The Early Pneumatic Chemists and Physicians:

Their Influence on the Development of Surgical Anesthesia

Thomas E. Keys, M.A.*

MANY OF US have taken for granted that modern anesthesia is strictly an American discovery. Even Robert Liston, the famous English surgeon who is usually thought of as the first in Great Britain to use ether anesthesia in a major surgical operation (Dec. 21, 1846), credited the Americans with the innovation. He told the audience witnessing the procedure: "This Yankee dodge beats mesmerism hollow."[1]

But, of course, all discoveries are dependent upon previous knowledge; and I propose here to trace the steps leading to the development of surgical anesthesia. The inspiration for this lecture came from reading Dr. F. F. Cartwright's book, *The English Pioneers of Anaesthesia.*[2] In this stimulating work Cartwright considered the pioneer efforts of Thomas Beddoes and Sir Humphry Davy and their importance in the development of anesthesia. He also included a section on Henry Hill Hickman and his "suspended animation" which, although apparently unrelated to the efforts of Beddoes and Davy, nevertheless forms a logical sequence.

Cartwright's thesis is that "anaesthesia is the outcome of pneumatic medicine"[2a] and that pneumatic medicine depended upon pneumatic chemistry as well as upon the efforts of the early physiologists who discovered the nature of oxygen and the mechanism of respiration. After studying the evidence I am inclined to agree with Dr. Cartwright although, necessarily, my approach is somewhat different.

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Pneumatic Chemistry

In the field of science the 18th and 19th centuries brought about important advances due to the impetus from the great achievements of the 17th century. Gases were being discovered and studied then, and the pioneers in this field that especially claim our attention are Otto von Guericke and Robert Boyle. Everyone today is familiar with the facts that air has weight and that it exerts pressure. But these truisms were not known until the 1600's. Until this time Aristotle's writings dominated the thinking of many generations. He was the originator of the expression that "nature abhors a vacuum," and thought that air's natural property was lightness, not heaviness.

Interestingly enough, Torricelli, the Italian natural philosopher (1608–1647), discovered the barometer. About his time the suction pump was invented to raise drinking water from a well and Torricelli found that water could be raised to a height of 33 feet by such a pump. Having this information, Torricelli experimented with mercury, whose density is about 13 times that of water. He found that a column of mercury of about 30 inches was upheld by atmospheric pressure. He also determined that changes in the height of the column meant changes in the pressure of the air. This was the first crude barometer. The French philosopher Pascal (1623–1662), working with Torricelli's barometer, demonstrated that air pressure diminishes with altitude.

Meanwhile, Otto von Guericke (1602–1686) of Germany made experiments on the vacuum. He invented the first effective air pump. By its use he removed the air from a large metal sphere made of two halves placed together. The atmospheric pressure held hemispheres together, and they could not be separated even

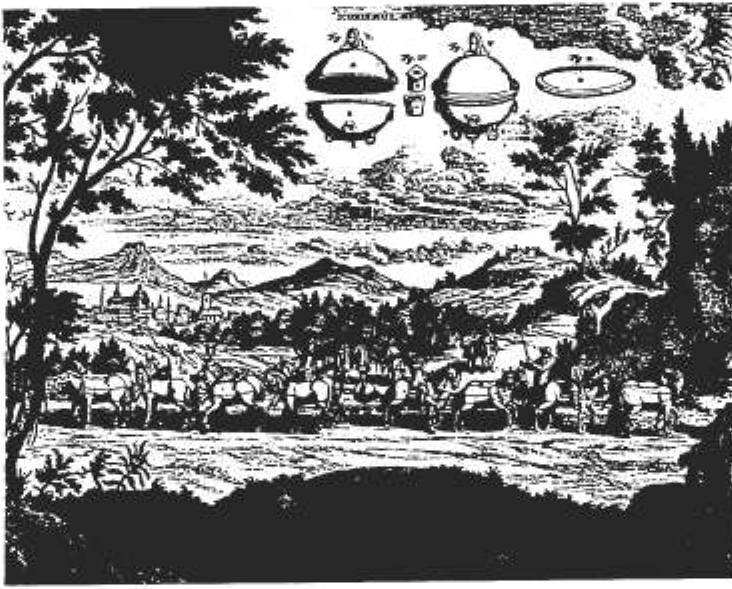


FIG. 1. Otto von Guericke's demonstration. (From Wolf, A.: A History of Science, Technology, and Philosophy in the 16th and 17th Centuries. New York, The Macmillan Company, 1939, opp. p. 100.)

by teams of horses harnessed to them and driven in opposite directions (fig. 1).

Robert Boyle. Much has been written by and about Robert Boyle (fig. 2),[3] and everyone is familiar from high-school days with Boyle's law that the pressure of a gas is directly proportional to its density[4]—or in other words, that volume and pressure vary inversely at constant temperature. As pointed out by Marie Boas,[5] Boyle's public reputation has always been greater as a physicist than as a chemist; but he thought of himself as a chemist, and his influence on chemistry is lasting and important.

The Honourable Robert Boyle was born at Lismore in Ireland in 1627. He was the seventh son of Richard Boyle, the Earl of Cork. Robert was educated at Eton and Geneva. After a few years in Italy and France, he returned to his estates at Stalbridge in Dorchester in 1644. Then, after 14 years of living at Oxford, he moved to London. He spent much of his time in experimental study of many branches of natural science, and was one of the founders, and for a time, President, of the Royal Society. He died in 1691 and was buried in Westminster Abbey.

