# Richard Lower: Anatomist and Physiologist

The cardiovascular research of William Harvey (1578–1657), based on what he "could discover [of] the function and offices of the heart's movement in animals through the use of my own eyes," and summarized in *De Motu Cordis* (1628), marked the birth of modern circulatory physiology and made him one of the truly great physicians in medical history (1–3). Harvey's school of Oxford physiology, dismissed by the English Civil War (1642–1657), was revived in the last years of the Commonwealth under the leadership of Robert Boyle (1627–1691) and Thomas Willis (1621–1675) and attracted many hard-working and productive students whose works are still insufficiently appreciated (3–5). One of the most versatile and resourceful of them was Richard Lower (1632–1691) (**Table** [3–6]).

Lower, a Cornishman, matriculated at Christ Church, Oxford, in February 1650 from Westminster School in London. Among his fellow students at both institutions were Christopher Wren (1632–1723), microscopist, physiologist, artist, and architect; John Locke (1632–1704), physician, political scientist, and philosopher; and Robert Hooke (1631–1703) of Hooke's law, later resident scientist of the Royal Society. When Willis was appointed Sedleian Professor of Natural Philosophy in 1660, Lower, Wren, Locke, and Hooke became his students and associates, actively engaging in anatomic and physiologic research (3–6). Before Lower went to London in 1666, he earned a bachelor's degree, a master's degree, and a medical doctorate. From 1656 through 1666, Lower brought his extraordinary skill in anatomical dissection to Willis's pioneering study of the central nervous system and cerebral circulation—assistance that was graciously acknowledged by Willis in his classic monograph, *Cerebri anatome* (1664):

> But for the more accurate accomplishment of [dissection] I had not sufficient leisure, and perhaps, not sufficient ability, so I was not ashamed to summon . . . others. I employed . . . Richard Lower, a doctor of outstanding learning and an anatomist of supreme skill. The sharpness of his scalpel and of his intellect . . . enabled me to investigate better both the structure and functions of bodies, whose secrets were previously concealed. [In a short time] the cerebrum and its appendages seemed clearly revealed and thoroughly explored . . . [then in] the dissection of the [cranial] nerves, the really wonderful dexterity of this worker and his untiring perseverance were conspicuous in the extreme . . . outlines or plans of all the branchings of any particular pair in their long and widespread course, he set down with his own hand (3–6).

When Willis began his Sedleian lectures, he ignored the required exposition of Aristotelian science, instead emphasizing the medicine he studied and practiced. Lower and Locke attended early lectures and left copious notes; these notes were recently translated by Dewhurst, who added valuable information about the Oxford school. Locke's material is particularly detailed about Willis's brain research, which led to the emergence of neurology as a separate medical discipline (3, 5).

Study of the circulation of experimental animals was difficult in the beginning because vascular access was limited by blood clotting and primitive equipment. Quills could not be easily fixed into blood vessels and were neither firm nor durable enough. Silver, however, was malleable and firm, so that pipes of varying caliber could be fashioned and their ends rimmed for anchoring with ligatures. Such improved instrumentation allowed the exploration of many hitherto unplumbed fields by injection studies and administration of many agents. As Lower wrote, "For many years at Oxford, I saw

**Table. Major Events in the Life of Richard Lower**

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|---|---|
| 1632 | Born at Tremeer in Cornwall |
| 1649 | Enrolled at Christ Church, Oxford, from Westminster School, London |
| 1652 | Bachelor's degree, Oxford |
| 1655 | Master's degree, Oxford |
| 1656 | Began 10-year association with Thomas Willis in research and medical practice |
| | Participated in the birth of modern pharmacology in studies to determine the effects of agents injected intravenously into dogs |
| | Started anatomic dissections of the brain and central nervous system |
| | Began anatomic and physiologic investigations of the circulation and of chyle |
| 1660 | Medical degree, Oxford |
| | Willis appointed Sedleian Professor of Natural Philosophy at Oxford |
| 1664 | Willis's *Cerebri Anatome* published |
| | Preliminary experiments with blood transfusion in dogs |
| 1665 | Published *Vindicatio*, a spirited polemic in defense of Harveian science |
| | Performed the first successful mammalian blood transfusion at Oxford |
| 1667 | Followed WIllis to London to establish his own medical practice |
| | Before the Royal Society, carried out the first blood transfusion in a human in England and the second in the world |
| | Fellow, Royal Society |
| 1669 | Published *Tractatus de Corde*, summarizing his cardiovascular and gastrointestinal research |
| 1672 | *De Catarrhis* published |
| 1675 | Fellow, Royal College of Physicians |
| | Death of Willis |
| 1691 | Died in London, probably of pneumonia |

 

others at work, and myself, for the sake, injecting into the veins of living animals various and emetic solutions, many medicinal fluids of that sort," procedures that might be considered the birth of scientific pharmacology (3, 7).

