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(*b* Freshwater, Isle of Wight, England, 18 July 1635; *d*, London, England, 3 March 1702)

physics

The son of John Hooke, a minister, Hooke was a sickly boy; although he ultimately lived to be nearly seventy, his parents did not entertain serious hope for his very survival during the first few years of his life. His very survival during the first few years of his life. His father, one of three or four brothers, all of whom found their calling in the church, intended young Robert for the ministry also; but when persistent headaches interrupted the intended program of study, his father abandoned the plan and left the boy to his own devices. What these would be was immediately manifest. When he saw a clock being dismantled, he promptly made a working replica from wood. He constructed ingenious mechanical toys, including a model of a fully rigged man-of-war which could both sail and fire a salvo. B his tenth birthday Hooke had already embraced what his biographer Richard Waller called “his first and last Mistress”—mechanics. His role in the history of science is inextricably bound to his skill in mechanics and his allied perception of nature as a great machine.

When his father died in 1648, Hooke inherited £100. Since he had displayed some artistic talent, his family packed him off to London, where his legacy was to finance an apprenticeship to Sir Peter Lely. Hooke decided to save his money; and it was his good fortune that Richard Busby, the master of Westminster School, befriended him and took him into his home. The teacher had recognized the pupil. Not only did Hooke learn Latin, the staple of the secondary curriculum, together with Greek and a smattering of Hebrew; he also discovered mathematics. By his own account he devoured the first six books of Euclid in a week, and he proceeded to apply geometry to mechanics. Nor was mathematics all. By his own account again, he learned to play twenty lessons on the organ and invented thirty ways of flying. Having exhausted the resources of Westminster, he moved on to Oxford, where he entered Christ Church as a chorister in 1653.

Apparently Hooke never took a bachelor’s degree. The only Oxford degree associated with his name is the Master of Arts, to which he was nominated in 1663. Meanwhile, Oxford had given him more than a thousand degrees could match. At the time of his arrival the university was the home of the brilliant group around which the Royal Society later crystallized. John Wilkins, Thomas Willis, Seth Ward, William Petty, John Wallis, Christopher Wren, Robert Boyle— these and others, some already recognized scholars, some still students, some merely resident near the university—covered regularly for the discussion of scientific matters. Hooke soon found his place in the circle. They recognized and drew upon his talent in mechanics, and they gave him in return his introduction to the new world of thought then fomenting the scientific revolution. For a time Hooke was an assistant to Willis. Willis introduced him to Boyle, and as Boyle’s assistant Hooke launched his independent career.

Typically, Hooke’s initial triumphs were mechanical inventions. Although Boyle’s interest focused primarily on chemistry, the report of Guericke’s air pump caught his attention. He instructed Hooke to devise an improved instrument, and the modern air pump duly appeared. With the air pump and with Hooke’s assistance, Boyle conducted the experiments that concluded in Boyle’s law, published in 1662. As with so much, Hooke’s role in the investigation is unclear. Boyle never suggested that he played any part; and Hooke, who was not reluctant to assert himself, never claimed that he did. Hooke was Boyle’s paid assistant at that time, however, and the position of assistant may well have seemed to both to preclude any right of discovery. A number of historians assign the discovery to Hooke without further ado, and almost no one wants to deny outright that he participated in it.

In 1658, at the same time that he developed the air pump, Hooke turned his attention to chronometers. It was widely recognized that an accurate portable clock could solve the critical navigational problem of determining longitude. Hooke reasoned that one might be constructed by the “use of Springs instead of Gravity for the making of a Body vibrate in any Posture.” That is, by attaching a spring to the arbor of the balance wheel, he would replace the pendulum with a vibrating wheel that could be moved because it oscillated around its own center of gravity. This is, of course, the principlle of the watch, and on this principle a marine chronometer with which longitude could be determined was constructed in the eighteenth century. Once again, the exact nature of Hooke’s contribution to clockmaking is shrouded in mystery. About 1660 three men of means— Robert Morary, and William Brouncker, all later prominent in the Royal Society—considered backing Hooke’s invention. Should the clock have worked, the profits might well have been immense. A patent was drawn up; but before the agreement was completed, Hooke withdrew, apparently demanding of his backers assurances they were unwilling to give.

