

JOHN SNOW'S EARLY RESEARCH ON CARBON DIOXIDE

RICHARD FOREGGER, M.D.

IN the *London Times*¹ for November 20 and 24, 1838, appears a report of the death of a night watchman, James Trickey, who had remained the whole night in St. Michael's Church, Cornhill, to watch the effects of a new type stove. At the coroner's inquest some of the medical practitioners who testified were of the opinion that the deceased, who had been found a yard and a half from the stove, had died of the inhalation of noxious vapors from the stove and that the lethal ingredient from the vapors was carbonic acid gas which had been demonstrated to be present. This and other deaths from the noxious vapors of the Harper and Joyce² stove created considerable interest among the members of the medical profession including John Snow, at that time concerned about the toxic properties of carbon dioxide gas, although it was subsequently recognized and is now known that the vapor emanating from the incomplete combustion of carbonaceous material contains carbon monoxide in addition to carbon dioxide and other gases.

The *London Times* report quoted the testimony of the eminent physician, Dr. Golding Bird,³ and on the same evening, November 24, 1838, the members of the Westminster Medical Society questioned Dr. Bird on his statements.

Dr. Bird replied, that the evidence ascribed to him by the reporter in the *Times*, was not only not correct, but the precise contrary of what he said. . . . What he really stated in evidence was, that different quantities of carbonic acid produced different effects; four per cent. would produce coma, a little more asphyxia, and from 8 to 10 per cent. suffocation, by spasmodic closure of the glottis. . . . In St. Michael's church, near the stone where the man lay dead, the air over the floor was highly impregnated with carbonic acid. In stooping to collect some of it in a phial, he (Dr. B.) was affected with headache and throbbing of the temples; and some limewater, which he held in his hand, was *instantly* made turbid.⁴

The subject excited a good deal of interest and it was generally agreed to continue at the

next meeting of the Society at which time Mr. Snow opened the discussion of the above statements of Dr. Golding Bird.

The meeting of the Westminster Medical Society on December 1, 1838, was not the first time that Snow is recorded to have spoken before that society. Snow had arrived on the London scene as Richardson relates⁵ in October, 1836, and is mentioned in the discussions of the Society on November 4, 1837, at which time he was still a student. On December 16, 1837 he reported the results of some experiments he had performed to ascertain the effects of combustion of candles containing arsenious acid on animal life.⁶ On March 17, 1838, he is recorded as making a report of his correspondence with the secretaries of several abstinence societies indicating his early interest and activity on the subject of abstention from intoxicating liquors.⁷

The abstracted material in the following and other sections is designed to show the development of Snow's knowledge of the action of carbon dioxide; to enable the reader to gain insight into his methods of fact finding and decision making, and to record statements which might reveal his personal characteristics. At the time of this discussion, John Snow had recently become qualified for general practice, having passed the examinations to become a member of the Royal College of Surgeons (M.R.C.S.) in May, 1838, and the License of Apothecaries Hall in October, 1838.⁸ Dr. Golding Bird on the other hand, although of the same age has been described as a precociously eminent physician. He had been granted the License of Apothecaries Hall without examination in 1836 and had received the M.D. degree in April, 1838.

At the meeting of the Westminster Medical Society on December 1, 1838, John Snow arose and questioned the statements of Golding Bird made at the previous meeting.

Mr. Snow asked Dr. G. Bird if, in the statement he had made to the Society at the last meeting, that from eight to ten per cent. of carbonic acid gas in the atmosphere would be fatal to life, he meant that quantity of gas mixed with the atmosphere in experiment, or arising from a brewer's

Accepted for publication September 21, 1959.
Dr. Foregger's address is 2373 N. 101st Street,
Milwaukee 13, Wisconsin.

vat, or when produced by respiration, or by the burning of a stove . . . ?