Lower also examined the effects of changes in blood volume on circulatory function and developed methods for cross-circulatory study in animals, obviating clotting by closed arteriovenous connections. His newly devised instruments eventually led to actual transfusion of blood (7). Many of his colleagues were present. . .

> . . . towards the end of February 1665 [when he] selected one dog of medium size, opened its jugular vein, and drew off blood, until . . . its strength was nearly gone . . . Then, to make up for the great loss of this dog by the blood of a second, I introduced blood from the cervical artery of a fairly large mastiff, which had been fastened alongside the first, until this latter animal showed . . . it was overfilled . . . by the inflowing blood."

After he "sewed up the jugular veins," the animal recovered "with no sign of discomfort or of displeasure." Lower had performed the first blood transfusion between animals. He was then "requested by the Honorable [Robert] Boyle . . . to acquaint the Royal Society with the procedure for the whole experiment," which he did in December of 1665 in the Society's *Philosophical Transactions.* On 15 June 1667, "a certain Denis, Professor of Philosophy & Mathematics" in Paris carried out the first transfusion between humans and claimed credit for the technique, but Lower's priority cannot be challenged (3, 7).

Six months later in London, Lower performed the first human transfusion in England, where he "superintended the introduction in his [a patient's] arm at various times of some ounces of sheep's blood at a meeting of the Royal Society, and without any inconvenience to him." The recipient was Arthur Coga, "the subject of a harmless form of insanity." Sheep's blood was used because of speculation about the value of blood exchange between species; it had been suggested that blood from a gentle lamb might quiet the tempestuous spirit of an agitated person and that the shy might be made outgoing by blood from more sociable creatures. Lower wanted to treat Coga several times, but his patient wisely refused. No more transfusions were performed. Shortly before, Lower had moved to London, where his growing practice soon led him to abandon research (3, 5, 7).

When Charles II returned from exile in 1660 to restore the monarchy, Oxford scientists regained prominence and were instrumental in establishing the Royal Society in 1662. At the Society many Oxonians remained active in research, usually in collaboration with Hooke. Some of their presentations drew large audiences from the court, who came to be edified and amused by its members, the virtuosi. Not surprisingly, such doings attracted satirists among the literati; in an early version of his *Essay on Criticism*, Alexander Pope included lines now found only in footnotes (8, 9):

> Many are spoiled by that pedantic throng
> Who with great pains teach youth to reason wrong.
> Tutors, like virtuosos, oft inclined
> By strange transfusion to improve the mind
> Draw off the sense we have, to pour in new;
> Which yet, with all their skill, they ne'er could do.

Lower was both Willis's expert blade and his vigorous advocate, an expert polemicist in an age when the diatribe approached art. When Edmund O'Meara, an Irish galenic–humoral physician, attacked Willis, Lower responded with *Vindicatio* (10), his first important publication. Ostensibly a defense of his mentor, *Vindicatio* is both a vicious attack on O'Meara and his coterie and a ringing assertion of the primacy of the scientific method espoused by Harvey and his followers. When he wrote *Vindicatio*, Lower still held the Harveian view that the fermentation essential for the generation of body heat took place in the left ventricle; he did not yet grasp the significance of the differences in the color of blood in pulmonary artery and vein.

These errors were corrected in his second book, *Tractatus de Corde* (1669), finally translated into English from the Latin in 1932, in which Lower clearly established himself as a scientist (7). In this book he described his experimental methods; reported the transfusions; provided detailed clinical observations about heart disease; and discussed the nature and function of heart muscle, the change in the color of blood as it passed through the lungs, and the behavior of the pericardium. Lower explained that pericardial fluid was secreted in order to bathe "the entire surface of the heart, and render its movement more ready and easy" and to form "a white jelly when heated only a little." If the pericardial sac was "full in hydrops Cordis" (pericardial effusion), he suggested that cardiac filling might be restricted. He also reported the first case of chronic constrictive pericarditis in a young woman who "suffered from breathlessness on the least exertion and had a small and intermittent pulse" for 3 years. At autopsy, her pericardium was so firmly adherent to the heart's surface "that it could only with difficulty be separated [because it] had become thick, opaque, and hard [with] no space for free movement of the heart." Lower explained that she had a paradoxical pulse because "the diaphragm must of necessity have carried the heart down at every inspiration. . . so [that] intermission of the pulse succeeded regularly at every inspiration." He also suggested that pleural effusion or pulmonary edema might restrict