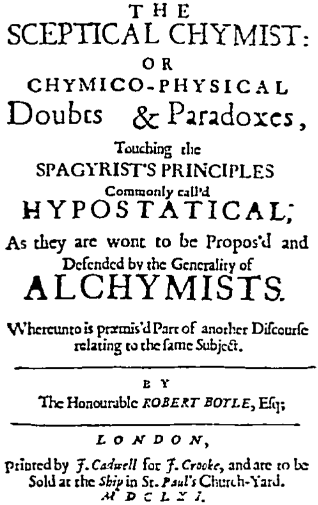
Of his numerous works, the most important is the *Sceptical Chymist,*[6] first published in 1661 (fig. 3). As mentioned by Pattison Muir,[7] the subjects which chiefly claimed Boyle's attention were air pressure, distribution of pressure in liquids, fire and flame, acids and alkalis, volatility, and especially the composition and qualities of material things.

Boyle knew about the work of Von Guericke and, with the help of Robert Hooke, constructed an improved air pump. With this pump Boyle demonstrated that air has weight and therefore is a material substance. Boyle used his pump in experiments upon small animals and showed that air is necessary to support life.

Boyle's interest in the nature and action of fire almost led him to the discovery of oxygen.[5a] He observed that fire burning various substances when placed in the receiver of his pump became extinguished when the air surrounding it was withdrawn. He also noted that flame went out, even in an unexhausted receiver, and that only some part of air was necessary for combustion. He concluded that there must be something in the atmosphere necessary to the existence of flame.

Robert Hooke. Robert Hooke,[5b] who assisted Boyle in the construction of the pump as mentioned earlier, was born in 1635 at Freshwater, Isle of Wight. In 1655 he was

FIG. 2. Robert Boyle. (From Farber, E., ed.: Great Chemists. New York, Interscience Publishers, Inc., 1961, opp. p. 137.)



THE
SCEPTICAL CHYMIST:
OR
CHYMICO-PHYSICAL
Doubts & Paradoxes,
Touching the
SPAGYRIST'S PRINCIPLES
Commonly call'd
HYPOSTATICAL;
As they are wont to be Propos'd and
Defended by the Generality of
ALCHYMISTS.
Whereunto is præmis'd Part of another Discourse
relating to the same Subject.

BY
The Honourable *ROBERT BOYLE*, Esq;

LONDON,
Printed by *J. Cadwell* for *J. Crooke*, and are to be
Sold at the *Ship* in St. *Paul's* Church-Yard.
MDCLXI.

FIG. 3. Title-page to the first English edition of Boyle's The Sceptical Chymist. (Reproduced from the facsimile edition issued by Dawson's of Pall Mall, 16 Pall Mall, London, S.W. 1, 1965.)

employed by Boyle as a research assistant. In 1662 he was appointed Curator of Experiments to the Royal Society, and he carried out physiologic experiments until his death in 1703. In 1664 Hooke showed that a lamp would continue to burn much longer, and a bird or mouse would continue to live much longer, in a receiver containing compressed air than in one containing air at atmospheric pressure. In this respect he advanced beyond Boyle, for he determined that the same air necessary for combustion was also essential for respiration. In 1665 Hooke showed that plants need air for their growth and development. In 1667 and 1668 Hooke studied experimentally the entry of air into the blood of animals. He showed by experiment that the blood of an embryo lives by the help of the mother's respiration. Another experiment showed that blood when exposed to air changes in color from dark to light.

FIG. 4. Richard Lower. (From Stirling, W.: Some Apostles of Physiology. London, Waterlow and Sons, Limited, 1902, p. 14.)

Richard Lower. The noted English physician, Richard Lower[8c] (1631–1691) (fig. 4), is remembered chiefly for transfusing blood between animals for the first known time (February 1665).[9]

In his *Tractatus de Corde*, published in 1669,[10] Lower showed that the blood in the arteries and veins is the same, and that the change in color from dark to bright red is due to the action of the air in the lungs.

John Mayow. Another contemporary English physician who contributed to our understanding of respiration was John Mayow[11a] (1643–1679), who was born in London, studied law and medicine at Oxford, and practiced medicine at Bath. He first published his small treatise on respiration in 1668. That same year he wrote a small volume on rickets. These treatises were revised and issued, along with three others, at Oxford in 1674.[12] According to Wolf,[8c] Mayow knew Lower personally and was familiar with his experimental work as well as the experiments of Boyle and Hooke. His publications caused hardly any notice, though they brought together in a concise form the scattered contributions of his contemporaries. But a century later, after the discovery of oxygen, Mayow was recognized as one who had anticipated Priestley, Scheele and Lavoisier by a hundred years. It is thought that Thomas Beddoes[12a] was the first to recognize Mayow's contributions.

Mayow thought that the air we breathe was impregnated with a nitrosaline salt whose volatile part came from the air and whose fixed part was derived from the earth; he felt that these "nitro-aerial" particles were indispensable to the production of fire. Thus Mayow anticipated the discovery and respiratory use of oxygen. He thought, too, that fermentation and respiration were also due to the action of nitro-aerial particles—that in respiration these particles are taken from the air by the lungs and passed into the blood. Thus he believed that these particles played a leading role in the life and movement of animals and plants.

FIG. 5. Joseph Priestley. (From Farber, E., ed.: Great Chemists. New York, Interscience Publishers, Inc., 1961, opp. p. 241.)