In 1674 Christiaan Huygens constructed a watch controlleed by a spiral spring attached to the balance; and Hook, suspecting that his invention has been peddled to Huygens, cried foul. Working with the clockmaker Thomas Tompion, he made a similiar watch to present to the king; and on it he defiantly engraved the assertion “Robert Hooke inven. 1658. T. Tompion fect 1675,” Despite his contentions, there is no evidence that his watch of 1658, if indeed it worked, employed a spiral spring, the device of crucial importance. On the other hand, his pamphlet that pronounced Hooke's law, *De potentia restitutiva* (1678), employed a spiral spring as one example and offered a demonstration (faulty, to be sure) that the vibrations of springs obeying Hooke's Law are isochronal. It is worth adding that neither Hooke's nor Huygens' watch worked satisfactorily enough to determine longitude. Although the exact nature of Hooke's contributions cannot be determined with any assurance, knowledgeable men at the time considered him to have made important inventions in chronometry; and historians are unanimous in agreement.

In 1659 and 1660 the Oxford circle dissolved with the collapse of the Protectorate and the restoration of the Stuarts. Relieved of their academic appointments, which many of them owed to their Puritan sympathies, most of the circle moved back to London, where they continued their meetings and formalized them in November 1660. Two years later the group acknowledged the king's patronage by taking the name Royal Society. A number of the early members knew Hooke from Oxford days; and others were impressed by his first publication, a pamphlet on capillary action which appeared in 1661. As a result Sir Robert Moray proposed him for the post of curator of experiments late in 1662. With untroubled confidence the Society charged him to furnish each meeting "with three or four considerable Experiments" as well as to try such other experiments as the members might suggest.

Probably no man could have come as close to fulfilling the impossible demand as Hooke did. He provided the major portion of intellectual content at the weekly meetings. It is hard to imagine that the Royal Society would have survived the apathy that succeeded its initial burst of enthusiasm without the stimulus of Hooke's experiments, demonstrations, and discourses. Some commentators have suggested that the Society's good fortune was Hooke's calamity. Its excessive demands imposed on him a pattern of frantic activity that made it impossible for him ever to finish a piece of work. On the contrary, the tendency to flit from idea to insight without pause was Hooke's innate characteristic. He never performed so well as he did during the first fifteen years of his tenure as curator, when, with a thousand demands on his time, he poured out a continuous stream of brilliant ideas. When the demands relaxed, the temper of his mind went slack as well; and his creative period came to a close. Far from destroying him, the Royal Society provided the unique milieu in which he could function at his best.

In 1664 Sir John Cutler founded a lectureship in mechanics for Hooke; it carried an annual salary of £50. Although Hooke's initial appointment as curator had involved no remuneration, the Royal Society now appointed him to the position for life with a salary of £30, together with the privilege of lodging at Gresham College. By September 1664 he had taken up residence there in the chambers that were his home until his death. Until 1676 he was in charge of the Society's repository of rarities, and he served as librarian until 1679. In 1665 the position of Gresham professor of geometry added a further duty, and a further salary of £50. Hooke's financial position was in fact far less secure than it may appear. The Royal Society was perpetually in financial straits and unable to sustain its obligations. As for his salary as lecturer, Cutler made a career of bestowing in public benefactions that he refused in private to fulfill, and Hooke had to take him to court to obtain his due.

In 1666 another job, probably the most onerous of all in its demands on his time, came Hooke's way. The great fire of London offered a considerable opportunity to one with Hooke's technical skills. Almost on the morrow of the disaster he came forward with a plan to rearrange the city wholly by laying it out on a rectangular grid. The plan won the approval of the city fathers; although it never approached implementation, it did promote his nomination as one of three surveyors appointed by the city to reestablish property lines and to supervise the rebuilding. As surveyor, Hooke was thrown into daily commerce with Sir Christopher Wren, one of the men appointed by the royal government to the same task of rebuilding. Wren and Hooke dominated and guided the work, and cemented a friendship that lasted throughout their lives. To Hooke the position of surveyor was a financial boon, more than compensating for the uncertainty of his other income. It also provided an outlet for his artistic talents. The title "surveyor" is misleading, for if he surveyed, he also functioned as an architect. A number of prominent buildings, such as the Royal College of Physicians, Bedlam Hospital, and the Monument, were his work. Hooke's reputation as a many-sided genius has tended to focus on his manifold scientific activities. His career as an architect adds another dimension to his achievement.

