

ematics, and can make progress only when its fundamental principles are expressed in mathematical form. These views are in close accord with the best modern ideas, and foreshadow very clearly the methods used by Newton; but they were so far in advance of Bacon's age that they were utterly incomprehensible to his contemporaries.

A more successful advocate of the employment of mathematics in scientific research was the brilliant French philosopher, René Descartes, who was born near Tours on March 31st, 1596. He pointed out that geometers, starting with a few self-evident axioms, were able to deduce the most abstruse propositions from those axioms by a vigorous process of reasoning, and maintained that in a similar manner the mysteries of the universe could be solved by mathematical reasoning based on a few fundamental principles. This is but a partial statement of the true method, for Descartes fails to emphasize, as Bacon did, the necessity of frequent appeals to observation and experiment to verify the results of the reasoning; to this contempt for experimental verification is to be ascribed the failure of Descartes' attempt to explain physical phenomena.

Descartes says science is a tree of which metaphysics is the root, physics is the trunk, and the three branches are mechanics, medicine, and morals; these branches being the applications of our knowledge to external affairs, to the human body, and to the conduct of life. In 1644 he published his *Principia Philosophiæ* ("Principles of Philosophy"), which deals chiefly with physical science and in which he treats of the laws of motion and the theory of vortices. Descartes' philosophy was long dominant in Europe; it was taught in all the universities, Newton himself was brought up in

this faith, and for a time the vortex theory maintained itself as a rival of the Newtonian theory of universal gravitation; it is, therefore, germane to our purpose to give a slight account of Descartes' vortices. In his *Principia*, Descartes attempts to construct a system of philosophy that is absolutely free from assumptions; accordingly he begins with an attempt to demonstrate his own existence; this he conceives to be proved by his famous aphorism, "I think, therefore, I exist." This is the starting point of his system; he then asserts that it is manifestly impossible that a vacuum can exist anywhere, and maintains that the universe is a *plenum*, "filled with matter." Originally this matter consisted of equal parts with sharp corners; by the motion of the parts, their corners are rubbed off till the parts are reduced to spherical form, and the dust produced by the abrasion constitutes another and subtler form of matter. There is also a third form of matter—the material of which the earth and all opaque bodies are composed. Luminous bodies, like the sun, are composed of the first kind of matter, the transparent interplanetary spaces are filled with the second kind of matter. All this matter is revolving in circular currents, or whirlpools, which are called vortices. The first kind of matter naturally collects together at the centre of each vortex, the second kind of matter forms an all-pervading medium surrounding the center. Thus he accounts for the fact that the sun is the center of the solar system; to explain the motion of the planets, each planet has a special vortex in which it is whirled round like a straw in the eddy of a swift-flowing stream. Gravitation is attributed to the settling down of bodies toward the center of each vortex.

It is easy to show that Descartes'