Joseph Black. Another chemist, also a physician, who contributed to the new chemistry of gases was Joseph Black[13a] (1728–1799). He was born of Scottish parents in Bordeaux, went to grammar school in Belfast, and enrolled in 1746 in the University of Glasgow. There, he decided to study medicine and was attracted to chemistry by William Cullen. Cullen noticed his aptitude and took a personal interest in Black, imparting to him his fine sense of experimentation. Black completed his medical education at the University of Edinburgh.

His thesis, presented in 1754, was devoted chiefly to his experimentation with magnesia alba[14] and helped to lay the foundation of quantitative analysis in chemistry. He found that heating caused magnesia to lose seven-twelfths of its weight, but only a small portion of this loss could be recovered by water condensation. Black concluded that the rest of the weight loss must be due to the emission of uncondensable vapors from the heated magnesia. Upon further experimentation he was able to determine the precise amount of weight lost by magnesia when heated, and he reasoned that the difference between uncalcined and calcined magnesia was that the former contained a considerable quantity of air. He thought that there was a difference between this "fixed" air and atmospheric air. Thus, he contributed to our understanding of the chemical nature of carbon dioxide. Black succeeded to Cullen's chair in chemistry and anatomy at Glasgow University, and in 1766 he followed Cullen as professor of chemistry and medicine at the University of Edinburgh. There he remained until his death in 1799.

Joseph Priestley. The next advance was was made by Joseph Priestley (1733–1804), a Unitarian minister and a celebrated man of science[13b] (fig. 5). Priestley was born at Fieldhead, Yorkshire, in 1733.[11b] He studied for the ministry and was ordained in 1762. In 1772, William Fitzmaurice-Petty, who later became the first Marquis of Lansdowne, appointed Priestley his librarian or literary companion. In spite of his lack of scientific training, Priestley laid the foundation for the chemistry of gases.

Fig. 6. Carl Wilhelm Scheele. (From Farber, E., ed.: Great Chemists. New York: Interscience Publishers, Inc., 1961, opp. p. 255.)

Priestley's first experiments dealt with carbon dioxide, which he termed "fixed" air. He investigated also the solubility of fixed air in water and produced what we now call "soda water." Priestley's experiments on oxygen dated from 1771. In 1772 Priestley had also prepared nitrous-oxide air.[15] As pointed out elsewhere,[11c] the oxides of nitrogen are sometimes toxic. This, and the fact that Priestley had to work with impure nitrous oxide, probably are the reasons he did not discover the anesthetic properties of the gas. He did say, however, "I cannot help flattering myself that, in time, very great medicinal use will be made of the application of these different kinds of air to the animal system."[11c]

Priestley obtained many distinctions. The Copley Medal was awarded to him in 1773. He was elected an Associate of the French Academy of Sciences and a member of the Imperial Academy of Sciences at St. Petersburg. But he was known to be sympathetic with the French revolutionists, and a mob burned his house in 1791. After the riots his three sons migrated to America in 1793, and Priestley and his wife followed them in 1794. He made North Cumberland, Pennsylvania, his

FIG. 7. Henry Cavendish. (From Farber, E., ed.: Great Chemists. New York, Interscience Publishers, Inc., 1961, opp. p. 229.)

home. He continued his experiments until his death in 1804.

Carl Wilhelm Scheele. Notice also is due Carl Wilhelm Scheele[13c] (1742–1786) (fig. 6), who independently discovered oxygen in the same year as Priestley (1771) but did not publish his work on this subject until 1777. Scheele was born at Stralsund, Pomerania, which then belonged to Sweden. His report,[16] written in his native German, was translated into Swedish for the *Transactions of the Academy of Sciences* at Stockholm; this Swedish version was translated into English in 1786 by Thomas Beddoes.[17] Much later—in 1923—the original German was translated into English for the Alembic Club.[18] Because of this indirection and delay, Scheele's endeavors have not been fully appreciated; but according to Birger Strandell,* the Editor of *Acta Medica Scandinavica,* this will be remedied by publication of a definitive biography of Scheele now being prepared.

Scheele moved to Upsala in 1770. He had worked in pharmacies from the age of 14, and in 1775 he was elected a member of the Academy of Sciences at Stockholm and that same year opened his own pharmacy at Köping on Lake Malmar. As mentioned by Wolf,[13] Scheele worked unceasingly in all fields of chemistry, and overwork caused his early death. Scheele first determined the properties which distinguished air from other gases and showed by many experiments that air comprises two different gases. He prepared oxygen in many different ways. Time does not permit us to consider all of Scheele's discoveries, but his experiments embraced oxygen, nitrogen, carbon dioxide, hydrochloric acid, sulfuretted hydrogen, and nitric oxide. For his discoveries Scheele is regarded as one of the founders of organic chemistry.

Henry Cavendish. Another pneumatic chemist of distinction was Henry Cavendish (fig. 7), who was born at Nice in 1731 and died in London in 1810. Like many others of his generation, he was interested in many branches of science, including astronomy, mathematics, chemistry, and physics. As pointed out by Thorpe,[19] he made accurate observations on the properties of carbonic acid and hydrogen, and was the first to establish the uniformity of the composition of air. Thorpe thought Cavendish's great contribution was the discovery, through many experiments, that water is a product of the union of hydrogen with oxygen. His experiments also led to the discovery of the composition of nitric acid.

