Chapter 2
Crediting Six Discoverers of Oxygen

John W. Severinghaus

Abstract Recent events have called long-overdue attention to one of the first investigators to discover the roles of something in air changing the color of the pulmonary blood flowing through the lung.

Keywords Oxygen • Michael Servetus • Robert Boyle • Joseph Priestley • Henry Cavendish

More than two centuries before Joseph Priestley, recent historic research has found that the mixing of venous blood and inspired air in the pulmonary circulation was discovered and published by Michael Servetus (Fig. 2.1). He was a Spanish-French precocious, brilliant anatomist and physician, a liberal renaissance humanist, versed in pharmacology, mathematics, astronomy, geography and jurisprudence. Fourteen years after Luther posted his 95 theses, Servetus started critically examining the bible. Influenced by Erasmus and other reformation scholars, from 1531 to 1553, he wrote books and essays claiming there was no support in the Bible for the Christian doctrines of the trinity and infant baptism. In 1553, he published a diatribe against church doctrines titled *Christianismi Restitutio*. Like the Czech liberal early reformer hero Jan Hus 140 years earlier, Servetus was declared a heretic, captured, imprisoned for months and burned at the stake by the Calvinist reformation authorities in Geneva in 1553. They burned all available copies of his book.

In a surviving copy of that book, hidden among the theology scholarship, was his claim that blood flows through the lung where it disposes of waste products and where air causes passing blood to become a bright red color. This was written 75 years before William Harvey published discovery of the circulation in *De Motu Cordis*.

J.W. Severinghaus (✉)
Professor Emeritus Anesthesiology and Cardiovascular Research Institute, University of California at San Francisco, San Francisco, CA 94957, USA
e-mail: jwseps@comcast.net

H.M. Swartz et al. (eds.), *Oxygen Transport to Tissue XXXVI*, Advances in Experimental Medicine and Biology 812, DOI 10.1007/978-1-4939-0620-8_2,

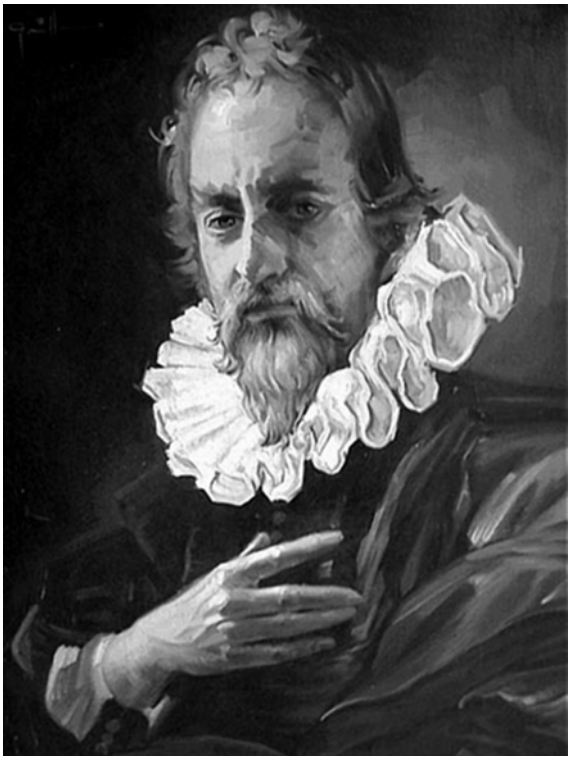

Fig. 2.1 Michael Servetus

In 1668, after working for several years in Robert Boyle's Oxford laboratory, John Mayow published two books of his research (Fig. 2.2). He showed that air was a mixture of two components of which 1/5th was essential for life, consumed during breathing, and in fire, and thus was used to provide both body heat and energy. He named that part of air "spiritus igneo-aereus". He had no way to isolate it or further study its chemistry. His writings were ignored when science adopted the false theory of fire called phlogiston, first described in 1667 by a German alchemist-physician J. J. Becher, and then widely promoted by a famous physician Georg Ernst Stahl in Halle. In that idea, the function of breathing was to eliminate phlogiston released from food within the body. Although some faults in that theory were found, it became the universally accepted chemistry until 1784.

In 1771, Carl Wilhelm Scheele (Fig. 2.3, possible portrait), a brilliant Swedish apothecary and research chemist in Torbern Bergman's chemistry department in Uppsala, generated an unknown gas by heating the calc (oxide) of manganese or mercury. He named it "Ilds Luft" (fire air) because it supported combustion better than air. Unable to understand how it fit into the phlogiston theory, he delayed publication. In 1775 he finally finished writing a book about it and his many discoveries of elements and compounds, but its publication, at first in Swedish and then in

Fig. 2.2 John Mayow

German, was delayed until 1777 by Bergman's 1 year delay in writing a preface, and another year by the German printer. As the book neared publication, he became aware that Priestley had independently described the same method of making this new air. Not able to claim priority, he added a note that he had described his methods and findings to Lavoisier in a letter he said he had posted in September 1774. He stated that Lavoisier had never responded nor acknowledged the letter.

