Chapter 1
The Most Important Discovery of Science

John W. Severinghaus

Abstract Oxygen has often been called the most important discovery of science. I disagree. Over five centuries, reports by six scientists told of something in air we animals all need. Three reported how to generate it. It acquired many names, finally oxygen. After 8 years of studying it, Lavoisier still couldn't understand its nature. No special date and no scientist should get credit for discovering oxygen. Henry Cavendish discovered how to make inflammable air (H2). When burned, it made water. This was called impossible because water was assumed to be an element. When Lavoisier repeated the Cavendish test on June 24, 1783, he realized it demolished two theories, phlogiston and water as an element, a Kuhnian paradigm shift that finally unlocked his great revolution of chemistry.

Keywords Plagiarism • Cavendish, Henry • Sendivogius, Michael • Discoveries of oxygen • Scheele, Carl Wilhelm

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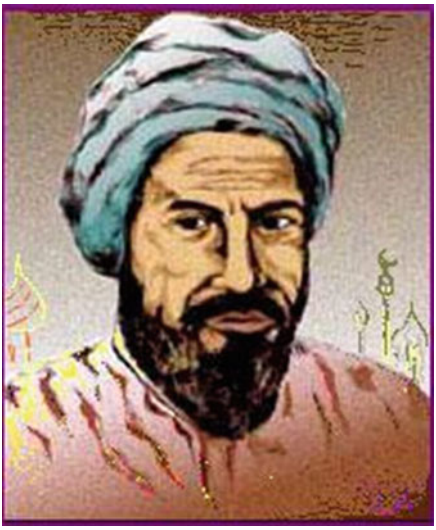
1 Ibn al Nafis 1213–1288



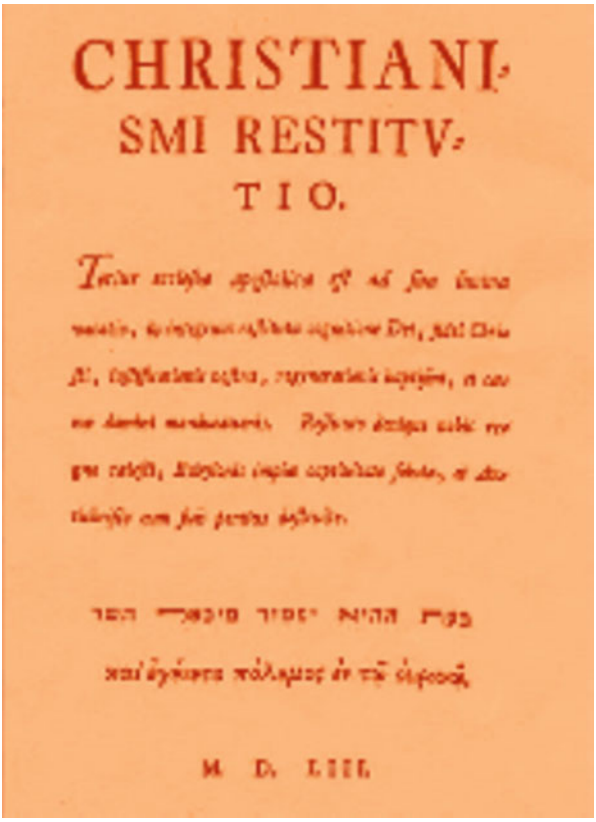
The story of oxygen begins in the thirteenth century with Ibn al Nafis, a Syrian physician and anatomist who became the Egyptian sultan's doctor and chief of Cairo's hospital. In 1250 AD he correctly described the pulmonary circulation and oxygen in a single sentence: "Pulmonary arterial blood passes through invisible pores in the lung, where it mingles with air to form the vital spirit and then passes through the pulmonary vein to reach the left chamber of the heart". Vital spirit was a term used by Galen about 200 AD to refer to red (arterialized) blood.

Nafis clearly was the first to understand lung blood flow, 400 years before William Harvey. This finding was scarcely known in the West until discovered in the Prussian state library in 1924 [1].

Nafis was also the first author to write both SCI FI stories and humorous theological novels.

2 Michael Servetus 1511–1553

Three hundred years later Michael Servetus rediscovered the pulmonary circulation. He was a brilliant polymath, poet, politician, geographer, mapmaker, biblical scholar and doctor who became physician to the archbishop of Lyon, France. Early in Martin Luther's Reformation, Servetus got into trouble by repeatedly writing that doctrines of the trinity and infant baptism were not biblical. Both Catholics and Protestants declared him a heretic. To avoid the Inquisition, he hid in Strasburg under a new name. In 1553 he wrote "Christianity Restored", proposing that the Reformation should return to biblical roots. He sent John Calvin a copy. Here is the cover page.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Here is the cover page. Calvin threatened to have him killed for heresy if he came to Geneva. Inquisition leaders burned him in effigy.