The ten years following the fire constituted a period of hectic activity. The very time when the demands of his surveyorship were at their peak was also a period of productive scientific work. To be sure, Hooke's scientific career was already well launched. In 1665, the year before the fire, he had published *Micrographia*, the most important book that he produced. If not the first publication of microscopical observations, *Micrographia* was the first great work devoted to them; and its impact rivaled that of Galileo's *Sidereus nuncius* half a century before. For the first time, descriptions of microscopical observations were accompanied by profuse illustrations—another display of Hooke's artistic talent. In the public mind, Hooke's name became identified with microscopical observations; and when Thomas Shadwell wrote his wretched physicolibidinous farce, *The Virtuoso*, he modeled the leading character on Hooke. Hooke attended a performance in June 1676: "Dammd Doggs. Vindica me Deus, people almost pointed."

No amount of ignorant ridicule could dim the book's luster. It remains one of the masterpieces of seventeenth-century science. Like Galileo's *Nuncius, Micrographia* presented not a systematic investigation of any one question but a banquet of observations with courses from the mineral, vegetable, and animal kingdoms. Above all, the book suggested what the microscope could do for the biological sciences. Hooke's examination of the structure of cork led to his coining the modern biological usage of the word "cell." (The use of the word did not entail that he had any notion of modern cytology, of course. He referred to "pores or cells"; conceived of them as passages to carry liquids for the plant's growth; and, led on by Harvey's discovery, tried to locate the valves that must obviously be present as well. Nevertheless, the later biological usage of "cell" descended directly from the *Micrographia*.) In the animal realm, he inaugurated the study of insect anatomy. His horrendous portraits of the flea and the louse, a frightening eighteen inches long, are hardly less startling today than they must have been in the seventeenth century. He examined and understood the multiple eye of the fly, and he portrayed such diverse structures as feathers and apian stings. Frequent reproduction of the *Micrographia* testifies to the unfading fascination it continues to exercise.

Hooke also used the book as a vehicle to expound his own scientific theories. A work devoted to the microscope may be excused for proposing a theory of light, however tenuously connected to microscopical observations as such. An adherent of the mechanical philosophy of nature, Hooke held light to be mechanical as well: pulses of motion transmitted through a material medium. Neither in the *Micrographia* nor in his later lectures on light, delivered before the Royal Society, did he examine the theory at any great depth; but its mere proposal suffices to enroll him among the forebears of the wave theory of light. Moreover, the specific cause that shaped the theory was a set of observations destined to play an important role in the history of optics. Initially with mica, and then with soap bubbles, layers of air between sheets of glass, and a host of analogous instances, Hooke examined phenomena of colors in thin, transparent films. He recognized that the colors are periodic, with the spectrum repeating itself as the thickness of the film increases. His theory of light intended specifically to account for such phenomena. Except in the most general terms, the theory has. not survived. Yet his observations of thin films did exert an extensive influence. Both Huygens and Newton saw that the thickness of the films could be calculated from the diameters of rings formed in the layer of air between a flat sheet of glass and a lens of known curvature. Newton's experiments, stemming directly from his reading of the *Micrographia*, became the foundation of Book Two of the *Opticks*, the source of the concept of periodicity in modern optics. The demonstration of periodicity was Newton's; the original suggestion of periodicity was Hooke's.