Antoine-Laurent Lavoisier. A giant of the chemistry of his era was Antoine-Laurent Lavoisier (fig. 8), who was born in Paris in 1743. His wealthy father, a lawyer, was interested in science, but probably wished his son to complete a legal education. Lavoisier also studied astronomy, botany, chemistry, and geology.[13e, 20] In 1772 he began the study of combustion and oxidation of metals. He proved that sulfur and phosphorus gain weight when they are fired and thought that this was due to their absorption of air. In 1768 Lavoisier was elected a member of the Royal Academy

* Personal communication.

of Sciences.[13e] About that time he was appointed a farmer-general of taxes. The income from this post of tax collecting was used to defray the heavy costs of his experiments.

Lavoisier, with the help of his wife, repeated many of the experiments of his predecessors. He confirmed Cavendish's findings concerning the composition of water. He demonstrated, also, that Priestley's "dephlogisticated air"—which Lavoisier named "oxygen" —is the element actually absorbed by metals.

Although he is not thought of as making original observations, Lavoisier brought together all the chemical knowledge available and verified many chemical truths that today are taken for granted.

His two important books, both of which were translated into English, were his *Opuscules Physiques et Chimiques* (1774) and his *Traité Elementaire de Chemie* (1789).

According to Wolf,[13f] Lavoisier furnished the correct explanation for respiration as well as that for combustion. He was an indefatigable worker in organic analysis and was also known for his many quantitative studies.

FIG. 8. Antoine-Laurent Lavoisier. (From Farber, E., ed.: Great Chemists. New York, Interscience Publishers, Inc., 1961, opp. p. 265.)

FIG. 9. Thomas Beddoes. (From Frontispiece to Stock, J. E.: Memoirs of the Life of Thomas Beddoes, M.D., With an Analytical Account of His Writings. London, J. Murray, 1811.)

Because he was a tax-collecting official, the Revolutionary Committee issued a warrant for his arrest, and in 1793 he went into hiding. On May 8, 1794, he surrendered himself and was sent to trial. Before the day was over he was beheaded by the guillotine on very insubstantial charges.

Charles and Gay-Lussac. Two other contemporary Frenchmen whose contributions claimed the attention of anesthesiologists[21] were Jacques Alexandre Cesar Charles (1746–1823) and Joseph Louis Gay-Lussac (1778–1850). Both made several balloon ascents and studied the expansion of gases. Charles, who was the first to use hydrogen for balloon inflation (1783), anticipated Gay-Lussac, who in 1802 found experimentally that equal volumes of all gases kept at constant pressure expand by equal increments of volume with each degree of rise in temperature. In other words, this is the law of physics named after both men—that the pressure of a gas kept at constant volume is directly proportional to its absolute temperature.

Applications in Medicine

The principles laid down by the pneumatic physicists and chemists mentioned and by others led to the rise of pneumatic medicine. Inhalations have a long history; and Ellis,[22] in his study of primitive anesthesia, referred to the yogis of India, who by repeated deep breathing can bring about a state in which pain is reduced so that they can be indifferent to cuts by knives. Among other examples, Ellis cited from the Ebers Papyrus a statement that smoke which had certain ingredients added to it was inhaled for therapuetic purposes. Also on record is Hoah Tho, a Chinese surgeon who practiced about AD 230 and had his patients inhale medicines prior to surgery. It is thought that the drugs he used in this manner probably were aconite, datura, and hyoscyamus. As mentioned elsewhere,[23] Hugh of Lucca, in the thirteenth century, was reported by his son Theodoric to have prepared a soporific agent which had opium as a base and included hemlock, henbane, mandragora, and other ingredients. It was administered on a sponge and apparently was successful in producing anesthesia for some surgical procedures. There were many other examples, but time requires us to move forward to the juncture when the contributions of the pneumatic chemists were available.

One of those who sought to apply the new knowledge in pneumatic medicine was Richard Pearson of Birmingham, England. His pamphlet, *A Short Account of the Nature and Properties of Different Kinds of Airs, so far as relates to their Medicinal Use,* was published in 1795. After citing a case of the application of carbonic-acid air to cancerous sores with favorable results, he said:

> We shall not attempt to enumerate all the diseases in which pneumatic medicine promises to be of use. It will be sufficient to state in a general way, that those are proper cases for the application of factitious airs, which resist, or do not readily give way to the common modes of treatment: such are consumption, asthma, scrophula, palsy, etc.[24]

Pearson also mentioned "that he has found *the Vapour of Aether* remarkably serviceable in phthisical cases."[24]

Thomas Beddoes. The principal focus of our attention, however, must be Thomas Beddoes and the Pneumatic Institution at Clifton near Bristol. The late Dr. Albert Miller, whose contributions to anesthesia are well known to this audience, said in 1931:

> . . . no other event in the history of nations has so influenced modern civilization as did the work of the Pneumatic Institution at Clifton. Without this link in the chain of scientific progress, we might today lack all the applications of chemical knowledge to medicine and many of the physical aids to diagnosis and treatment of disease, including surgical anesthesia and the *x*-ray.[25]

Although the claim may be an exaggeration, there is no doubt that Beddoes and his Pneumatic Institution had a profound influence upon the development of anesthesiology.