While escaping to Italy, rashly and inexplicably, he snuck into Calvin's church in Geneva. He was recognized, reported, arrested and jailed as a heretic by order of Geneva's government. He was held for over 2 months in prison while Calvin consulted with all the Swiss cantons, and then indicted.

On Oct. 27, 1553, Servetus was burned at the stake in the Champel district of Geneva, with a copy of "Christianity Restored" strapped to his leg.

Calvin ordered the burning of all copies of his book that contained Servetus's only description of the effects of air on blood in the lung. His science report remained unknown for 400 years.

A French historian, August Dide, published a book called "Heretics and Revolutionaries" in 1887. After his election as a Senator in 1900, Dide proposed erecting a monument in Geneva to the most important French heretical martyr, Michael Servetus. In 1907, Rodin's pupil Clothilde Roch finished a sculpture of Servetus in prison. The Calvinist Geneva town council refused to celebrate a heretic. So Dide had it mounted nearby in France, angering the Calvinists. During WWII the

pro-Nazi Vichy government melted the monument down because Servetus had been a martyr to freedom of speech.

In 1953, 400 years after his martyrdom, Roland Bainton, Yale professor of ecclesiastical history [2], published the most authoritative Servetus biography, "Hunted Heretic". He had spent most of 20 years studying Servetus' life and works. (His son is an anesthesiologist at UCSF and his daughter married my wife's brother Bill Peck.) Also in 1953 at Yale, John Fulton, professor of physiology, found Servetus's unknown description of the pulmonary circulation in one of the three surviving copies of his heretical book [3, 4]. It is now clear that Servetus had discovered, a century before Sir William Harvey, that blood flows through the lung tissue, excreting waste products into the air and changing blood color.

In 2011, just 3 years ago, on Servetus's 500th birthday, Roch's sculpture was recast and mounted in Geneva near the site of his burning. Even now, Calvinist authorities refused to attend.

3 Michael Sendivogius 1566–1636

The third discoverer of oxygen, Michael Sendivogius, was a famous sixteenth century Polish noble, physician and alchemist. In 1604 he published that air contains what he named the *Secret Food of Life*. He had realized that this "food" was the same gas emitted by heating saltpetre (potassium nitrate). He called it part of the "salt-nitre of the earth". Sendivogius's writings were frequently copied and read for over a century. However, no one grasped the chemical importance of his discovery, not even Boyle and Newton at Oxford 60 years later.

In 1621, a Dutch inventor named Drebbel built the world's first manned submarine. King James I and a horde of viewers watched it travel submerged 10 miles down the Thames from Westminster to Greenwich. Drebbel never revealed the secret of refreshing submarine air but newspapers and others believed that he had learned from Sendivogius in Prague how to make oxygen on board. I doubt that and suspect he pumped in air through snorkles from little surface floats some said they saw.

Forty years later, Robert Boyle in Oxford wrote that he had spoken with a mathematician who had been on Drebbel's submarine. He said that "Drebbel used a chemical liquor to replace the quintessence of air". Although both Boyle and Newton read Sendivogius, they ignored his work, perhaps because they didn't grasp the importance of his chemistry. Or perhaps they thought he was just another fraudulent alchemist.

Sendivogius' "Food of Life" story was only recently rediscovered. I first learned about him a year ago from Martyna Elas, a Polish biochemist. A biography of Sendivogius was published in Warsaw by Roman Bugnai in 1968 [5] and a study of his alchemical pursuits, "Water which does not wet hands; the alchemy of Michael Sendivogius", was published in 1994 by Andrew Szydlo [6]. Szydlo himself was born of Polish parents in England and educated in London's universities. He teaches chemistry at London's Highgate School. Last June, when in London, I invited him to my lecture and a dinner discussion honoring him. He is a dramatic lecturer with demonstrations to fascinated audiences.

4 John Mayow 1641–1679

In Oxford in 1668 Robert Boyle's former student John Mayow, wrote a book about a part of air he named *SPIRITUS NITRO-AEREUS*. He wrote that it is consumed in fire and that we breathe it to provide both body heat and energy. He was the fourth discoverer of oxygen but ignored Sendivogius.

Mayow's own work sank into obscurity when all scientists accepted the false phlogiston theory postulated by Georg Ernst Stahl. This mythical substance, invented to avoid need for air, obstructed reality-based science for nearly a century.

In 1955, Mayow's book about oxygen was rediscovered and published by Donald Proctor at Johns Hopkins University School of Medicine [7].