Most commonly credited with discovery of O_2 was Joseph Priestley (Fig. 2.4, by Gilbert Stuart), an English Unitarian (non-conforming) minister. Several churches had fired him as too liberal, so he became a self-trained scientist and teacher, making Warrington the finest academy in England. With Benjamin Franklin's help he wrote a textbook about electricity that became very popular. In 1768, he was awarded the Copley medal, for that book and for having invented and discovered how to make soda water from brewery gas much cheaper than importing pyramont water from France. By 1772, he had discovered seven new gases, N_2O, NO_2, NO, HCl, SO_2, SO_3, and SiF_4 (and later CO). In 1773, the 2nd Earl Shelburne attracted Priestley as a tutor for his sons. He provided a laboratory and funds for his research in his Bowood palace in Calne, Wiltshire, and homes in London and Calne.

Priestley discovered how to generate oxygen in his new laboratory on August 1, 1774, independently of Scheele, but also by heating mercuric calc. It caused a glowing splinter to burst into flames. He named it dephlogisticated air. He showed that mice

Fig. 2.3 Carl Wilhelm Scheele

could live in it longer than in a similar volume of air. He reported that its ability to support life returned after a few weeks following the death of a mouse in it when he included a sprig of mint in the closed space. He immediately sent notes to the Royal Society and friends.

Two months later, while in Paris, Priestley later wrote that he had demonstrated to the world's best chemist Antoine Lavoisier and associates his method of making dephlogisticated air. Priestley wrote that Lavoisier never acknowledged his visit and demonstration. Joseph Black, discoverer of CO_2, repeatedly, in print, accused Lavoisier of failing to credit him. Much evidence has survived that Lavoisier tended to claim credit for work by others.

In 1775, after the Royal Society published several of Priestley's letters, Lavoisier began studying the new gas. He may have failed to discover it earlier because he added charcoal to remove impurities, causing all the O_2 to be consumed. In 1777, he named it principe oxigen, Greek 'oxi' for acid or sharp, incorrectly believing that all acids contain oxygen. He extensively studied its chemistry over the next 10 years, but was unable to prove whether oxygen was a new element.

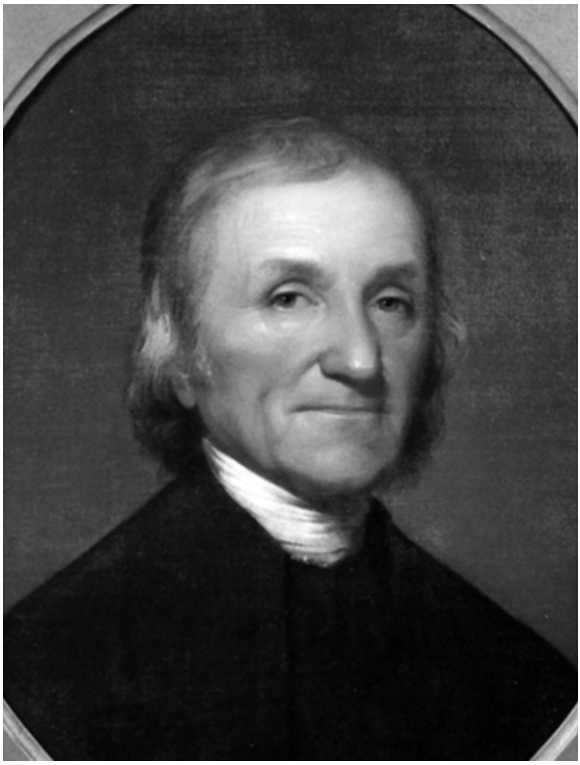

Fig. 2.4 Joseph Priestley

The final proof came from an old experiment. In 1766, Henry Cavendish (Fig. 2.5), by mixing iron filings with acid, had made a new gas he called "inflammable air" (hydrogen). He wrote that when it was burned, pure water appeared on the vessel walls. He was ignored because no scientist, including Lavoisier could believe that burning a gas could generate water. Since antiquity water had been assumed to be an element.

In 1783, 17 years later, the Royal Society invited Cavendish to review, at a Society meeting, his still mysterious, incredible finding. A few weeks later, Cavendish's assistant, Dr. Charles Blagden, traveling to Paris, told Lavoisier about the renewed interest at the Society meeting of Cavendish's 1766 claim of generating water. Lavoisier had read the 1766 paper but was sure that Cavendish was wrong. The Royal Society's invitation and presentation stimulated Lavoisier to prove or disprove the Cavendish experiment.

