Commentary

A History of the Ecological Sciences, Part 16: Robert Hooke and the Royal Society of London

Although the versatile Robert Hooke (1635–1703) was not an "early ecologist," he made enough innovations and discoveries essential for the prehistory of ecology to merit our consideration. For too long, he was overshadowed by his formidable rival, Isaac Newton, but now there are four excellent biographies of Hooke: 'Espinasse (1956) provides a brief overview, Drake (1996) provides a geological perspective on his life and career, and Inwood (2002) and Jardine (2004) provide detailed account of all aspects of his life. Another volume written by Bennett, Cooper, Hunter, and Jardine (2003) celebrates Hooke's life and work on the 300th anniversary of his death. Finally, Nichols' is a pleasant, brief study of Hooke's relations with the Royal Society (1999), but it lacks the sophistication of Pumfrey's article on the subject (1991). All of these books are well illustrated. A useful biographical article provides additional references (Pugliese 2004).

Hooke was born on the scenic Isle of Wight, two miles south of England's mainland, and as a child he was fascinated by both its geological formations and its fossil shells. His preacher father died when he was 13, and he was apprenticed to a London artist. He had the talent to become an artist, but paint fumes affected him adversely, and so he was sent to Westminster School, where the headmaster, Dr. Richard Busby, recognized his genius and provided him not only with a solid academic education, but also had him trained as an instrument maker (Jardine 2004:63).

In 1653 Hooke entered Oxford University and soon became Robert Boyle's laboratory assistant. He built an air pump for Boyle, and Hooke used it himself to demonstrate the hypothesis that became known as Boyle's Law (1662). The Royal Society of London for Promoting Natural Knowledge was founded in 1660 and received a royal charter (but no money) from Charles II. The Society soon had 115 members (Stimson 1948:51), although only about 20 were active (Inwood 2002). It was inspired by and organized with the writings of Sir Francis Bacon in mind (Purver 1967:235–236). In 1662 Hooke became its curator, responsible for three or four experiments or demonstrations at each weekly meeting. This was an unrealistic expectation, but he came closer than anyone else could have done. By 1664 the Royal Society decided to pay him a modest annual stipend. In 1665 he became Professor of Geometry at Gresham College, and the Royal Society met often in his rooms there.

His book, *Micrographia: or Some Physiological Descriptions of Minute Bodies made by Magnifying Glasses* (1665) contains 9 months of his experiments and demonstrations. He used a commercial microscope, probably from instrument-maker Richard Reeve (Simpson 1989:37–41). His most famous observations and illustrations in it are of plant cells, which he discovered and named (Hooke 1961:112–116).

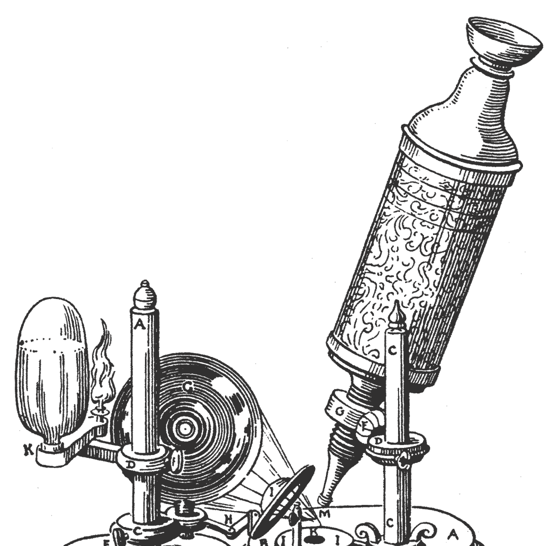

Fig. 1. Hooke's compound microscope. *Micrographia* (Hooke 1961: facing p.1).