Thomas Beddoes (fig. 9) was born at Shifnal, England, in 1760.[2b] After being privately tutored, he became in 1776 a student at Pembroke College, Oxford. Here he studied modern languages, which enabled him later to translate many of the works of the foreign pneumatic chemists into English. The other subjects that interested him were chiefly scientific, including chemistry. After receiving his A.B. degree in 1781, Beddoes began the study of medicine in London, working under Sheldon; in 1784 Beddoes continued his medical education at the University of Edinburgh, where he was influenced by William Cullen. In 1786, as I have mentioned, Beddoes translated Scheele's *Chemical Essays,* and in that year he received his M.D. degree from Oxford. In 1787 Beddoes was appointed Lecturer in Chemistry at Oxford. The subject of chemistry was timely and popular, and Beddoes possessed eloquence and personal magnetism, so his lectures were well attended.[2b] One of his early pupils was Davies Giddy (later Davies Gilbert), who became a lifelong friend.

In 1790 Beddoes sent up a balloon filled with a mixture of "light" and "heavy" inflammable air. The balloon carried a paper treated chemically to burn steadily without flame, which fired the mixture at an elevation of one mile. The casing of the balloon fell away and a ball of flame shot straight up in the air. This experiment was to explain the occurrence of meteors![2c] In 1790 also, as I have mentioned, earlier, Beddoes published an analytical account of John Mayow's work on respiration.

No sympathizer with the French revolution was regarded with favor in England, but as Stock[26] declared, "Beddoes hailed the dawn of French freedom with enthusiasm." During 1792 he published a pamphlet concerning his views of the revolution. This created a clamor at Oxford; and Beddoes, finding his position intolerable, resigned. In 1793 he moved to Bristol with letters of introduction to Richard Lovell Edgeworth, and he remained there for the rest of his life. Beddoes' chemical interests and his medical training led him to advocate pneumatic medicine. At Bristol he set up a "gaseous" laboratory, which at first met with opposition, but his new friend Edgeworth interceded for him so that he continued in his practice and experiments. Cartwright characterized the beliefs of the pneumatic physician as follows:

> The "pneumatic physician" held that atmospheric air, a loose combination of nitrogen with oxygen, was the principle best adapted to the healthy individual, but that the course of disease might be affected by deliberate alteration of the constituents.[27]

For example, Beddoes felt that consumption could be cured by submitting the patient to an atmosphere devoid of oxygen,[2d] and he described a case in which inhalation of hydrogen proved helpful.

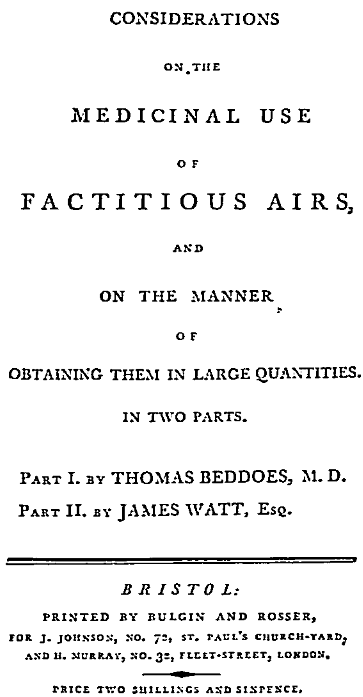
Beddoes built up a large practice in the nearby village of Clifton, especially among the visitors who came to Hotwells for the beneficial effects of the springs. His contact with Edgeworth and his circle of friends led to the marriage of Thomas Beddoes to Anna Edgeworth in 1794. Beddoes kept busy with his practice, experiments in his laboratories at Bristol, and the writing of books and pamphlets.

Meanwhile, his work on pulmonary tuberculosis attracted the attention of the famous engineer, James Watt (1736–1819) (fig. 10). Watt had a consumptive son, Gregory, who was put under Beddoes' care. As a result of this interest, James Watt designed Beddoes' gas machines and also aided in the manufacture of the gases employed by Beddoes in his pneumatic medicine.

FIG. 10. James Watt. (From Crew, H.: The Rise of Modern Physics, a Popular Sketch. Baltimore, Williams & Wilkins Company, 1928, opp. p. 204.)

With Beddoes, Watt coauthored the famous pamphlet *Considerations on the Medicinal Use of Factitious Airs,* first issued in 1794 (fig. 11).[28] In the proposal (that is, the preface), Beddoes said ". . . it is abundantly proved that the application of factitious airs to the cure of diseases, is both practicable and promising. . . . This object," Beddoes continued, "I conceive, may be much more effectually accomplished in two years, by means of a small appropriated *Institution,* than a twenty years of private practice. . . ."[28a]

Indeed, his enthusiasm knew no limits. After animal and human experimentation and treatment, he reported in the second edition of his pamphlet cures for dropsy, asthma, the ill effects of taking opium, paralysis, chlorosis, epilepsy, headache, dyspepsia, scrofulous tumors, impaired sense (hearing?) organs, ulcers,


CONSIDERATIONS

ON THE

MEDICINAL USE

OF

FACTITIOUS AIRS,

AND

ON THE MANNER

OF

OBTAINING THEM IN LARGE QUANTITIES.

IN TWO PARTS.

PART I. BY THOMAS BEDDOES, M. D.

PART II. BY JAMES WATT, ESQ.

BRISTOL:

PRINTED BY BULGIN AND ROSSER,

FOR J. JOHNSON, NO. 72, ST. PAUL'S CHURCH-YARD, AND H. MURRAY, NO. 32, FLEET-STREET, LONDON.

PRICE TWO SHILLINGS AND SIXPENCE.

