orbits around the sun, may be investigated, and their behavior predicted. Newton did not merely state these laws of mechanics; he himself, using the mathematical tools of the calculus, showed how these fundamental laws could be applied to the solution of actual problems.

Newton's laws can be and have been applied to an extremely broad range of scientific and engineering problems. During his lifetime, the most dramatic application of his laws was made in the field of astronomy. In this area, too, Newton led the way. In 1687, he published his great work, the *Mathematical Principles of Natural Philosophy* (usually referred to simply as the *Principia*), in which he presented his law of gravitation and laws of motion. Newton showed how these laws could be used to predict precisely the motions of the planets around the sun. The principal problem of dynamical astronomy—that is, the problem of predicting exactly the positions and motions of the stars and planets—was thereby completely solved by Newton in one magnificent sweep. For this reason, Newton is often considered the greatest of all astronomers.

What, then, is our assessment of Newton's scientific importance? If one looks at the index of an encyclopedia of science, one will find more references (perhaps two or three times as many) to Newton and to his laws and discoveries than to any other individual scientist. Furthermore, one should consider what other great scientists have said about Newton. Leibniz, no friend of Sir Isaac's, and a man with whom he engaged in a bitter dispute, wrote: "Taking mathematics from the beginning of the world to the time when Newton lived, what he has done is much the better part." The great French scientist Laplace wrote: "The *Principia* is preeminent above any other production of human genius." Lagrange frequently stated that Newton was the greatest genius who ever lived, while Ernst Mach, writing in 1901, said: "All that has been accomplished in mathematics since his day has been a deductive, formal, and mathematical development of mechanics on the basis of Newton's laws." This, perhaps, is the crux of Newton's great accomplishment: he found



Newton analyzes a ray of light.

science a hodgepodge of isolated facts and laws, capable of describing some phenomena but of predicting only a few; he left us a unified system of laws, which were capable of application to an enormous range of physical phenomena, and which could be used to make exact predictions.

In a brief summary like this, it is not possible to detail all of Newton's discoveries; consequently, many of the lesser ones have

been omitted, although they were important achievements in their own right. Newton made significant contributions to thermodynamics (the study of heat) and to acoustics (the study of sound); he enunciated the extremely important physical principles of conservation of momentum and conservation of angular momentum; he discovered the binomial theorem in mathematics; and he gave the first cogent explanation of the origin of the stars.

Now, one might grant that Newton was by far the greatest and most influential scientist who ever lived but still ask why he should be ranked higher than such major political figures as Alexander the Great or George Washington, and ahead of such major religious figures as Jesus Christ and Gautama Buddha. My own view is that even though political changes are of significance, it is fair to say that most people in the world were living the same way 500 years after Alexander's death as their forebears had lived five centuries before his time. Similarly, in most of their daily activities, the majority of human beings were living the same way in 1500 A.D. as human beings had been living in 1500 B.C.. In the last five centuries, however, with the rise of modern science, the everyday life of most human beings has been completely revolutionized. We dress differently, eat different foods, work at different jobs, and spend our leisure time a great deal differently than people did in 1500 A.D. Scientific discoveries have not only revolutionized technology and economics; they have also completely changed politics, religious thinking, art, and philosophy. Few aspects of human activity have remained unchanged by this scientific revolution, and it is for this reason that so many scientists and inventors are to be found on this list. Newton was not only the most brilliant of all scientists; he was also the most influential figure in the development of scientific theory, and therefore well merits a position at or near the top of any list of the world's most influential persons.

Newton died in 1727, and was buried in Westminster Abbey, the first scientist to be accorded that honor.