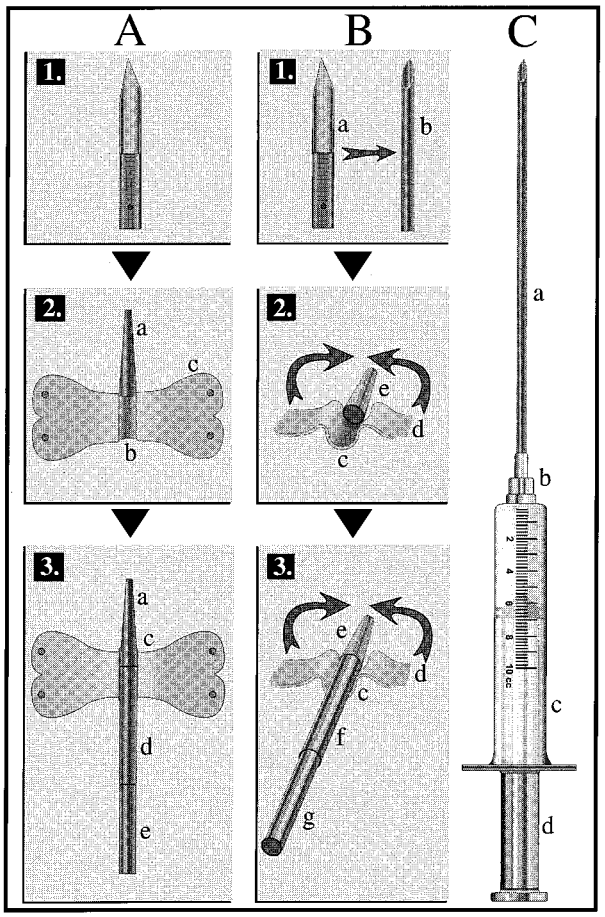


**Figure. The evolution of Lower's instruments into a modern syringe and needle. A.** Lower's original instrument designs. A1. Lower's lancet for venesection. A2 and A3. Lower's apparatus for transfusion: tapered silver tube (*a*) for placement in blood vessel, groove in pipe (*b*) for placement of connector from infusion, flange (*c*) to fix tube by suture, connector or emissary tube (*d*), and wooden rod (*e*) to close emissary tube while preparing infusion. **B.** Changes made to Lower's instruments. B1. The lancet (*a*) is rolled to become a tube (*b*) with a pointed end. B2. The groove (*c*) and the flanges (*d*) are truncated, rolled, and fused to form the hub of the needle. The silver pipe (*e*) is altered to become the needle. B3. The connector (*f*) and the wooden rod (*g*) become the barrel and plunger of the syringe. **C.** The modern syringe with needle. The lancet and silver pipe have become the needle (*a*). The transformed flange has become the needle hub (*b*). The connector, tipped and scored, has become the barrel of the syringe (*c*). The wooden rod has become the plunger (*d*).

excursion of the lungs in a similar manner so that they were "unable to distend sufficiently."

In other studies, Lower clarified the distribution and course of the coronary vasculature and found the heart muscle "more carefully fashioned than all other[s]" and extended his observations of pulmonary circulation. Puzzled by brighter blood in the pulmonary vein than in the pulmonary artery, a fact that was unappreciated in *Vindicatio*, he insufflated the perforated lungs of a dog and found that pulmonary venous blood remained brighter. In a later experiment suggested by Hooke, Lower maintained ventilation with a bellows and confirmed this finding (7).

