The achievements of John Snow (1813-1858) are respected by anesthesiologists of all countries. His publications, particularly the 88-page monograph “On the Inhalation of the Vapour of Ether in Surgical Operations,” first published in September 1847, are regularly reprinted and are now more widely read than are the works of any other 19th-century pioneer of anesthesiology. Scholars are deeply impressed by the broad scope and rapid development of his scientific observations. Clinicians admire Snow’s ability to relate his research to clinical practice. Distinguished investigators believe that John Snow’s understanding of the scientific foundations of anesthesia were unequaled for almost a century.

An example of Snow’s skill in intermingling practical concern and scientific observation is his ether inhaler, shown on page 17 of his 1847 monograph (Figure 1). As the accompanying text reveals, he selected its components carefully. For example, he chose a breathing tube which “… ought to be so capacious as to offer no impediment to the most rapid inspiration; and to meet this requirement it must be wider than the trachea….” Although recent reconstructions of this device are on display in British museums, originals are not. A fortuitous discovery was recently made in the United States at the American Society of Anesthesiologists’ Wood Library-Museum (WLM), Park Ridge, Illinois. A previously unappreciated instrument has been identified as an authentic inhaler of John Snow’s design. It now ranks among the most prized objects of the WLM collection.

Visitors to the WLM marvel that a prototype of Snow’s inhaler could have been designed, introduced in the medical literature and marketed commercially within a month of Snow’s first having witnessed ether anesthesia. From the moment when the inhaler was identified, I have been curious to learn the history of its development. How could Snow have prepared it so quickly? Did he create an original design or did he re-assemble components
device for other applications? If so, what was their original purpose? These questions reflected my ignorance of 19th-century technology, a deficiency compounded by a lack of access to journals of that period. Recent opportunities to correspond with British scholars and to visit historical libraries in Britain, have given me a better understanding of the origins of the vaporizer's components. For readers who, like me, enjoy resolving historical puzzles, I would like to describe my "path of discovery" chronologically from when I first saw this intriguing device.

**Identification of the Anesthesia Inhaler**

In 1979 the Trustees of the WLM purchased an "Anaesthesia Inhaler" from Simon Kay, a London antique dealer for £540. Its provenance was, and still remains, unknown. For many years thereafter it rested undisturbed in its finely crafted wooden box on a shelf in the WLM rare book room. It came to attention again when Dr. Garth Huston showed the WLM Trustees some valuable books that had been recently purchased for the library. As he surveyed the shelves, he saw the box and casually placed it on a table with the comment that it was believed to be an early nitrous oxide inhaler.

While the group moved on to inspect other objects, I opened the box. The largest objects within it were a coiled tube and a black metal tin. A cursory examination showed that the small, circular and rather shallow tin, about 5 inches in diameter and 2-1/2 inches deep, could not have been constructed to contain a gas; it had to have been designed to receive a liquid, which from the volume contained was likely to be ether. Although slightly rusted, the metal tin showed no marks of use. With a clinician's curiosity, I assembled the components; a round metal vaporizing chamber, a brass quadrant valve which could be turned to allow the inspired vapor to be diluted with room air, a 28-inch-long flexible tube with an internal diameter of 5/8 of an inch, a wooden T-piece connector and a glass mouthpiece. Without deliberate thought, I reflexively tested my newly as-
assembled circuit by placing the mouthpiece against my lips and inhaling. To my chagrin, I immediately drew the dust of decades deep into my lungs provoking a violent cough. As the exhaled dust flew from the distal arm of the T-piece, I heard the lick of a valve closing, a sound which excited greater curiosity. I disassembled the T-piece and found that it contained two wooden spheres of 5/8-inch in diameter positioned as caged inspiratory and expiratory valves. Until that moment I had not appreciated that valves very similar in concept to the non-rebreathing valves of mid-20th-century construction had been used many decades earlier.

As I continued my examination, I was caught up in admiration for the utility of the vaporizer’s design and searched for any information that would identify its gifted designer. The wooden box was unlabeled, but a small brass plate on the vaporizer read:

“Ferguson
221, Giltspur Street”

The WLM librarian, Patrick Sim, and I were unable to find a reference to Ferguson in K. Bryn Thomas’ “The Development of Anaesthetic Apparatus” or other British and American historical texts. We did, however, find Ferguson of Giltspur Street, London, among the manufacturers listed in a copy of Elisabeth Bennon’s catalog, “Antique Medical Instruments,” but did not find a vaporizer among her illustrations of Ferguson’s equipment. From Bennon’s history of the Ferguson company, we were able to derive the period of its manufacture as follows: Ferguson had relocated to Giltspur Street in 1828; the firm’s name changed to Ferguson & Son in 1851; therefore, our vaporizer must have been manufactured before 1851 and after December 1846 when the news of ether anaesthesia crossed the Atlantic to Britain.