The theory of light was also the occasion of Hooke's initial confrontation with Newton. Seven years after the publication of *Micrographia*, Newton, then an obscure young academic almost completely unknown, sent his first paper on colors to the Royal Society. As the resident expert, Hooke was called upon to comment. More than somewhat magisterially, he rejected a new conception of colors he had not taken the trouble to understand. As far as colors were concerned, Hooke's theory had offered a new version of the old idea that colors arise from the modification of light which appears white in its pristine form. He had merely proposed a mechanism to account for the modification, and he failed now to see that Newton was replacing the concept of modification with an entirely different idea. Stung to fury by Hooke's critique, Newton penned a response that was little short of savage; and Hooke was subjected to the humiliation of seeing Newton's reply published in the *Philosophical Transactions* although his critique had been private. Late in 1675, when Newton sent the Royal Society his second paper on colors, observations on thin films together with the "Hypothesis of Light," Hooke claimed—or was reported to have claimed—that all of Newton's paper was found in his *Micrographia*. On this occasion Hooke, too, wrote privately, expressing his appreciation of Newton's work rather too formally and implying that Oldenburg was intriguing against him by spreading false reports. Newton's reply accepted the explanation in similar stilted phrases. The matter dropped for the time, but the complete lack of warmth between the men is manifest from this distance.

In addition to optics, the *Micrographia* also expounded a theory of combustion. At least four men in England were actively engaged at this time in investigating combustion and exploring its analogy with respiration. It is impossible to distinguish satisfactorily the independent roles of Hooke, Boyle, Richard Lower, and John Mayow; and it is difficult to assess adequately their total work. Individuals in the group, and Hooke among them, have been hailed as precursors—virtually forestallers—of Lavoisier and the discovery of oxygen. Close analysis of the various theories does not support such a judgment. In the *Micrographia*, Hooke argued that air is "the *menstruum*, or universal dissolvent of all *Sulphureous*bodies," a dissolution carried out by a salt in the air and accompanied by intense heat, which we call fire. He identified the salt with that in saltpeter, so that combustion, which usually requires air, can take place in a vacuum when saltpeter is present.

Instead of forestalling Lavoisier, who saw combustion as a chemical combination, Hooke's theory repeated the accepted view that fire is an instrument of analysis that dissolves and separates bodies. There is no occasion to scorn the insight obtained. Along with the other three men, Hooke was impressed by the analogy of combustion and respiration. He carried out experiments before the Royal Society demonstrating that a continued supply of fresh air is as essential to life as it is to fire. By opening the thorax of a dog, destroying the motion of its lungs, and then employing a bellows to maintain a stream of air which passed out of the lungs through holes that he pricked, he demonstrated conclusively that the function of respiration is to bring a constant supply of fresh air into the lungs—not to cool and not to pump, as prevailing theories held, but solely to supply fresh air. With Mayow and the others, Hooke identified the nitrous salt or spirit in the air as the ingredient essential to life. Although the conceptual expression of this insight differed radically from Lavoisier's, its significance cannot be denied; and Hooke's role in it cannot be ignored.

During the years following *Micrographia*, Hooke found time to conduct demonstrations before the Royal Society and to deliver the Cutlerian lectures despite his activities as surveyor. Part of this work extended earlier investigations—for example, both those on combustion and those on optics—but he also broke new ground. During the 1670's he published a series of six brief works which were gathered together in a single volume, the *Lectiones Cutlerianae*, in 1679. The Cutlerian lectures contain at least two important scientific discoveries. One of these was the law of elasticity to which Hooke's name is still attached—"ut tensio sic vis." That is, the stress is proportional to the strain. Hooke's law, which was implicit in much of mechanics before him, was not a major discovery. Nevertheless, no one before him had stated it explicitly. Moreover, Hooke perceived intuitively that a vibrating spring is dynamically equivalent to a pendulum; and in the lecture that announced Hooke's law, he undertook one of the early analyses of simple harmonic motion. He based it on what he referred to elsewhere as "the General Rule of Mechanicks":

Which is, that the proportion of the strength or power of moving any Body is always in a duplicate proportion of the Velocity it receives from it...

That is, the "quantity of strength" employed in moving a body is proportional to the square of the velocity it receives. In many ways the passage was typical of Hooke. The demonstration foundered on its inherent confusions—although it is necessary to add that in the seventeenth century only giants such as Huygens, Leibniz, and Newton succeeded in dispelling similar confusion in dynamics. In Hooke's case, the clarity of his mechanical conceptions and the power of his analysis were not able to match his intuitive insight.