5 Carl Wilhelm Scheele 1742–1786

The fifth discoverer of oxygen, Carl Wilhelm Scheele, was born in German-speaking Pomerania. Trained in Sweden, he became a very clever apothecary and chemist. In 1768, he published new studies of metal chemistry. In 1770, he became director of Locke Pharmacy in Uppsala. He worked at the university there with famous chemist Torbern Bergman who helped him publish his work in Latin in the journal Nova Acta.

In 1774, Lavoisier sent his new chemistry textbook to the Academy, including a copy for Scheele whose published work he much admired.

Scheele promptly wrote Lavoisier to thank him for the book. He explained how, in 1771, he had generated a strange new gas by heating certain metallic earths. He had named it FIRE AIR because it greatly brightened a candle flame and supported life in mice. Because neither he nor Bergman could relate it to the phlogiston theory, Scheele had delayed publishing. He asked Lavoisier to repeat the experiment and then help him explain it.

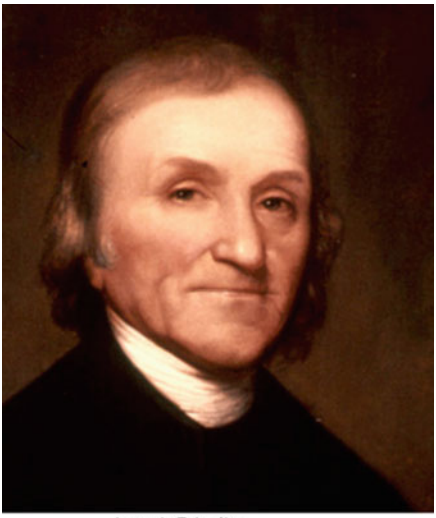
By the time Scheele finally decided in 1775 to publish his fire air with all his experimental findings, he had read about Joseph Priestley's 1774 discovery of the same gas, so it was too late to claim its discovery. Scheele wrote that Lavoisier never answered his letter [8]. His book was finally published in 1777 but he could not confirm his claim of discovering fire air. Scientists and historians therefore ignored his oxygen discovery.

Working in Uppsala and later in Köping, Sweden, as an apothecary, Scheele became one of the world's greatest experimental chemists. He discovered seven elements and much other new chemistry. On February 4, 1775, he was elected to membership in the Royal Swedish Academy of Sciences although his discovery of oxygen was unpublished and unknown. This great honor, with the King of Sweden attending, had never been given to an apothecary.

In 1893, French historian Édouard Grimaux was shown Scheele's letter to Lavoisier, never previously seen. He published the text but claimed the letter then had disappeared.

In 1993, to avoid taxation, various Lavoisier artifacts were donated to the French Academy of Science. Among them was Scheele's 1774 letter to Lavoisier [9]. Descendants of Lavoisier' wife had hidden the letter for 219 years because they feared the great chemist may have used Scheele's methods without acknowledgement, inferring guilt of plagiarism.

6 Joseph Priestley 1733–1804



Joseph Priestley
by Rembrandt Peale

Next comes oxygen's sixth discoverer, Unitarian minister Joseph Priestley. Two churches fired him as too radical but he soon became famous while teaching grammar and science at Warrington Academy near Manchester, helping to make it a leading school for dissenters – in fact, the "cradle of Unitarianism" as one scholar called it.

In the 1760s, Benjamin Franklin, while living in England, befriended Priestley and provided books on electricity as well as experimental apparatus. In 1766 Franklin persuaded the Royal Society to elect him to membership at age 33. The next year, Priestley published the most authoritative and popular text on electricity. He was awarded the Royal Society's Copley medal in 1773, partly for discovering how to make cheap soda water from brewery exhaust. Encouraged by Franklin, the Earl of Shelburne offered Priestley a laboratory on his Bowood estate in Wiltshire. On August 1, 1774, Priestley, by heating red mercury calc, generated a new gas that caused a glowing splinter to burst into flame and supported life in a mouse longer than air in a sealed bottle. Still in thrall to phlogiston theory, he described it as DEPHLOGISTICATED AIR [10] and published. He would write that, in October 1774 in Paris, he described to Lavoisier his method of making this new air. He said Lavoisier never acknowledged his help.

7 Antoine Laurent Lavoisier 1743–1794

Lavoisier had become the world's most brilliant chemist by age 30. In the spring of 1775 he began his studies of Priestley's new gas. He named it *principe oxigene* but continued to refer to it as 'vital air'. However, after 8 years of extensively examining its chemistry he was still unable to prove whether vital air was a new element or a compound. And he doubted but still couldn't disprove the phlogiston theory. By 1783 he was stalled by these dilemmas [11].

8 Henry Cavendish 1731–1810

In 1766, Cavendish discovered and published how to make an inflammable gas (H_2) by putting iron filings in strong acid [12]. In the late 1770s, others noted that burning inflammable air caused dew to form on the burner tube's walls. Cavendish analyzed and proved the dew was pure water. His peers in the Royal Society considered his claim of making water to be wrong, since all assumed that water is an element that can't be made.