Mr. Snow had asked the question because neither Christison,⁹ Orfila,¹⁰ nor any of the numerous authors to whom he had referred, made a distinction between the two cases. He was prepared to show there was a very wide difference. Death, he believed, in neither case arose from any sedative effect of carbonic acid gas, but from the diminished quantity of oxygen in a given volume of air. . . . Now when charcoal was burnt, or the gas was given out by respiration, the gas was formed at the expense of the oxygen of the air, and hence it must follow that an atmosphere containing a given quantity of carbonic acid gas arising from these causes, would be equally deleterious with one in which there were five times the quantity introduced by simple mixture. Tables were now shown to prove that about one and two-thirds per cent. of carbonic acid gas, produced by the burning of charcoal, formed an atmosphere in which the oxygen was as much diminished as though eight per cent. of the carbonic acid gas had been introduced into it by simple mixture; it would hence follow that, for the production of an atmosphere equal, as regarded oxygen, to one in which eight or ten per cent. of carbonic acid gas was formed from the burning of a stove, the large quantities of more than thirty-seven and forty-eight per cent. must be added by simple mixture. The reasons why carbonic acid gas was supposed to have a sedative effect were chiefly these:—First. Collard De Martigny¹¹ had found that, when he substituted carbonic acid gas for the nitrogen of the atmosphere, animals perished in the short space of two minutes in a mixture containing one volume of oxygen and four volumes of carbonic acid. Death in this case would, however, arise from the mere pungent effect of the large quantity of the carbonic acid on the glottis, producing its closure, and consequently, asphyxia. Secondly. That when a solution of the gas was taken into the stomach, as in soda-water, its absorption sometimes produced sedative effects; there was no proof, however, that the gas could be absorbed by the lungs, and the fact that we were giving it out from them every minute of our lives, offered a strong presumption to the contrary. Thirdly. That a person having his body inclosed in carbonic acid, and breathing the natural atmosphere, suffered from disagreeable sedative effects. Now, the gas might be absorbed by the skin, and not by the lungs. . . . Judging from his (Mr. S.'s) own feelings, when respiring an artificial atmosphere, it made no difference whether a portion of carbonic acid was present or not, provided the quantity of oxygen was the same. He had also found that the presence or absence of carbonic acid exerted little or no influence over the combustion of a common candle, when the oxygen remained the same. On comparing his own experiments on combustion, with those of Dr. Edwards¹² on

animals, he had found that animals would live in an atmosphere containing much less oxygen than was required to support a burning candle; . . . Two per cent. as he (Mr. S.) had shown, produced from a burning stove, would equal the ten per cent. by mixture . . . he (Mr. Snow) had that evening inhaled a mixture of ten, twenty, and forty per cent. of the gas with common air, and it had not even produced irritation of the fauces.¹³

During this meeting, the main discourse of Mr. Snow, evidently prepared and written for the recorder, states that tables were shown to demonstrate the evidence. Moreover he quotes at length from other authors indicating that he had consulted the literature on the subject. Lastly, in substantiation of his views he had performed experiments on candles, small animals, and on himself.

After an interval of a few months the problem of poisoning by carbonic acid gas was again placed upon the agenda of the Westminster Medical Society. At 9 o'clock on the evening of Saturday, March 16, 1839, Dr. Golding Bird delivered an address on the subject.¹⁴ He had repeated the experiments of the French physiologist, Collard de Martigny in order to determine whether carbon dioxide produces death by excluding oxygen or by acting as a specific poison, and inferred from the facts that carbon dioxide acts as a specific poison. The address was received with approbation and on the motion of Mr. Snow an ensuing Saturday evening was to be devoted to a discussion of the subject. Accordingly, at 9 o'clock on Saturday, March 30, 1839, the president called upon Snow as the mover of an adjournment on a previous meeting to proceed with the discussion of Dr. Golding Bird's address regarding the mode in which death is produced by carbonic acid gas.

Mr. Snow, on arising to open the adjourned debate on poisoning by carbonic acid, said, that he was now convinced that this gas exercised a deleterious effect independent of the diminution of oxygen consequent on its inhalation. He thought, however that some of the facts and arguments brought forward in support of that opinion were objectionable. For instance, in the experiments of Collard de Martigny, who descended into a brewer's vat, the air was respired through a long tube; he would, therefore, at each inspiration draw back a great part of the air he had already expired, which alone would account for all the alarming symptoms he had