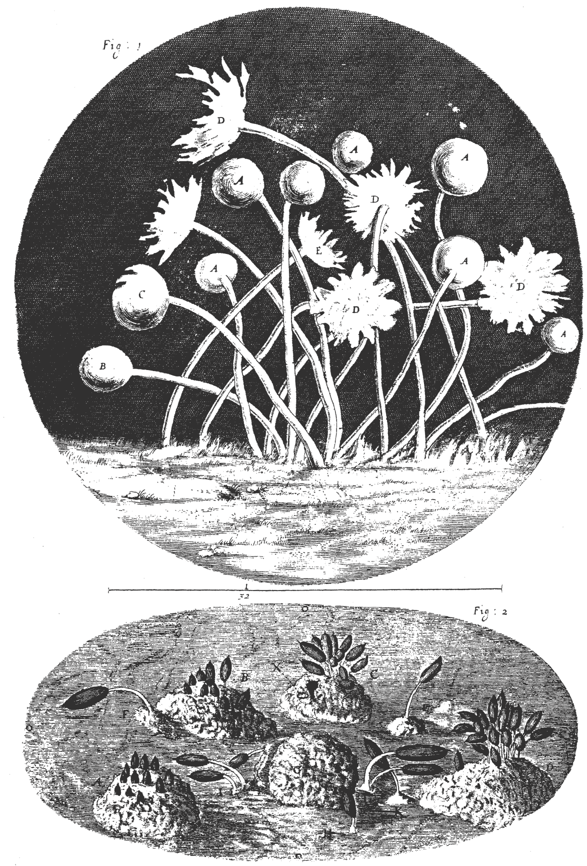

Fig. 2. Top: *Mucor*. Bottom: *Phragmidium mucronatum* (Hooke 1961: facing p.125).

He illustrated cells in cork and charcoal and said he had also seen them in at least eight other kinds of plants, possibly including moss, since his illustration of it shows cells in the leaves (Hooke 1961:facing p.131, Richards 1981:141, Harris 1999:4–7). Equally important, if less well known, was his discovery of microorganisms (Bardell 1988). He put some grains of sand under his microscope and discovered that one of them resembled a minute water snail shell, and he concluded it was a fossil shell (Hooke 1961:80–81, illustration facing p.44). He did not name what are now called foraminifera. Hooke intentionally investigated two familiar substances that turned out to be plant growths (at a time when fungi were considered plants). For several summers he had observed that the green leaves of damask roses became "all bespecked with yellow stains, and the undersides…have small black spots in the midst of these yellow ones, which to the naked eye, appear'd no bigger than the point of a Pin." (Hooke 1961:121). He examined them under his microscope and saw "several small yellow knobs…out of which I perceiv'd there sprung multitudes of little cases or black bodies like Seed-cods [pods]," though he was unable to see any "seeds." He had discovered, but did not name, the rose rust (*Phragmidium mucronatum*) (Ainsworth 1976:59). He suspected, despite his speculation about seeds, that these were simple moss or mold "which is set a moving by the *putrifactive* and *fermentative* heat, joyn'd with that of the ambient aerial" and so grows by the "same Principle, I imagine the Misleto of Oaks, Thorns, Appletrees, and other Trees, to have its original . . . seldom or never growing on any of these Trees, till they begin to wax decrepid . . . ."

Next, he investigated mold from a leather book cover and saw what seemed to be minute mushrooms. His illustration shows what are now called sporangiphores with sporangia. He speculated the latter might be seed cases, though he had never found seeds in mushrooms, "which seem to depend upon a convenient constitution of the matter out of which they are made, and a concurrence of either natural or artificial heat." (Hooke 1961:127). He smelled and tasted the mold and found it disagreeable. The microscope enabled him to raise the question of whether microscopic plants reproduce by "seeds," but he did not pursue this investigation long enough to find out—so many other experiments to perform.

He then studied moss, which is visible to the naked eye, though its fine structures are best studied under a microscope. He easily identified its seed case, which was solid before it ripened, but after it grew bigger a hole appeared, out of which seeds probably fell, since later the seed cases were hollow. Although he failed to find any moss seeds, he assumed they existed, but even so, he remained uncertain about whether moss could also arise "out of corruption, without any disseminated seed . . . .” (Hooke 1961:131–132). The four specimens on his plate XIII are well drawn, though they inadvertently came from two or three different species, and there is some mismatch between the letters on the drawings and the discussion in his text. Despite these minor confusions, Hooke gave “an excellent account of the structure of the moss, with a surprising amount of detail.” (Richards 1981:142).

When he turned to insects, he commented that a large fly (such as the blue fly, *Calliphora erythrocephala*, he illustrated) at one time lays 400–500 eggs, and their numbers would increase prodigiously “were they not prey’d on by multitudes of Birds, and destroy’d by Frosts and Rains,” which led him to conclude that the absence of climatic checks causes the tropics to be “infested with such multitudes of Locusts, and such other Vermine.” (Hooke 1961:182). He concluded from watching blue flies that they were stimulated by putrefying meat to lay their eggs on it.