FIG. 11. Title page to the first edition of Considerations on the Medicinal Use of Factitious Airs [1794]. (Courtesy of the National Library of Medicine, Hist. Med. Div.)

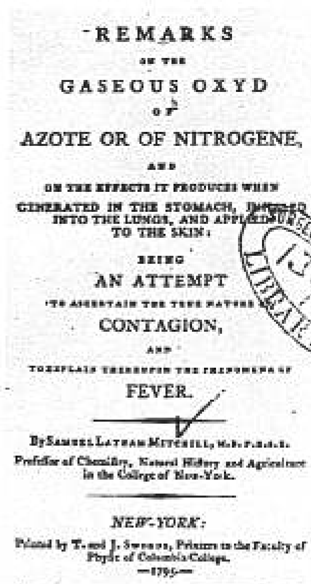
carbuncles, syphilis, and other conditions, including melancholia![29]

And in the third edition of this work Beddoes continued to extol the medicinal properties of these airs: "I could prove by sufficient testimonies, how favourably the proposal for the extensive employment of aeriform remedies has been received in different parts of the civilized world." He even referred to the yellow fever epidemic in Philadelphia, and suggested that medicinal airs could cure that disease.[30]

G. M. Smith, in his *History of the Bristol Royal Infirmary,* mentioned that Beddoes not only treated hundreds of patients with nitrous oxide inhalations but advocated the inhalation of cow's breath as a remedial agent![31]

In Part II of the brochure, James Watt described the "apparatus for producing and receiving the various airs which may be supposed to be useful in Medicine. . . ."[28b]

Speaking as a layman, Watt reasoned: "It appears to me, that if it be allowed that poisons can be carried into the system by the lungs, remedies may be thrown in by the same channel."[28c] Watt further felt that experiments with different gases might prove one of them to be beneficial in consumption and analogous disorders of the lung. He suggested, also, that various substances be tried in the powdered state and inhaled deeply. Remedies to be tried in this respect included iron for disorders of the lungs, calx of zinc for healing


REMARKS

ON THE

GASEOUS OXYD

OF

AZOTE OR OF NITROGENE,

AND

ON THE EFFECTS IT PRODUCES WHEN

GENERATED IN THE STOMACH, INHALED INTO THE LUNGS, AND APPLIED TO THE SKIN:

BEING

AN ATTEMPT

TO ASCERTAIN THE TRUE NATURE OF

CONTAGION,

AND

TO EXPLAIN THEREFROM THE PHENOMENA OF

FEVER.

By SAMUEL LATHAM MITCHILL, M.D. F.R.S.E.

Professor of Chemistry, Natural History and Agriculture in the College of New-York.

NEW-YORK:

Printed by T. and J. Swords, Printers to the Faculty of Physic of Columbia College.

—1795.—

FIG. 12. Title page to Remarks on the Gaseous Oxyd of Azote or of Nitrogene. (Courtesy of the National Library of Medicine, Hist. Med. Div.)

of external sores, and charcoal for "correcting putridity, and in disposing ulcers to heal."

As Appendix I to this brochure, Beddoes had reprinted a small work by Samuel Latham Mitchill, professor of chemistry, natural history, and agriculture in the College of New York. This was entitled *Remarks on the Gaseous Oxyd of Azote or of Nitrogene,*[32] and had been printed originally in New York by T. and J. Swords, Printers to the Faculty of Physic of Columbia College (fig. 12).[33]

Mitchill, who was a physician, said:

> It has a long time appeared to me highly probable, that contagion was an aëriform fluid, produced occasionally, and exercising for a season its destructive effects. . . . In the course of my experiments and inquiries, I have become satisfied my original conjecture was right; and I have to acknowledge the pneumatic philosophy has led the way to an elucidation of this hitherto dark and intricate subject. The combination of the *base of vital air* with the *radical of nitrous acid* forms a compound which, though little known, possesses very remarkable qualities. If the principles laid down in the following pages are true, a considerable number of interesting deductions may be drawn from them, both in the theory and practice of physic, and in relation to health offices and the means to be adopted for guarding against infectious distempers. . . .[33a]

Mitchill then discussed nitrous oxide, mentioning Priestley's discovery of it; and he argued that nitrous oxide was formed by decomposition:

> In these several ways, we find nitrous acid afforded by the putrefaction of animals themselves, and by changes in their excretions. Now, nitrous acid, differing from the gaseous oxyd, barely in the degree of oxygenation, there is no difficulty in comprehending, that if there was in any instance a spontaneous formation of the former, there would, *a fortiori,* be a more easy and frequent production of the latter.[33b]

In accord with his theory of contagion, Mitchill further thought that nitrous oxide was of local origin. He believed that it was most abundant in large cities because of sewers, wharfs, and docks, and that the vapors settled there because of difficulties of ventilation. It was poisonous and destructive, Mitchill said:

Fig. 13. Sir Humphry Davy. From an engraving by E. Scriven from the painting by Sir Thomas Lawrence. (Reproduced from Paris, J. A.: The Life of Sir Humphry Davy. London, Henry Colburn and Richard Bentley, 1831.)

> When applied to a living body, fresh and strong . . . it produces violent inflammation and ulceration of the fingers or hand . . . or drawn into the nostrils, it excites alarming tumefaction . . . or, if inspired fully into the lungs, it brings on instant death.[33c]

Sir Humphry Davy. Such was the state of scientific knowledge when Humphry Davy[2e] (fig. 13) became interested in pursuing by himself an education his circumstances did not enable him to seek in school.