experienced. . . . Mr. Snow had performed some experiments in which he had tried to avoid the usual sources of error. He procured a very large bottle containing 2000 cubic inches; this he filled with 75 parts of atmospheric air, 20 parts of carbonic acid gas, and 5 parts of oxygen. So that with 20 parts of carbonic acid gas, the natural proportion of oxygen was preserved. Two small birds were introduced, they began to breathe laboriously, and in a few minutes were withdrawn but died shortly afterwards. A white mouse died in an hour and a half after breathing laboriously. The same bottle was then filled 85 parts of atmospheric air, 12 of carbonic acid, and 5 of oxygen. Here, then, there were 12 parts of carbonic acid, while the natural quantity of oxygen was preserved; a sparrow was put into this mixture, it shortly began to breathe in a very deep and laborious manner, and to open its bill in inspiration. It died after a period exceeding two hours and a half. A white mouse was afterwards put into the same mixture, it began to breathe with difficulty, in ten hours it breathed seldom and irregularly and in fourteen hours was taken out in a very feeble state, but recovered. From these experiments it was evident that carbonic acid produced fatal effects independent of any diminution in the quantity of oxygen.¹⁵

In this discussion at the Westminster Medical Society John Snow relates that he also performed experiments to determine the effects of diminishing the natural quantity of oxygen in the air, when no excess carbonic acid was present. Limewater was kept in agitation in the bottle to absorb the small quantity of carbonic acid coming from the lungs of the bird as it was formed. The animals became seriously ill or died from the effects of diminished oxygen where no carbonic acid was present. He also observed that where carbonic acid gas and a diminution of oxygen existed together, the effects were more quickly fatal than from the presence of either of the causes separately. He related several experiments in illustration of this fact. He was acquainted with the concept of mechanical dead space for he observed that when air was respired through a long tube, each inspiration would draw back a great part of the expired air which would in turn give rise to alarming symptoms. Although he had formerly entertained the idea that carbon dioxide, like hydrogen and nitrogen, produced death simply by the exclusion of oxygen, the experiments he had initiated and the statements of Golding Bird and Collard de Martigny had convinced

him that carbon dioxide did not kill merely by excluding oxygen.

The discussion at the Westminster Medical Society¹⁶ on poisoning by carbon dioxide gas appears to terminate with the meeting of March 30, 1839. Snow read papers in the following years on the anasarca which follows scarlatina,¹⁷ on a fatal case of poisoning with carbonate of lead,¹⁸ on a new instrument for performing paracentesis of the thorax, on the circulation in capillary vessels, and on distortion of the chest and spine in children from enlargement of the abdomen.¹⁹

Snow's interest in carbon dioxide gas continued during this period. In the discussion to the paper, "On Asphyxia and on the Resuscitation of Still-Born Children,"²⁰ before the Westminster Medical Society, he defines asphyxia as the absence or diminution of oxygen. Carbon dioxide he considers to have a specific poisonous effect of its own. He rejects mouth-to-mouth artificial respiration because a physiologist has reported the exhaled breath to contain 6 per cent carbon dioxide gas. To sustain his reasoning, Snow refers back to the experiments which he had performed and reported to the Society three years previously in which animals had died in atmospheres where five percent of the oxygen had been replaced by as much carbon dioxide.¹⁵

The pages of the *Lancet* and *London Medical Gazette* record the proceedings of the Westminster Medical Society and show that Snow was a frequent and active participant in the discussions, sometimes speaking several times during the evening.²¹ Snow became active building his medical practice and obtained the M.B. and M.D. degrees at the University of London.²² Richardson records that in the summer of 1845 he became ill with a renal disorder. These interests and activities and his illness perhaps account for the delay in final publication of his work on the pathological effects of atmospheres vitiated by carbonic acid gas, and by a diminution of the due proportion of oxygen which did not appear until 1846 when it was published in the *Edinburgh Medical and Surgical Journal*.²³

Snow begins by referring back to the discussion at the Westminster Medical Society on March 30, 1839, and states that the experi-

ments are now placed in detail before the profession because the subject to which they relate is of great importance.

The greatest difference of opinion has existed amongst authors, not only with respect to the amount of deterioration which is fatal or dangerous, but also as to whether carbonic acid is an active poison or is merely injurious by displacing the atmospheric air; and although the experiments of Collard de Martigny show, in my opinion, the active nature of carbonic acid, they do not show the quantity necessary to produce injury or death; and I know of no experiments on animals, except these I am about to relate, which are calculated to point out the condition of an atmosphere which may or may not be fatal to persons breathing it, . . . In order to investigate this subject properly, I sought to determine separately the effects of carbonic acid and of a diminished amount of oxygen; and the quantity of air used, in proportion to the size of the animals experimented on, was so great that the result could not be vitiated by the products of their respiration during the experiments.