His most detailed insect study was on mosquitoes, which he called water-insects or gnats. The name “mosquito” was in use by 1665, but it was borrowed from Spanish to refer to small American flies. Our distinction between biting mosquitoes and nonbiting gnats only gained common usage about 1900 (Christophers 1960:1–2). Hooke observed them in the aquatic stage, which he though was generated in rainwater (presumably by spontaneous generation). He was fascinated by their shape and motion, and perhaps because of this fascination, he discovered after two or three weeks that they metamorphosed into gnats, “leaving their husks behind them in the water floating under the surface. . . .” (Hooke 1961:187). He described the process in detail because he had “not found that any Author has observ’d the like; and because the thing it self is so strange. . . .” He described two adults, guessing correctly their sex, though his larval stage (Fig. 3) is *Culex* and his adults (Hooke 1961:facing pages 193 and 195) are *Chironomus* (Bodenheimer 1928–1929, II:368; Christophers 1960: 4). In the interest of science, he let a mosquito bite his hand and watched it suck his blood and “fill its belly

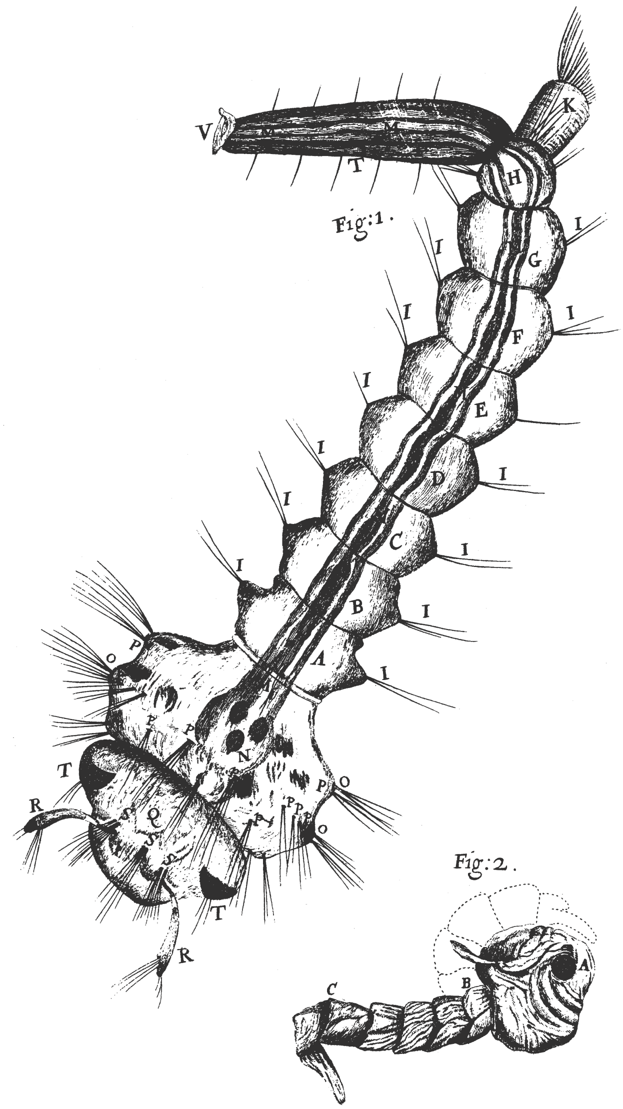

Fig. 3. Mosquito larva and pupa (Hooke 1961: facing p.186).

as full as it could hold, making it appear very red and transparent…” (Hooke 1961:195).