In another Cutlerian lecture, Hooke announced the three basic suppositions on which he intended to construct a system of the world corresponding to the rules of mechanics:

First, That all Coelestial Bodies whatsoever, have an attraction or gravitating power towards their own Centers, whereby they attract not only their own parts, and keep them from flying from them, as we may observe the earth to do, but that they do also attract all the other Coelestial Bodies that are within the sphere of their activity.... The second supposition is this, That all bodies whatsoever that are put into a direct and simple motion, will so continue to move forward in a streight line, till they are by some other effectual powers deflected and bent into a Motion, describing a Circle, Ellipsis, or some other more compounded Curve Line. The third supposition is, That these attractive powers are so much the more powerful in operating, by how much the nearer the body wrought upon is to their own Centers.

This remarkable statement, together with others that date back to 1664, has become a major piece of evidence in the case for Hooke's claim on the law of universal gravitation. It contains two elements. On the one hand, it proposes a concept of apparently universal attraction. It is only apparently universal, however. An idea of gravitational attractions specific to each planet, forces by which they maintain the unity of their systems, was widely held in the seventeenth century. Although Hooke took a major step toward generalizing this idea, his understanding of gravitation never eliminated the notion of a force specific to certain kinds of matter and hence never reached the level of universal gravitation. Gravity, he said elsewhere, is "such a Power, as causes Bodies of a similar or homogeneous nature to be moved one towards the other, till they are united...." Planets are of the same nature as the sun and hence are attracted to it. Comets are not related, and they are repelled.

Hooke himself never laid claim to the concept of universal gravitation. Rather, he asserted his propriety over the second element in the passage above, the celestial dynamics. In fact, his proposal did contain a revolutionary insight that reformulated the approach to circular motion in general and to celestial dynamics in particular. Notable in his statement is the absence of any reference to centrifugal force. Hooke was the man who first saw clearly the elements of orbital dynamics as we continue to accept them. If the principle of rectilinear inertia be granted, a body revolving in an orbit must be continually diverted from its inertial path by some force directed toward a center. When Hooke was formulating this view, Newton still thought of circular motion in terms of an equilibrium of centrifugal and centripetal forces. Moreover, it was Hooke who taught him to see it otherwise. Late in 1679 Hooke wrote to Newton, among other things asking for Newton's opinion of his proposed planetary dynamics. The correspondence is too well known to need repeating. Suffice it to say that in response to Newton's assumption of uniform gravity in a problem mechanically identical to orbital motion, Hooke stated his conviction that gravity decreases in power in proportion to the square of the distance. Hooke was always convinced thereafter that Newton had stolen the inverse square relation from him. Newton himself acknowledged in 1686 that the correspondence with Hooke stimulated him to demonstrate that an elliptical orbit around a central attracting body placed at one focus entails an inverse square force.

Nevertheless, one must beware of attributing too much to Hooke. Once again, his power of analysis could not support the brilliance of his insight. The insight cannot be taken from him. Where earlier investigations of the dynamics of circular motion had based themselves on the notion of centrifugal force, Hooke (as it were) stood the problem right side up and put it in a position to be attacked fruitfully. But his own mechanics was not adequate to that job. Although he proposed the problem of the dynamics of elliptical orbits, he acknowledged his inability to solve it; and his very derivation of the inverse square relation, on which he insisted with such vehemence, was so defective as to be ludicrous. He justified the inverse square relation, not by substituting the formula for centripetal force (which he appears not to have known) into Kepler's third law, but by a bastardized application of his own general rule of mechanics to Kepler's aborted law of velocities. Hooke did not discover or even approach the law of universal gravitation. But he did set Newton on the correct approach to orbital dynamics and, in this way, contributed immensely to Newton's later triumph.

Although one important area of Hooke's scientific activity, his study of fossils and his related contribution to geology, also figured in the *Micrographia,* its major exposition appeared only in the "Lectures and Discourses of Earthquakes," the largest section of his *Posthumous Works*. Spread over a period of thirty years, the lectures testify that geology was one of Hooke's enduring interests. Geology might almost have been created to display his talents to maximum advantage. An almost untouched field, it presented no massive volume of data to be mastered and offered few constraints to curb his facile imagination. Hooke repaid it handsomely. He provided a solution to the controversy over the origin of fossils by dividing "figured stones" into two categories-those with forms characteristic of the organism and those with forms characteristic of the substance. In regard to the latter, Hooke may be described as a protocrystallographer. He showed how the polyhedral forms of crystals (as he saw them under the microscope) could be built up from packings of bullets, the basis for the claim that he anticipated Steno in the law of constancy of interfacial angles.