In 1783, Cavendish' associate, physicist Charles Blagden, persuaded the Royal Society to invite Cavendish to try to explain his 'impossible' finding. Cavendish replied that he had repeated burning inflammable gas with Priestley's air and it again produced water. It remained a mystery. Blagden then visited Lavoisier, asking help to understand the unbelievable Cavendish report. His visit stimulated Lavoisier to test the Cavendish-Priestley observation by burning inflammable air himself.

On June 24, 1783, Lavoisier invited eight chemists to watch him prove that Cavendish was wrong. When water appeared, Lavoisier was stunned! He suddenly realized that the Cavendish observation had revealed a universally accepted error. He declared: "Inflammable air and vital air are elements. Water is *not an element* but a compound made of them".

Lavoisier's insight created the greatest *Kuhnian paradigm shift* [13] in the history of chemistry. It unlocked his great chemical revolution. Cavendish had provided the key.

Lavoisier named inflammable air hydrogen and vital air oxygen. Over the next 6 years Lavoisier demolished phlogiston and revised all chemical theory. In 1788, at age 45 he finished writing his great treatise Elements of Chemistry [14].

In celebration, his 29-year-old wife Marie Anne commissioned a portrait from France's greatest artist of the time, Jacques Louis David. He charged perhaps the highest artistic fee of all time, 7000 livre, about a quarter million US dollars for this now famous huge (2.6 m tall) double portrait of Lavoisier and his wife. It is well worth visiting the Met.

9 What About Lavoisier?

In his Elements of Chemistry Lavoisier falsely wrote: "This species of air was discovered almost at the same time by Mr Priestley, Mr Scheele, and myself", both a bold lie and proof that he had read Scheele's 1774 letter revealing his method of making fire air but failed to acknowledgement it!

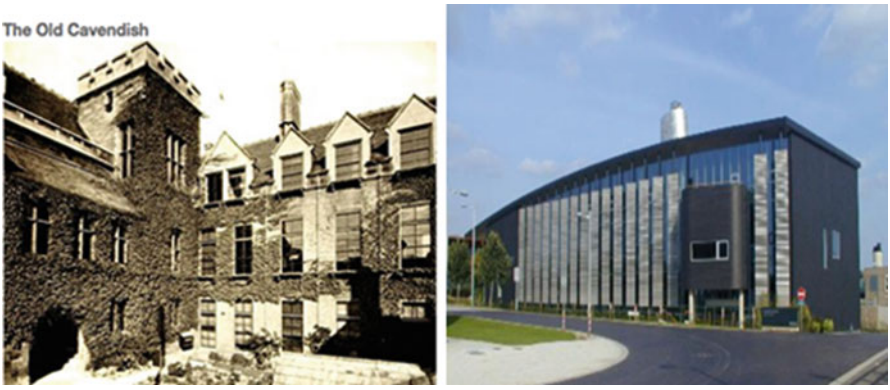
Lavoisier was condemned in print by Edmond Genet, later French ambassador to the United States, by Joseph Black, the discoverer of CO_2, and by Priestley himself who accused him of plagiarism [15] for claims of discoveries that actually belonged to others.

Lavoisier was a brilliant polymath, meticulous scientist and the most able chemist of his time. Born into a wealthy family, he became even richer as a despised tax "farmer" in France's *ancien régime* who built a hated wall around Paris to ensure that incoming merchants would pay taxes. As a leading figure in the Academy of Science in 1780 he belittled the work of an aspiring academician, Jean Paul Marat, making a bitter enemy. More than a decade later, during the French Revolution, the now radical revolutionary publicist Marat would repeatedly demand in newspapers that Lavoisier be guillotined as among the worst of the *ancien régime*. At the peak of the Reign of Terror, the Revolutionary Tribunal tried, convicted and beheaded the great chemist all in 1 day, May 8, 1794 [11].

10 What About Henry Cavendish, FRS?

He was part of eight centuries of an immensely wealthy aristocratic family. He was very shy and reclusive. He never married and never sat for a portrait. He built his laboratory and lived most of his life in the home of his father, Lord Charles Cavendish, in Bloomsbury on the corner of Bedford Square beside the British Museum and University College. This plaque is on the wall there.

Cavendish was a natural philosopher, scientist, and a great experimental and theoretical chemist and physicist, distinguished for accuracy and precision in his researches into the composition of atmospheric air, the properties of different gases and the law governing electrical attraction and repulsion. He was first to weight the earth by a method still named the Cavendish experiment. The very famous original and new physics laboratories in Cambridge are named after him.



Credits: Milton Djuric, history editor, Williams College and Martyna Elas, biochemist, Krakow Univ (for Sendivogius).

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