Power (1945) argues that some of Hooke’s most striking illustrations were made by his lifelong friend and colleague, Sir Christopher Wren (1632–1723). Architect–scientist Wren had developed the techniques of drawing microscopic subjects, and the Royal Society had asked him to make insect drawings for Charles II. It was only because Wren had more compelling demands on his time that Hooke took up the project. In the preface to *Micrographia* Hooke praised Wren without specifically attributing any of the drawings to him. Power suspects that plates illustrating the head of a "drone fly," a flea, and a louse (plates XXIV, XXXIV, and XXXV) are Wren's, and possibly also plate XXXVI on two mites. Drawings of the fly head, flea, and louse are all gigantic; the flea, at 16.5 inches (43.5 cm) long, is surely the largest insect drawing in the scientific literature. It is ironic that Hooke published a large illustration of a flea in the very year that a plague epidemic struck London, killing almost 100,000. The Royal Society was alerted to the epidemic's seriousness from the published bills of mortality and suspended its meetings in late June. Charles II also fled the city for safer climes (Gregg 1978:9–11). No one, of course, made the connection between the rat flea (*Nosophyllus fasciatus*) and the plague.

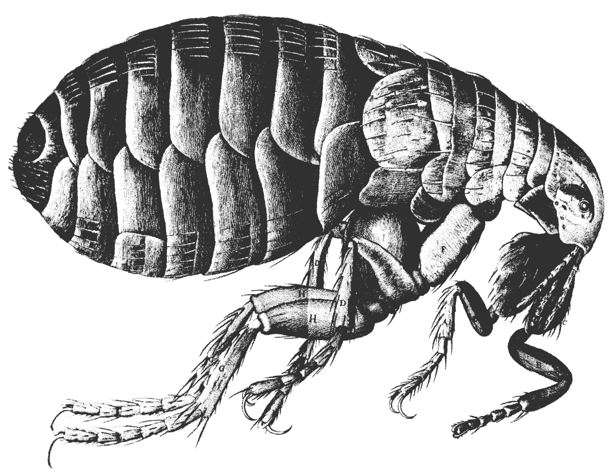

Fig. 4. Flea (now called the dog flea, *Pulex irritans*) (Hooke 1961: facing p. 210).

Hooke observed a louse sucking blood after fasting for two days; presumably it was his blood, as it had been with the mosquito he observed. He found that the louse was "so greedy, that though it could not contain more, yet it continued sucking as fast as ever, and as fast emptying it self behind…" (Hooke 1961:213).

Since Hooke was uncertain about the possibility of spontaneous generation in small organisms, it is interesting that he discovered the eggs of mites. The mites themselves were barely visible to the naked eye, yet he undoubtedly found their eggs. He estimated that a mite is only one-hundredth of an inch thick, which means that there would be a million in a cubic inch, yet their eggs are only a 400th or 500th the size of the adult. "Notwithstanding which minuteness a good Microscope discovers those small moveable specks to be very prettily shap'd Insects, each of them furnish'd with eight well shap'd and proportion'd legs…" (Hooke 1961:213–214). He believed that a mite

> *is very much diversify'd in shape, colour, and divers other properties, according to the nature of the substance out of which it seems to be ingendred and nourished, being in one substance more long, in another more round, in some more hairy, in others more smooth, in this nimble, in that slow, here pale and whiter, there browner, blacker, more transparent, &c. I have observed it to be resident almost on all kinds of substances that are mouldy, or putrifying, and have seen it very nimbly meshing through the thicket of mould, and sometimes to lye* dormant *underneath them; and 'tis not unlikely, but that it may feed on that vegetating substance,* spontaneous Vegetables *seeming a food proper enough for* spontaneous Animals.

But then again, he says, maybe they all come from eggs!

The illustrations in *Micrographia* inspired the Dutchman Antoni van Leeuwenhoek (1632–1723) to begin sending his own findings to the Royal Society in 1673. Leeuwenhoek could not read the English text, but may have had help from someone who could (Jardine 1993:314). Hooke often repeated Leeuwenhoek's investigations for the Society and sometimes added his own comments (Hooke 1968, Inwood 2002, Jardine 2004). In 1692 Hooke expressed regret that, although there had been other microscopists in the 1660s to 1680s, Leeuwenhoek was the only one still publishing scientific observations. He could not return to the subject himself because of declining eyesight (Hooke 1967:262, Wilson 1995:226).