Eighteen experiments are reported in three divisions to show (1) the effect of diminishing the amount of oxygen, (2) the effect of carbonic acid gas, the due amount of oxygen being preserved, and (3) the effect of carbonic acid, with a diminished amount of oxygen. Snow concluded that the experiments clearly establish the fatal effects of carbonic acid.

It must follow that 5 or 6 percent of carbonic acid cannot exist in the air without danger to life, and that less than half this amount will soon be fatal, when it is formed at the expense of oxygen of the air, as it is in most cases of accident and suicide. . . . Carbonic acid gas caused deep and laborious breathing, but in what way it was destructive to life, these experiments do not enable us to state.

In the discussion to these experiments he makes the statement that:

Professor Graham suggested a plan, which has been published in the reports of the Royal Humane Society of absorbing the carbonic acid gas remaining after the explosion of fire-damp in coal mines, by means of inhaling the air through a cushion filled with a mixture of slaked lime and pounded sulphate of soda.^{24, 25, 26}

As is well known, Snow in later years used solution of potassa (caustic potash solution) to absorb carbonic acid gas from a closed system apparatus in which he rebreathed a

mixture of chloroform and oxygen and ether and oxygen. He used the same arrangement to administer oxygen gas to a cholera patient.²⁷ Soon after the introduction of the inhalation of ether he made observations on the amount of carbonic acid gas exhaled from the lungs under its influence, by passing the expired air through limewater and found the quantity to be diminished.²⁸ In 1850 and 1851 he performed quantitative experiments on himself and on animals to determine the diminution of the amount of carbonic acid gas excreted by the lungs under the influence of chloroform and ether.

It is of interest to consider what previous knowledge existed to influence Snow in his studies. He refers to Orfila and Christison but the amount of information on carbonic acid gas is scant in the writings of Orfila. Christison in his book on toxicology reviews several accounts of poisoning with carbonic acid gas encountered in wells, pits, closed rooms, and mines, as well as some of the experimental work. It is evident from Snow's remarks that he took much information from Christison's book. Christison refers to Collard de Martigny who seems also to have influenced Snow considerably as did Golding Bird. Neither Orfila nor Christison in the previously cited writings^{9, 10} refer directly to the work of Lavoisier or Black who were well acquainted with the toxic properties of carbon dioxide and with methods of absorbing it from closed spaces during experiments on animals and man. However, Christison was a student of Thomas Charles Hope, the successor to Joseph Black as professor of chemistry at Edinburgh. Hope was not only a student of Black's but had visited Lavoisier at his laboratory in Paris. Christison had also studied for a while under Orfila at Paris who in turn was also acquainted with the work of Lavoisier. Thus the knowledge of Lavoisier and Black on carbon dioxide had ample opportunity to be transmitted to Snow. Snow had studied chemistry under Hunter Lane at the Great Windmill Street School of Medicine and it is apparent from the recorded statements at the Westminster Medical Society and from his writings that he had an extensive knowledge of chemistry. At this period, 1838, it was general chemical knowledge that the caustic alkalis and caustic

alkaline earths would absorb carbon dioxide so that Snow's use of these agents in his experiments would naturally follow.

CONCLUSION

Thus, by the year 1839 when Snow was a recently qualified practitioner, he had performed and reported experiments to show that carbon dioxide gas was toxic when inhaled; a decrease of oxygen in the atmosphere was dangerous to life; and that the two conditions when combined were more rapidly fatal. He had undertaken quantitative experiments to show that 5 to 6 per cent was the concentration above which carbon dioxide gave rise to alarming symptoms. He had controlled the concentrations of carbon dioxide in closed spaces first with limewater, later with caustic potash solution.

I am grateful for the services of St. Joseph's Hospital Medical Library, Milwaukee, in obtaining photoduplicates of some of the material needed for this paper from the National Library of Medicine; and for the facilities of the Marquette University Medical-Dental Library, the Milwaukee Academy of Medicine Library, the John Crerar Library, the Library of Congress, the libraries of the University of Wisconsin, and the British Museum.