In an age when the biblical account of creation made fossils with organic forms a riddle to most investigators, Hooke was remarkable for his steadfast refusal to consider them as anything but the remains of organic creatures. His refutation of the argument that they are *lusus naturae*, sports of nature produced to no purpose, is one of the classic passages of scientific argumentation in the seventeenth century. He refused to call in the Deluge to explain the presence of marine fossils far from the sea, but he concluded that the surface of the earth has been subject to vast upheavals and changes. When fossils could not be identified with existing creatures, he did not hesitate to consider the mutability of species.

One must be careful not to exaggerate the modernity of Hooke's geological ideas. Unable to destroy the preconception of a limited time span, he identified the upheavals of the surface of the earth with cataclysmic earthquakes. He has been called the first uniformitarian; quite the contrary, he was the first catastrophist. The mutations of species he conceived were limited variations under the stress of environmental change. To say as much is only to concede that Hooke could not leap from the seventeenth century into the nineteenth. With the possible exception of Steno, he was easily the most important geologist of his day. In nothing does he appear more modern than in his prescription of a program for geological study. Fossils are the "Monuments" and "Medals" of earlier ages from which the history of the earth can be reconstructed, just as the history of mankind is studied through human remains. The pursuit of Hooke's program for geology ultimately shattered the seventeenth-century preconceptions which confined his own geological theories.

Perhaps Hooke's most important contribution to science lay in the field of instrumentation. He added something to every important instrument developed in the seventeenth century. He invented the air pump in its enduring form. He advanced horology and microscopy. He developed the cross-hair sight for the telescope, the iris diaphragm, and a screw adjustment from which the setting could be read directly. He has been called the founder of scientific meteorology. He invented the wheel barometer, on which the pivoted needle registers the pressure. He suggested the freezing temperature of water as the zero point on the thermometer and devised an instrument to calibrate thermometers. His weather clock recorded barometric pressure, temperature, rainfall, humidity, and wind velocity on a rotating drum. Although it was not a scientific instrument, the universal joint was also his invention. Writing in the eighteenth century, Lalande called Hooke "the Newton of mechanics." One might add that he was the first mechanic of genius whose talent the mechanical philosophy of nature brought to bear directly on science.

The year 1677 brought significant changes to Hooke's life. The death of Henry Oldenburg led to his nomination as secretary of the Royal Society. For several years the two men had been mortal enemies. Convinced that Oldenburg had betrayed the secret of his spring-driven watch to Huygens, Hooke had publicly labeled him a "trafficker in intelligence"; but the Council of the Royal Society had come to Oldenburg's support. Now he sat in his enemy's position of power. It proved to be an empty triumph. Public success merely disguised private decline. Although he was only forty-two years old in 1677, and destined to survive another quarter of a century, Hooke had exhausted his scientific creativity. One year later the last of his Cutlerian lectures announced Hooke's law. From there on, everything was downhill.

His tenure as secretary was not successful, and he stepped down after five years. During that period he tried to continue Oldenburg's periodical—renamed *Philosophical Collections*—but he managed to bring out only seven issues in all. In 1686 Newton laid Book I of the *Principia* before the Society. Hooke was convinced that he had been robbed again, but hardly anyone listened to his protestations. And in 1687 his niece Grace, originally his ward and then his mistress through a prolonged and tempestuous romance, died. From that blow he never fully recovered. More and more he became a recluse and a cynic. A tone of bitterness pervades the small number of papers that survive from his final years. In the end he was almost bedfast. He died on 3 March 1702 in the room at Gresham College that he had inhabited for nearly forty years.