Hooke's, and the Royal Society's, interests were quite broad, and he easily wandered into other fields. In an effort to show the practical importance of science, both he and the Royal Society investigated various aspects of seafaring and navigation. Little was know about the oceans, and he thought sea captains might be willing to undertake some investigations if provided with equipment and a program. He invented a depth sounder and water sampler (described 30 September 1663) that might provide useful data. The former determined depths deeper than was possible by dropping a weighted line. It consisted of a larger hollow ball linked to a smaller solid metal ball by a clasp that opened when the solid ball struck the bottom, allowing the hollow ball to rise to the surface. One estimated depth by the time lapsed between dropping both balls into the water and the reappearance of the hollow ball. It was never widely used because it was an inconvenient device and because sailors were uninterested in great depths. However, his water sampler was commonly used by oceanographers in the 1700s and 1800s. It was "a square bucket with upper and lower hinged lids which opened upwards as it was lowered through the water on a weighted bracket" (Wolf 1950:117–119, Bennett et al. 2003:76–77). As one pulled the sampler back up, the lids closed automatically, enclosing the water sample.

Hooke, at the suggestion of the Royal Society in September 1663, began to keep daily weather records, and thereby founded the regular investigation of weather which he hoped would lead to weather prediction (Inwood 2002:43, Bennett et al. 2003:77–80). The subject stimulated his inventive genius, leading him to invent or improve all five basic meteorological instruments: barometer, thermometer, hygroscope, rain gauge, and wind gauge ('Espinasse 1956:50).

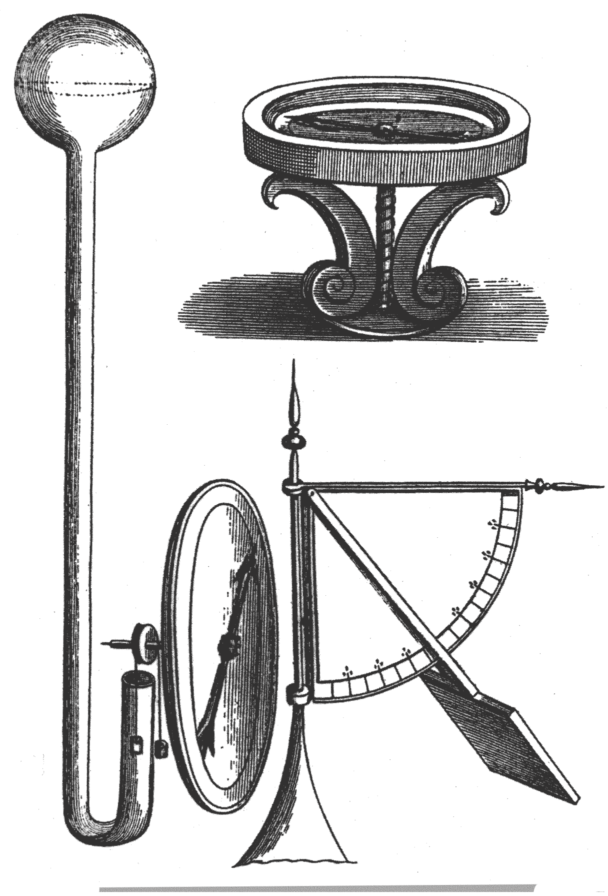

Fig. 5. Wheel-barometer, hygrometer, and wind gauge (Hooke 1958: facing p.173).

But making one of each was not enough for Hooke; he was always thinking up better versions of his instruments, which explains why the indexes of Middleton's histories of the barometer, thermometer, and weather instruments (1964, 1966, 1969), have longer entries under "Hooke" than for any other investigator-inventor.

The same is true for Bud and Warner's encyclopedia of scientific instruments (1998).

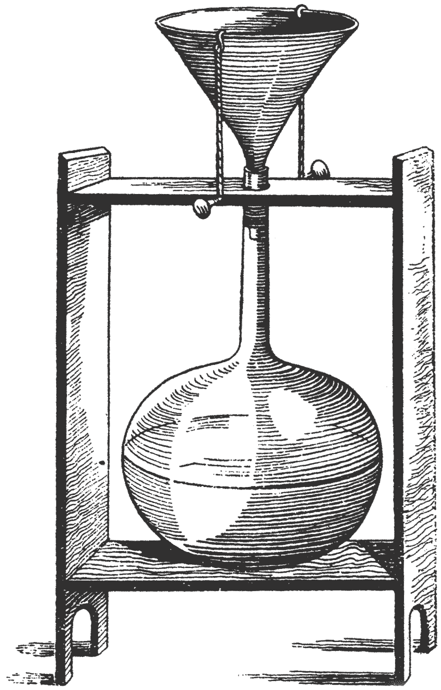

Fig. 6. Hooke's rain-gauge (Wolf 1950: 310).