He was born at Penzance, Cornwall, in 1778. When he was six, the Davy family moved to their small estate two or three miles from town, but the boy remained at Penzance to attend school, staying with Mr. John Tonkin, a surgeon who had adopted Humphry's mother when she was a child. After further education at Truro, Humphry's formal education was ended in 1794 because of his father's death and the family's financial reverses. In 1795 Mrs. Davy apprenticed her son to Mr. John Borlase, a surgeon and apothecary of Penzance. In Borlase's dispensary Humphry was exposed to chemistry and found it to his liking. He read Nicholson's *Dictionary of Practical and Theoretical Chemistry* and Lavoisier's *Elementary Treatise on Chemistry* in 1797; in the spring of 1798 he came across Mitchill's small treatise in the library of his friend Davies Giddy.[2f] Presumably, he had studied already the third edition of Beddoes and Watt's *Considerations on the Medicinal Use of Factitious Airs,* with which Mitchill's paper had been reprinted as an appendix. In the same year, Humphry busied himself with chemical experiments in Borlase's house.

In 1797, besides developing a friendship with Davies Giddy (Gilbert), Humphry became a friend of Gregory Watt, the consumptive son of the famous engineer James Watt, as mentioned earlier. Gregory had been sent to Penzance by his physician, Dr. Thomas Beddoes, who thought the climate there might help to cure his tuberculosis, and he lodged and boarded with Humphry's mother.

In March 1798 Humphry experimented with nitrous oxide gas (discovered, as earlier indicated, by Priestley). To test Mitchill's ideas about contagion, he submitted wounds made in the limbs of animals to the action of impure nitrous oxide and also hung muscle fibers in the gas. Unlike Mitchill, Humphry found no undue sepsis nor abnormal putrefaction in his specimens. His friend Giddy was then in the employ of Beddoes and brought Humphry's experimental results to him.

At this time Beddoes was organizing the Pneumatic Institution to study and administer gases for their therapeutic benefits, and he was looking for a superintendent to take charge of his newly-founded hospital and laboratory, for which he had leased two houses. According to Cartwright,[34] these houses still stand—numbers 6 and 7 Dowry Square in the Hotwells district of Bristol—and should be, like the Massachusetts General Hospital in Boston, a shrine for every traveling anesthetist. Davy was hired as superintendent of Beddoes' Pneumatic Institution upon the advice of Davies Giddy.

In October 1798, Davy entered into his new duties. His function was to supervise the administration of gases, presumably for their therapeutic effects; but the greater part of his time was spent in the laboratory, where in April 1799[35a] he prepared nitrous oxide in more or less pure state. The exact date that he first breathed his "pure" nitrous oxide is not known, but in his *Researches* he said it was April 11, 1799.

His experiments were made known to many of her acquaintances by Maria Edgeworth, sister-in-law of Dr. Beddoes:

> A young man, a Mr. Davy, at Dr. Beddoes', who had applied himself much to chemistry, has made some discoveries of importance, and enthusiastically expects wonders will be performed by the use of certain gases, which inebriate in the most delightful manner, having the oblivious effects of Lethe, and at the same time giving the rapturous sensations of the Nector of the Gods! But faith, great faith, is, I believe, necessary to produce any effects upon the drinkers, and I have seen some of the adventurous philosophers who sought in vain for satisfaction in the bag of "Gaseous Oxyd" and found nothing but a sick stomach and a giddy head.[36]

Nevertheless, Davy's research on nitrous oxide was to have far-reaching consequences. It was reported in his book, *Researches, Chemical and Philosophical; chiefly concerning Nitrous Oxide, or Dephlogisticated Nitrous Air, and its Respiration.* Published in 1800 when Davy was only 21, this work clearly indicates his genius and had a direct bearing on the course of events leading to the introduction of surgical anesthesia.

Davy first denied Mitchill's theory of contagion and his assertion that nitrous oxide was a poison.

> The fallacy of this Theory was soon demonstrated, by a few coarse experiments made on small quantities of the gas procured from zinc and diluted nitrous acid. Wounds were exposed to its action, the bodies of animals were immersed in it without injury; and I breathed it mingled in small quantities with common air, without remarkable effects.[35b]

Davy continued to experiment upon himself, breathing the gas and recording his experiences. A few of his observations may be quoted, since they pertain to pain:

> In one instance, when I had head-ache from indigestion, it was immediately removed by the effects of a large dose of gas. . . .

Fig. 14. "Scientific Researches!—New Discoveries in PNEUMATICS!—or—an Experimental Lecture on the Powers of Air—" Published May 23, 1802, this caricature by James Gillray (1757–1815) satirized the public lectures of the Royal Institution, then fashionable in high circles. The subject of the experiment is Sir John Coxe Hippisley, M.P., diplomat, and a manager of the Institution. The experimenter is Dr. Thomas Young, professor of chemistry (or Dr. Garnet); his alert assistant is Humphry Davy; standing beside the door at right is Count Rumford. The majority of the others have been identified also.[38]

> The power of the immediate operation of the gas in removing intense physical pain, I had a very good opportunity of ascertaining.
>
> In cutting one of the unlucky teeth called dentes sapientiae, I experienced an extensive inflammation of the gum, accompanied with great pain, which equally destroyed the power of repose, and of consistent action.
>
> On the day when the inflammation was most troublesome, I breathed three large doses of nitrous oxide. The pain always diminished after the first four or five inspirations. . . .[35c]

And finally the suggestion of its use to prevent the pain of surgery, which unfortunately had to wait more than 40 years for application: "As nitrous oxide in its extensive operation appears capable of destroying physical pain, it may probably be used with advantage during surgical operations in which no great effusion of blood takes place."[35d]

The last part of Davy's book on nitrous oxide described the effects of the inhalation of nitrous oxide by Davy and his talented friends, including the poets Southey, Coleridge, and Wordsworth, the engineer James Watt, the playwright Tobin, the Wedgewoods, the Edgeworths, and the younger Joseph Priestley. (As mentioned elsewhere,[23a] it was the employment of nitrous oxide and ether for pleasurable purposes that largely contributed to the use of these gases in anesthesia.)