REFERENCES AND NOTES

1. *London Times*, November 20, 1838, page 6, column 1; *London Times*, November 24, 1838.
2. For a description of Harper and Joyce's stove, see *Lancet* 2: 152-54, 1837-38, and *Lancet* 2: 613-15, 1837-38. For an interesting editorial opinion of the deaths caused by the stove, see *London Medical Gazette* 23: 343-44, December 1, 1838.
3. Wilks, S., and Bettany, G. T., *Biographical History of Guy's Hospital*, Ward Lock, Bowden & Co., London, 1892, and *Dictionary of National Biography*. Golding Bird (1814-1854) was granted the license of Apothecaries Hall at age 21 in consideration of the reputation he had already obtained. He received the M.D. degree in April, 1838, and became a lecturer at Guy's Hospital Medical Surgical School in the 1836-37 session. His biographer describes him as an individual of precocious intellectual ability. He was an author of several books and various articles. In the reports of the Westminster Medical Society in the *Lancet* and *London Medical Gazette*, the record indicates that he and Snow were often discussants at the same meeting.
4. Westminster Medical Society, Saturday, November 24, 1838, *London Medical Gazette* 23: 380-82, December 8, 1838. Also in *Lancet* 1: 383, 1838-39. Golding Bird sent in a corrected statement to the *London Times*, November 26, 1838, page 3, column 1.
5. Snow, John: *On Chloroform and Other Anaesthetics, their Action and Administration*, ed. by B. W. Richardson, London, 1858.
6. Westminster Medical Society, Saturday, December 16, 1837, *Lancet* 1: 461-63, 1837-38.
7. Westminster Medical Society, March 17, 1838, *Lancet* 2: 29-31, 1837-38.
8. At that time, 1838, there existed various bodies for granting degrees, diplomas, and licenses to practice. The standard qualification for general practice was the M.R.C.S., L.S.A. Practice on the strength of a single qualification was however prevalent. The Apothecaries Act of 1815 conferred a legal right to dispense prescriptions to those holding the license of the Apothecaries Society. For a history of the Society of Apothecaries' influence on medical licensure and education, see D'Arcy Powers, "The Society of Apothecaries of London," *British Medical Journal* 1: 1349-50, 1895; Bishop, W. J., "Evolution of the General Practitioner in England," in *Science, Medicine, and History*, ed. by Underwood, E. A., 2: 351-57, Oxford University Press, Oxford, 1953 and Cope, Z., "Influence of Society of Apothecaries upon Medical Education," *British Medical Journal* 1: 1-6, 1956.
9. Christison, Sir Robert (1797-1882), *Dictionary of National Biography*, Medical Professor at Edinburgh, author of *A Treatise on Poisons*, 1829, was a recognized authority of the time on toxicology. Snow did not indicate the source of literature for the authorities he mentioned in references 9 through 12.
10. Orfila, P. (1787-1853), founder of the science of toxicology, was born in Spain and lived in Paris. He was the author of many works in forensic medicine, toxicology, and medical chemistry, including *A General System of Toxicology*, translated by Nancrede, J. G., M. Carey & Son, Philadelphia, 1817. For short biography, see *Lancet* 1: 326-27, 1853.
11. Collard de Martigny, C. P., "De l'action du gaz acide carbonique (mofette atmosphérique, air fixe, acide méphytique, acide crayeux, etc.) sur l'économie animale," *Archives Générales de Médecine* 14: 203-22, 1827.
12. Probably Edwards, W. F. (1777-1849), Parisian physiologist, author of "De l'influence des agents physiques sur la vie," Paris, 1824, 654 pages, translated from the French in 1832. Snow mentions him at length in his 1841 paper, "On the Resuscitation of Still-born Children, and on Asphyxia in General," *Lancet* 1: 132-34, 148-51, 211-14,