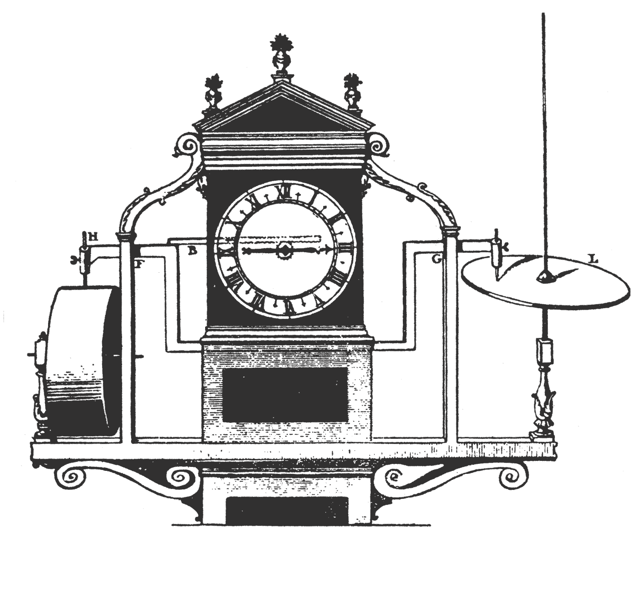

Fig. 7. Hooke's self-recording weather clock (Wolf 1950: 311).

Not only did he invent the instruments, he also developed and printed a meteorological form on which to record the data (Hooke 1958, Wolf 1950:308–313).

From the start, he and the Royal Society realized that any scientific study of weather required both a uniform set of records and a standard set of instruments (Patterson 1953). However, science was not yet well enough organized for these insights to be widely implemented. That would take another two centuries.

The kind of seaman-investigator whom the Royal Society longed for eventually appeared—the remarkable William Dampier (1652–1715). It seems unlikely that the Royal Society influenced him before his first voyage around the world (early 1679–September 1691), during which he collected valuable information on geography, ocean currents, prevailing winds, people, animals, and plants. After he returned, however, he discussed his findings with Hooke and the Royal Society (Preston and Preston 2004:230–235), and those discussions undoubtedly increased his sophistication when he was writing *A New Voyage Round the World* (Hooke 1697). It was the most important travel book since Marco Polo's *Travels* (which appeared about 1300). After it appeared, Hooke (1697) summarized it for the Royal Society.

Robert Hooke, son of a clergyman, was a pious Christian as well as a brilliant scientist, yet he thought many students of Earth history exaggerated the importance of Noah's flood to account for geological strata. From a modern perspective, we could say that he, in turn, exaggerated the importance of earthquakes to account for the same strata. But that was a small mistake when compared with his sophisticated approach to geology and Earth history. He studied and theorized on the shape of the earth, the wandering of the poles, cyclic terrestrial processes, fossil formation, and subterraneous eruptions and earthquakes causing changes from land to sea (Hooke 1996:96). He was one of the earliest defenders of the idea that fossils represent the remains of once living beings. His reason was simple: there is no other adequate explanation. Nevertheless,

A
SCHEME
At one View repreſenting to the Eye the Obſervations of the Weather for a Month.

Dayes of the Month and place of the Sun. Remarkable houſe.	Age and ſign of the Moon at Noon.	The Quarters of the Wind and its ſtrength.	The Degrees of Heat and Cold.	The Degrees of Dryneſs and Moyſture.	The Degrees of Preſſure.	The Faces or viſible apearances of the Sky.	The Notableſt Effects.	General Deductions to be made after the ſide is fitted with Obſervations: As,
4 8 14 ♊ 12.46 12 4 8 12	27 ♉ 9. 46. Perigeũ.	W. 2. 3 3½ W.SW.1	9 ¾ 12 ½ 16 10 ⅛ 7 ½	2 5 2 8 2 9 2	29 1/16 29 ⅛ 29 ⅜	Clear blew, but yellowiſh in the N. E. Clowded toward the S. Checker'd blew.	A great dew. Thunder, far to the South. A very great Tide.	From the laſt quar:of the Moon to the change the weather was very temperate but cold for the ſeaſon; the Wind pretty conſtant between N. and W.
8 15 ♊ 13.40 4 6 10	28 ♉ 24.51.	N.W. 3 4 N. 2 1	9 8 ½ 7	2 8½ 2 9 2 10	29 1/16 29	A clear Sky all day, but a little checker'd at 4. P.M. at Sunſet red and hazy.	Not by much ſo big a Tide as yeſterday. Thunder in the North.	A little before the laſt great Wind, and till the Wind roſe at its higheſt, the Quickſilver continued deſcending till it came very low; after which it began to reaſcend,
10 16 ♊ 14.37	N.Moon. at 7. 25′ A.M. ♊ 10. 8.	S. 1	10	1 10	28 ½	Overcaſt and very lowring.	No dew upon the ground, but very much upon Marble ſtones,	
	&c.	&c.	&c.	&c.	&c.	&c.	&c.	&c.