After moving to London in 1667, Lower devoted his time to medical practice, to preparation of *Tractatus* for publication, and to a few experiments before the Royal Society. Usurped by his growing practice, Lower's research career was nearly over, but Lower did publish his last report, *De Catarrhis*, in 1672, finally translated from the Latin in 1963. Humoral theory had long held that phlegmatic individuals were wet, cold, indolent, apathetic, and susceptible to excessive accumulation of fluid, which could be corrected by sweating or urination. If sweat were suppressed, fluid (catarrh) then flowed from overloaded cerebral ventricles, through the cribriform plate, to the respiratory passages. Such secretion was also called phlegm, coryza, mucus, rheum, rhinorrhea, or defluxion, all connoting a downward flow. Lower's anatomic knowledge led him to question this theory, which he shortly disproved by injecting "milk or some black substance" into openings in the base of the brain and found that neither appeared "around the palate, nostrils, mouth, throat or larynx." He added that "If effluvia or very subtle particles . . . pass along the olfactory nerves to transmit their specific nature to the brain . . . [this] should serve the purpose of retaining the odours and conveying them to the brain"—an astute observation indeed (11).

The antiquity of the word *catarrh* and uncertainty among Galenists about the fluid's anatomical source are attested to by a Salernian verse quoted by Lower in *De Catarrhis*:

> Call your Catarrh a Rheum, where'er it flows
> Towards the chest; if to the throat it goes
> A Cough; and a Coryza, if to the nose.

*Catarrh* survived through World War II in the term *catarrhal jaundice* and in U.S. naval diagnostic parlance as *cat fever*—any upper respiratory condition with a runny nose.

In the appendix to *De Catarrhis*, "On Venesection," Lower described and illustrated his device for controlling blood flow when a vessel was opened for bleeding, which was a common therapy of that time. To prevent injury to vein, nerve, or tendon by excessive penetration of a lancet used "by an inexperienced hand," he made the lancet's shaft "blunt and a little rounded" and pointed its end (**Figure**). Lower wrote that after tourniquet placement, the pointed end should depress the vessel upward and cut it "gradually in a slanting way, crosswise" so that it "will not evade the point" (11). In devising his technique for transfusion, Lower tapered one end of a silver pipe for vascular insertion and perforated flanges at the other for fixation with a ligature (7); a groove made in the pipe held the tube connecting the infusion or animal blood. Eventually, the flanges were rounded, shortened, and fused to become the hub of a needle, derived from the silver tube and lancet, and pointed for easier venesection. The short silver connector became a syringe barrel that

was tipped to fit the hub of the needle and the wooden rod that Lower inserted into the intravenous pipe before connecting his system to the syringe's plunger (**Figure**). Before leaving the laboratory, Lower had designed and made the basic parts for modern syringes and needles, and he had taken the necessary steps, except typing and cross-matching, for intravascular administration of blood and other liquids and for extracorporeal circulation. Without better methods of measurements and knowledge of ABO compatibility, blood coagulation, the behavior of blood gases, osmotic equilibrium, and the role of ions, Lower could do no more.

In 1667, Willis left Oxford for London, where he was asked to practice medicine by the Archbishop of Canterbury—an invitation he could hardly refuse. He retained his professorship at Oxford, but when his delegated lecturer returned to Aristotelian methods, the Oxford physiologic school was finished (3, 5, 7). At his death in 1675, Willis was London's most celebrated physician.

Lower, who had followed Willis to London, inherited his mentor's practice, including attendance at the royal court. However, Lower's opposition to Charles's successor, James II, cost him his court appointment and much of his carriage trade, some of which was regained after the Glorious Revolution of 1688 (7). After his death from pneumonia in January 1691, Lower's relationship to Willis was exalted in a fulsome eulogy typical of the era:

> Unhappy Age! That must at last resign
> A Soul so great, and so Adorn'd as thine:
> Adorn'd with all that former Times could shew;
> All that the Ancients taught, or Moderns knew.
> When the learned WILLIS dy'd, he did impart
> His utmost Skill to thy capacious Heart.
> Full well he knew, there was no other Shrine
> So fit to keep his Treasure in, as thine.
> WILLIS expiring, joy'd in thee, to find
> He'd such a legacy for human kind. (7)

But another eulogy was curt and less kind (7):

> upon Dr. Lowers death being A man of morose disposition.
> By Dr. Baynard
> Had not good nature o're ye ill prevail'd
> Death in attempting Dr. Lower had fail'd
> who might have lived with us many a yeare
> prepared [in his owne pickle] vinigar.
> But when ye Alkali had kill'd ye soure
> His blood being sweetened off went dr. Lower.

If his disposition was morose, his scientific legacy was not. We still remain so much in debt to "His utmost Skill" that we may ask with the first elegist, "How many Millions did thy Art restore?" (7).

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