Hooke was a difficult man in an age of difficult men. His life was punctuated with bitter quarrels that refused to be settled. When he offered criticism of Hevelius' use of open sights for astronomical observations, he did it in such a way that the consequences dragged on for ten years. His conflicts with Oldenburg and Newton have already been mentioned. It is only fair to add that the other three men were at least as difficult in their own right, and that Hooke won and held the esteem and affection of such men as Boyle, Wren, and the antiquarian John Aubrey. Hooke's disposition was probably exacerbated by his physical appearance. Pepys said of him, while he was still a young man, that he "is the most and promises the least of any man in the world that ever I saw." As every description testifies, his frame was badly twisted. Add to his wretched appearance wretched health. He was a dedicated hypochondriac who never permitted himself the luxury of feeling well for the length of a full day. Hooke's spiny character was nicely proportioned to the daily torment of his existence.

As for his role in the history of science, it is impossible to avoid the commonplace assessment—that he never followed up his insights. Indeed, he was incapable of exploring them in their ultimate depths—as Newton, for example, could do. Early in his career Hooke composed a methodological essay that earnestly advocates orderly procedure and systematic coverage. It appears almost to be Hooke's judgment on himself. Typically, it remained unfinished. Waller records that in his old age Hooke intended to leave his estate to build a laboratory for the Royal Society and to found a series of lectures. He procrastinated in completing his will "till at last this great Design prov'd an airy Phantom and vanish'd into nothing." More than one of Hooke's grand designs proved an airy phantom and vanished into nothing—at least if we judge him by the standards of a Newton. Because of his claim on the law of universal gravitation, the comparison with Newton inevitably arises, but such a standard of judgment is unfair to Hooke. If he was not a Newton, his multifarious contributions to science in the seventeenth century are beyond denial; and on the crucial question of circular motion it was Hooke's insight that put Newton on the track to universal gravitation. The Royal Society honored its own wisdom when the members attended his funeral as a body.

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II. Secondary Literature. The best contemporary sources on Hooke's life are John Aubrey's sketch in *Brief Lives*, I (Oxford, 1898), 409–416; and Richard Waller's biography, prefaced to the *Posthumous Works*. See also John Ward, *Lives of the Professors of Gresham College* (London, 1740), pp. 169–193. Hooke has recently been the subject of a more extended, perhaps excessively enamored, biography: Margaret 'Espinasse, *Robert Hooke* (London, 1956). Among the innumerable general articles on him, E. N. da C. Andrade, "Robert Hooke," in *Proceedings of the Royal Society*, **201A** (1950), 439–473, is of special importance. There is also a general discussion of his scientific career in the introduction by Richard S. Westfall to a reprint ed. of the *Posthumous Works* (New York, 1969). Mary Hesse has published two articles devoted to general aspects of his scientific thought: "Hooke's Philosophical Algebra," in *Isis*, **57** (1966), 67–83; and "Hooke's Vibration Theory and the Isochrony of Springs," *ibid*., 433–441.

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For Hooke's contributions to clockmaking, see A. R. Hall, "Robert Hooke and Horology," in *Notes and Records. Royal Society of London*, **8** (1950–1951), 167–177. His work on combustion is treated in D. J. Lysaght, "Hooke's Theory of Combustion," in *Ambix*, **1** (1937), 93–108; Douglas McKie, "Fire and the Flamma Vitalis: Boyle, Hooke and Mayow," in *Science, Medicine and History, Essays… in Honour of Charles Singer,* E. Ashworth Underwood, ed., 2 vols. (London, 1953), 1, 469–488; and H. D. Turner, "Robert Hooke and Theories of Combustion," in *Centaurus*, **4** (1956), 297–310. The best discussion of Hooke's optics is in A. I. Sabra, *Theories of Light From Descartes to Newton* (London, 1967), pp. 187–195, 251–264, 276–284, 321–333; see also Richard S. Westfall, "The Development of Newton's Theory of Color," in *Isis***53** (1962), 339–358; and "Newton and His Critics on the Nature of Colors," in *Archives internationales d'histoire des sciences***15** (1962), 47–58. On Hooke as a geologist, see A. P. Rossiter, "The First English Geologist," in *Durham University Journal*, **27** (1935), 172–181; W. N. Edwards, "Robert Hooke as a Geologist and Evolutionist," in *Nature*, **137** (1936), 96–97; and a commentary on Edwards' article by Rossiter, "Hooke as Geologist," *ibid*., 455.

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