Fig. 8. Form for a weather report (Hooke 1958:179).

he had to argue the point with colleagues in the Royal Society who defended the idea of a "plastic virtue" in the earth that could produce fossils (Rudwick 1985: 53–56, Rappport 1997:106). His claims about fossils were based on observations going back to his boyhood on the fossil-rich Isle of Wight. He was especially fascinated by what he called "snail-stones" or "snake-stones," now called ammonites. These were much larger than any known living species, though he compared them with the chambered nautilus, which he illustrated as cut in half along the spiral axis (Hooke 1971:281–285, Drake 1996:161–167, Jardine 2004:37–42). The only way he could account for fossils that do not resemble living species was to assume that species must change over time (Drake 1996:97–103). If species change, then fossils might indicate the chronology of the world (Rossi 1984:12–17, Drake 1996:233, 304). When he was informed that the Danish physician Niels (or Nicolaus) Stensen (or Steno) shared his perspectives, instead of welcoming the support, he wondered if someone had secretly sent his own ideas to Stensen (Cutler 2003:130–138). Hooke's thoughts on fossils were published posthumously.

Robert Hooke was active in the Royal Society for 40 years, during its golden age. His own most important contributions came in his earlier years in the Society, when the standards and traditions of modern science were developing. After his death, Sir Isaac Newton became president of the Royal Society, yet in the 1700s the Society mostly continued along the paths blazed in the later 1600s. The loss of Hooke's portrait contributed to his being overshadowed by Newton. Some historians have wondered if Newton permitted it to disappear when the Royal Society moved from Gresham College after Hooke's death. Lisa Jardine has a different answer to the mystery: a picture clearly mislabeled "John Ray" is the long-lost portrait of Hooke (Jardine 2004:17).

Literature cited

Ainsworth, G. C. 1976. Introduction to the history of mycology. Cambridge University Press, Cambridge, UK.

Bardell, D. 1988. The discovery of microorganisms by Robert Hooke. American Society for Microbiology News **54**:182–185.

Bennett, J., M. Cooper, M. Hunter, and L. Jardine. 2003. London's Leonardo—the life and work of Robert Hooke. Oxford University Press, Oxford, UK.

Bodenheimer, F. S. 1928–1929. Materialien zur geschichte der entomology bis Linné. Two volumes. W. Junk, Berlin, Germany.

Bud, R., and D. J. Warner, 1998. Instruments of science: an historical encyclopedia. Garland, New York, New York, USA.

Christophers, S. R. 1960. Aëdes aegypti (L.), the yellow fever mosquito: its life history, bionomics and structure. Cambridge University Press, Cambridge, UK.

Cutler, A. 2003. The seashell on the mountaintop: a story of science, sainthood, and the humble genius who discovered a new history of the earth. Dutton, New York, New York, USA.

Drake, E. T. 1996. Restless genius: Robert Hooke and his earthly thoughts. Oxford University Press, Oxford, UK.

'Espinasse, M. 1956. Robert Hooke. William Heinemann, London, UK.

Gregg, C. T. 1978. Plague! The shocking story of a dread disease in America today. Charles Scribner's Sons, New York, New York, USA.

Harris, H. 1999. The birth of the cell. Yale University Press, New Haven, Connecticut, USA.

Hooke, R. 1697. An account of a new voyage round the world, by William Dampier. Royal Society Philosophical Transactions **19**:426–433.

Hooke, R. 1958. Method for making a history of the weather. Pages 173–179 in T. Sprat, editor. The history of the Royal-Society of London, for the improving of natural knowledge. Reprinted from the 1667 edition with notes by J. I. Cope and H. W. Jones. Routledge and Kegan Paul, London, UK.