The final decisive event occurred on June 24, 1783. Lavoisier with eight chemist observers repeated the Cavendish experiment. They were astonished to confirm that, when inflammable air was burned, water appeared. Lavoisier then, suddenly, realized the implication of this experiment. He promptly stated and reported to the Academie: "Inflammable air and oxygen are elements. Water is not an element but a compound made of them!" He forthwith named inflammable air *hydrogen*. With this new insight, he demolished the phlogiston theory and founded modern chemistry.

Fig. 2.5 Henry Cavendish

Lavoisier had become the world's best-known chemist by 1770. His much younger wife Marie-Anne became a skilled draftsman, his secretary, lab assistant, and business manager. In 1789 she commissioned a huge painting by France's celebrated artist Jacques Louis David (Fig. 2.6). It now hangs in the major gallery at the top of the grand staircase at the Metropolitan Museum in New York City.

Lavoisier became very rich as a tax collector, banker and gunpowder manufacturer. He was hated for building a wall around Paris to force incoming merchants to pay taxes on their goods for sale. When the physician-writer Jean-Paul Marat presented inadequate scientific research reports to the *Académie des Sciences* in the 1770s, Lavoisier, the editor, rejected the papers and his several applications for membership. During the terror, Marat's writings based on his residual hatred of Lavoisier, influenced the Revolutionary Tribunal to try, convict and behead him on May 8, 1794.

The French revolution also ended Priestley's safety. Church, Crown and press repeatedly attacked him for speaking and writing in support of the French and

Fig. 2.6 Marie-Anne and Antoine Lavoisier

American revolutions. On the third Bastille day in 1791, drunken rioters destroyed his Birmingham home and laboratory, and many homes and churches of the Unitarian dissenters. Priestley and his family fled to London, then to Philadelphia in 1793. There he persuaded Jefferson, who attended his sermons, to establish liberal education in the American form as we know it.

In 1795, Priestley built a home and laboratory in Northumberland, PA on the Susquehanna River. He wrote in defense of the phlogiston theory 16 years after it was demolished by Lavoisier and abandoned by all scientists. Near his life's end, in 1803 he described himself as an exhausted volcano. He died in 1804 in Northumberland. The American Chemical Society was founded there in 1874, the centenary of Priestley's discovery.

In 1890, the French historian, Edouard Grimaux, claimed that he had been shown Scheele's letter to Lavoisier. He published the text, but said he was unable to show it to any other scholar, claiming that it had disappeared. His publication led to erection of a Scheele sculpture by John Börjeson in Stockholm's Skulpturparken, in Humlegården. But for many scientists, inability to see Scheele's letter led to doubt.

Now jumping ahead another century to 1993, some personal properties of Marie-Anne Lavoisier were donated to the French Academy of Science when the government threatened to tax them. Among these personal belongings was the letter written by Scheele to Lavoisier, dated 30 Sept 1774. Descendants of Marie Anne Lavoisier's

Fig. 2.7 Servetus sculpture

brother had hid it for 219 years, presumably because it established that Lavoisier failed to credit other scientists for their help.

I began this discovery story with Michael Servetus and now will end with recent news about him. At the end of the nineteenth century, a famous author, Auguste Dide, published a book on heretics and revolutionaries, with special praise for Servetus. In 1903, he was elected as a French Senator. He proposed to erect a Servetus honorary monument in Geneva. Servetus supporters then commissioned Rodin's student Clothilde Roch to sculpt Servetus suffering in Geneva's prison. It was finished in 1907. The Geneva town council, still Calvinists, found excuses to refuse to mount it. Instead they named a nearby dingy alley "rue Michel-Servet". Dide then got it mounted in France on the Annemasse town hall square across the border 4 km east of Geneva, taunting the Calvinist Swiss. In 1942 during WW II, because Servetus had promoted freedom of conscience, the French Vichy (Nazi) rulers melted it down.

Finally, in 2011, on Servetus' 500th birthday, with approval of Geneva's now-secular town council, the Roch sculpture, recast from new molds of the century-old plaster original, was erected in the Champel district near the site of his execution, beside Geneva University Hospital (Fig. 2.7). The local Calvinist officials refused to attend the ceremony!

It has taken four and a half centuries to appropriately credit the contributions of these six scientists to the discovery of oxygen. The first five published experiments while the sixth, although a brilliant experimental chemist, found nothing by experiment leading to discovery of oxygen but deserves credit as first to comprehend, after 18 years of denying it, that Cavendish had proved experimentally that water was a compound of oxygen and hydrogen!

http://www.springer.com/978-1-4939-0583-6

Oxygen Transport to Tissue XXXVI
Swartz, H.M.; Harrison, D.K.; Bruley, D.F. (Eds.)
2014, XXX, 372 p. 152 illus., 50 illus. in color.,
Hardcover
ISBN: 978-1-4939-0583-6