- 1841-42. Also in *London Medical Gazette* 28: 222-27, 1841-42.
13. Westminster Medical Society, Saturday, December 1, 1838, *Lancet* 1: 418-21, 1838-39. Also in *London Medical Gazette* 23: 425-27, December 15, 1838.
14. Westminster Medical Society, Saturday, March 16, 1839, *London Medical Gazette* 24: 25-26, March 30, 1839. The *Lancet* 2: 27, 1838-39, refused to publish an abstract of Bird's address stating that the original facts were extremely few and the statements of opinion numerous. Bird's paper, "Observations on Poisoning by the Vapours of Burning Charcoal" was published in full in *Guys Hospital Reports* 4: 75-105, 1839. An earlier abstract appears in *London Medical Gazette* 23: 922-24, 1839.
15. Westminster Medical Society, Saturday, March 30, 1839, *Lancet* 2: 93-95, 1838-39. Also in *London Medical Gazette* 24: 60-62, 1839.
16. Westminster Medical Society. For a short history of the Westminster Medical Society, see Bailey, J. B., "The Medical Societies of London," *British Medical Journal* 2: 24-26 and 100-103, 1895. The Westminster Medical Society founded in 1809 was originally a society of students which met in the museum of the Hunterian School of Medicine on Great Windmill Street. By 1838-39 it was no longer predominantly a student society, the greater number of members being in practice. The place of meeting is described as cold and cheerless on a winters night and sufficiently dreary to prevent any but the staunchest friend from attending. By 1838 there was a cumulative total of 1,200 members since its formation. *Lancet* 1: 166, 1839-40, and 1: 132, 1841-42.
17. Westminster Medical Society, Saturday, December 1, 1839, *Lancet* 1: 440-44, 1839-40.
18. Westminster Medical Society, October 19, 1844, *Lancet* 2: 144, 1844-45.
19. The rules of procedure of the Westminster Medical Society provided that "a case, or cases, with accompanying observations shall be considered equivalent to an original paper, and worthy of occupying the attention of the Society." *Lancet* 1: 177, 1837-38.
20. *London Medical Gazette* 29: 222-27, 1841-42. Also Westminster Medical Society, October 16, 23, 30, 1841, *Lancet* 1: 132-34, 148-51, 211-14, 1841-42. Golding Bird was elected president of the Westminster Medical Society at the meeting of October 16, 1841. The *London Medical Gazette* did not report the proceedings of the Society at this time. *London Medical Gazette* 27: 175, 1840-41.
21. The caustic *Lancet* did not hesitate to admonish Snow. Snow had submitted a letter on the physiology of respiration which they refused to publish. "We cannot help think-
ing that Mr. Snow might better employ himself in producing something, than in criticizing the productions of others." *Lancet* 2: 352, 1838-39.
22. Snow attended the Hunterian School of Medicine in Great Windmill Street. He states that in 1836 he was injecting bodies with arsenic solution at the suggestion of Hunter Lane, the lecturer in chemistry, and in August of 1837 he was dissecting a body there, *Lancet* 1: 264, 1838-39. The *Lancet* carries the regulations for the M.B. and M.D. degrees each year for the University of London, but Richardson does not indicate whether Snow had to meet additional requirements before taking the examination. For a history of the medical schools of London at that time see Power, D'Arcy, "Rise and Fall of the Private Medical Schools of London," *British Medical Journal* 1: 1388-91 and 1451-53, 1895. The Hunterian School of Medicine, 16 Great Windmill Street, is no longer listed in the *Lancet* after the session of 1837-38. There is a Hunterian School listed for the sessions of 1840-41 and 1841-42 but the faculty is not the same and the address is at 20 Charlotte Street.
23. Snow, John, "On the Pathological Effects of Atmospheres Vitiated by Carbonic Acid Gas, and by a Diminution of the due process of Oxygen," *Edinburgh Medical and Surgical Journal* 65: 49-56, January 1, 1846. Snow refers directly to this paper on page 83 of his book, *On the Inhalation of the Vapour of Ether*, London, Churchill, 1847, indicating that these early researches influenced his subsequent writings on the inhalation of anesthetics, respiration, and asphyxia.
24. Graham, Thomas (1805-1869) was educated at Edinburgh and came to London in 1837 as Professor of Chemistry at the University of London. Anesthesiologists know him for his work on the diffusion of gases (Graham's Law). Odling, W., "On Professor Thomas Graham's Scientific Work," *Smithsonian Institution Annual Report for 1871*, Washington, 1872, pp. 177-216.
25. The Royal Humane Society collects and distributes information, investigates, and encourages research on the most approved methods of artificial respiration and resuscitation of asphyxiated persons. For history of its activities since its foundation in 1774 up to 1909, see Keith, A., *Lancet* 1: 745-49, 825-28, 895-97, 1909.
26. The Sixty-sixth Annual Report of the Royal Humane Society, 1840, pages 11-12.
27. Snow, John, *On Narcotism by the Inhalation of Vapours*, 1851. See experiments 67, 68, 69, part 15, pages 40-41.
28. Westminster Medical Society, Saturday, February 20, 1847, *Lancet* 1: 228, 1847; *London Medical Gazette* 39: 384-85, 1847.