Hooke, R. 1961. Micrographia: or some physiological descriptions of minute bodies made by magnifying glasses, with observations and inquiries thereupon. Reprinted from the 1665 edition. Dover, New York, New York, USA.

Hooke, R. 1967. Philosophical experiments and observations. W. Derham, editor. Reprinted from the 1726 edition. Frank Cass, London, UK.

Hooke, R. 1968. The diary of Robert Hooke, M.A., M.D., F.R.S., 1672–1680. H. W. Robinson and W. Adams, editors. Reprinted from the 1935 edition. Wykeham, London, UK.

Hooke, R. 1971. The posthumous works. Reprinted from the 1705 edition with introduction by T. M. Brown. Frank Cass, London, UK.

Hooke, R. 1996. Hooke's discourse of earthquakes and subterraneous eruptions (1667–1694). Pages 159–365 *in* E. T. Drake, editor. Restless genius: Robert Hooke and his earthly thoughts. Oxford University Press, Oxford, UK.

Inwood, S. 2002. The man who knew too much: the strange and inventive life of Robert Hooke, 1635–1703. Macmillan, London, UK.

Jardine, L. 1999. Ingenious pursuits: building the scientific revolution. Talese/Doubleday, New York, New York, USA.

Jardine, L. 2004. The curious life of Robert Hooke: the man who measured London. HarperCollins, New York, New York, USA.

Keynes, G. 1960. A bibliography of Dr. Robert Hooke. Clarendon Press, Oxford, UK.

Middleton, W. E. K. 1964. The history of the barometer. Johns Hopkins Press, Baltimore, Maryland, USA.

Middleton, W. E. K. 1966. A history of the thermometer and its use in meteorology. Johns Hopkins Press, Baltimore, Maryland, USA.

Middleton, W. E. K. 1969. Invention of the meteorological instruments. Johns Hopkins Press, Baltimore, Maryland, USA.

Nichols, R. 1999. Robert Hooke and the Royal Society. Book Guild, Sussex, UK.

Patterson, L. D. 1953. The Royal Society's standard thermometer, 1663–1709. Isis **44**:51–64.

Power, M. E. 1945. Sir Christopher Wren and the Micrographia. Connecticut Academy of Arts and Sciences, Transactions **36**:37–44.

Preston, D., and M. Preston. 2004. A pirate of exquisite mind: explorer, naturalist, and buccanee'r; the life of William Dampier. Walker, New York, New York, USA.

Pugliese, P. J. 2004. Robert Hooke (1635–1703), natural philosopher. Oxford Dictionary Of National Biography. Oxford University Press, Oxford, UK.

Purver, M. 1967. The Royal Society: concept and creation. M.I.T. Press, Cambridge, Massachusetts, USA.

Rapport, R. 1997. When geologists were historians, 1665–1750. Cornell University Press, Ithaca, New York, USA.

Richards, P. W. 1981. Robert Hooke on mosses. Farlow Herbarium Occasional Papers **18**:137–146.

Rossi, P. 1984. The dark abyss of time: the history of the earth and the history of nations from Hooke to Vico. Translated by Lydia G. Cochrane. University of Chicago Press, Chicago, Illinois, USA.

Rudwick, M. J. S. 1985. The meaning of fossils: episodes in the history of Palaeontology. Second edition. University of Chicago Press, Chicago, Illinois, USA.

Simpson, A. D. C. 1989. Robert Hooke and practical optics: technical support at a scientific frontier. Pages 33–61 *in* M. Hunter and S. Schaffer, editors. Robert Hooke: new studies. Boydell Press, Woodbridge, UK.

Stimson, D. 1948. Scientists and amateurs: a history of the Royal Society. Henry Schuman, New York, New York, USA.

Wilson, C. 1995. The invisible world: early modern philosophy and the invention of the microscope. Princeton University Press, Princeton, New Jersey, USA.

Wolf, A. 1950. A history of science, technology and philosophy in the 16th and 17th centuries. Second edition. Macmillan, New York, New York, USA.

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Frank N. Egerton
Department of History
University of Wisconsin-Parkside
Kenosha WI 53141
E-mail: frank.egerton@uwp.edu