Davy's research on gases in Bristol and his resultant publications were early noticed by many savants, including Benjamin Thompson,[37] Count Rumford (who later was to marry the widow of Lavoisier). In 1799 Rumford, with Sir Joseph Banks, projected the Royal Institution in London, which was chartered by George III in 1800; in 1801 Humphry Davy was appointed director of its laboratory and assistant professor of chemistry (fig. 14). So ended his association with Beddoes and the Pneumatic Institution. Thereafter, though Davy proceeded by swift successes in a dazzling array of problems (his most acclaimed achievement being the invention of a safety lamp for coal miners) to the first rank of scientists of his era, he did little more with nitrous oxide, and to the end of his life in 1829 he wrote nothing further of the possibility of its use in surgical anesthesia.

Yet, interestingly enough, it is possible, as mentioned by Cartwright,[34] that Davy in 1818 entered again into the chain of circumstances leading to the development of that medical blessing. There appeared in the *Journal of Science and the Arts*, the official organ of the Royal Institution, the following often-reprinted warning:

> When the vapour of ether mixed with common air is inhaled, it produces effects very similar to those occasioned by nitrous oxide. . . . In trying the effects of the ethereal vapour on persons who are peculiarly affected by nitrous oxide, the similarity of sensation produced was very unexpectedly found to have [taken] place. . . . It is necessary to use caution in making experiments of this kind. By the imprudent inspiration of ether, a gentleman was thrown into a very lethargic state, which continued with occasional periods of intermission for more than thirty hours, and a great depression of spirits; for many days the pulse was so much lowered that considerable fears were entertained for his life.[39]

This quotation has been attributed by many writers, including myself, to Faraday.[23b] But the article is unsigned and it is quite possible that Davy was its author. Upon close examination, it seems more in Davy's exuberant style than in Faraday's exact prose. Certainly, also, the subject is more that of Davy than that of Faraday.

As for the Pneumatic Institution—in 1800 a severe epidemic of typhus devastated the Bristol area,[25] and Beddoes turned his energy to combat the disease. The original aim of the institution was abandoned and it became an ordinary hospital. Davy's departure in 1801 was a serious loss; but even more serious, according to Cartwright,[25] was the lack of patients which was due to the lack of cures. The effect of it all was that the Pneumatic Institution declined and finally closed.

Eventual Relation to Anesthesia

It was probably not accidental that a chain of many events and circumstances led from Davy to Gardner Quincy Colton to Horace Wells to Charles Jackson to William T. G. Morton.

Cartwright[34] reported that Colton published advertisements using the words: "Robert Southey (poet) once said that the atmosphere of the highest of all possible heavens must be composed of this gas." The statement was drawn from a private letter of Southey to Davy, and Cartwright suggested that Colton had seen it in the pamphlet of Thomas Beddoes,[40] published in 1799.

In Pennsylvania, as pointed out by Eckenhoff,[41] Benjamin Rush was familiar with ether, oxygen, and nitrous oxide in 1801, and was at that time Professor of Chemistry at the Medical School of the University of Pennsylvania. These gases were used as remedies for colic, asthma, and malignant fever. Joseph Priestley, as mentioned earlier, had settled in Pennsylvania in 1794; he carried on experiments in North Cumberland. After Priestley decided not to accept the Chair of Chemistry at the Medical School at the University of Pennsylvania, it was awarded to James Woodhouse. He knew of Priestley's discovery of nitrous oxide and of Davy's experiments. Woodhouse prepared nitrous oxide and asked some students to breathe it and others to bear witness. The volunteers were usually exhilarated. Had Woodhouse not died in 1809 from overwork, more might have come from his investigations.

The use of nitrous oxide was spread by two of his students: Benjamin Silliman, who later founded the medical school at Yale University, and William P. C. Barton, who taught botany at the University of Pennsylvania and then became Professor of Materia Medica at Jefferson Medical College. In 1808 Barton published his M.D. thesis, entitled *A Dissertation on the*

Chymical Properties and Exhilerating Effects of Nitrous Oxide Gas: Its Application to Pneumatic Medicine.[42] This contained observations similar to Davy's. He once inhaled the gas when suffering from a blow on the head and found that the gas removed the resultant pain.[41] As a result of this experience, Barton agreed with Davy's opinion that nitrous oxide gas had the power of removing intense physical pain. Barton also suggested that nitrous oxide was of use in inhalation therapy for the treatment of mental disease.

In the same year Thomas Beddoes, who had lived strenuously and thought his life a failure, died at the age of 48. He little realized that he had set the stage for the new era of anesthesia in which, after the introduction of antisepsis by Lister, surgery was to make unprecedented advances and to lead to many remarkable developments for the field of medicine in the years to come.

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