Some time later I unexpectedly found an appreciation of Ferguson’s work when reading the papers of Dr. Alexander Wood, the Edinburgh pioneer of subcutaneous injection. Wood incorporated into his ingenious development of the syringe and hollow needle. In 1965 Faulconer and Keys expressed the opinion that Wood’s complete apparatus was manufactured by Ferguson. The WLM inhaler was produced by a leading British manufacturer of the period, but the identity of its designer remained a mystery.

This problem resolved unexpectedly when Dr. Samuel Tirer sent me a manuscript to review along with photocopies of pages from the Lancet of 1847. Fortuitously, even though it was not the topic of his research, my friend included an illustration which riveted my attention because it depicted an inhaler almost identical to that in the WLM collection. The accompanying text reported the January 23, 1847, meeting of the Westminster Medical Society. The first sentence began, “Dr. Snow placed on the table an apparatus for the inhaling of the vapour of ether.” The WLM Trustees were soon delighted to learn that the vaporizer, which had rested in obscurity in our museum, was a product of John Snow’s genius!

The Lancet diagram included details of the vaporizer’s construction. Although the device Snow demonstrated in January 1847 lacked the quadrant valve to permit the mixing of ether with room air, it was otherwise very similar to the WLM vaporizer. The article included a schematic internal view which revealed a spiral plate within the vaporizer. The article included a schematic internal view which revealed a spiral plate within the vaporizer. The accompanying description revealed Snow’s awareness of the advantages provided by the water bath. He stated:

When used, the inhaler was to be put in a hand-basin of water, mixed to a particular temperature, corresponding to the proportion of vapour that the operator might desire to give; and the caps being removed, and the mouth-tube attached, when the patient began to inhale, the air would gain the desired temperature in passing through the metal pipe; it would then come upon the surface of the ether, where it would have to wind round three or four times before entering the tube going to the mouth-piece, thus ensuring its full saturation, and preserving it at the desired temperature. There was no valve, or any
other obstruction to the air, till it reached the mouth-piece, which was of the kind used in other inhalers, and contained the valves necessary to prevent the return of the expired air into the apparatus.5

A review of the London Medical Gazette of 1847 revealed an article of March 19, 1847 in which Snow described a vaporizer which featured a quadrant valve that had been designed for Snow by Ferguson to permit the introduction of air without the requirement of removing the mouthpiece.6 This was the WLM vaporizer (Figure 2). Two weeks later on April 3, 1847, Snow described a portable ether vaporizer for which no illustration was provided.7 The final version was the model incorporating the rectangular metal tin described in the monograph. I have recently learned that Dr. Richard Ellis has catalogued Snow’s ether vaporizers chronologically as Mark I - January 23, Mark II - March 19, Mark III - April 3, Mark IV - September, 1847.8 The WLM is, in Dr. Ellis’ classification, a Mark II device.

At the first opportunity, I compared the WLM vaporizer with the text and illustrations of Snow’s September 1847 monograph. The WLM vaporizer was the second prototype of the well-known Snow ether vaporizer which we find illustrated within its rectangular metal water bath. I could now follow the evolution of his vaporizer from its original version as illustrated in January, 1847 in Lancet through the intermediary modification in the WLM collection and then to its final form in the Snow September 1847 monograph. The text of the monograph served as a guide to the factors which had motivated Snow’s responses to deficiencies in his early vaporizers. The most striking of these were the addition of the metal water bath to house the vaporizer and the substitution of a face mask incorporating inspiratory and expiratory flap valves for the mouthpiece.

Snow explained his motivation for designing a malleable facemask as follows:

“For the first three months I used a mouth-piece which did not include the nostrils; consequently they had to be closed, and the patient was obliged to breathe entirely by the mouth. This plan always succeeded (except, perhaps, in one instance), and generally very well, but sometimes not without difficulty; for some

Fig. 2. Snow’s Modified Ether Vaporizer (as illustrated in the London Medical Gazette p 501, March 19, 1847).
of the adult patients, after they lost their consciousness, made such strong instinctive efforts to breathe by the nostrils, that the air was forced through the lachrymal ducts, and occasionally they held the breath altogether for a short time, and were getting purple in the face, when the nostrils had to be liberated, for a short time, to allow respiration of the external air, and thus a delay was occasioned. I was therefore ready to adopt a face-piece invented by Mr. Sibson, of the General Hospital, Nottingham, which permitted inhalation by the nostrils as well as by the mouth. This face-piece... was the foundation of that I now use, which has been altered... to allow of the introduction of valves into it..."  

Snow explained his preference for the low resistance flap valves over the brass quadrant valve of the WLM model by stating:  

"I have contrived the expiratory valve to turn on a pivot, so as to allow of the admission of external air, and to supersede the use of a ferrule or two-way tap... When a stop-cock with graduated openings is used... the air passes through the external opening in preference to the more circuitous route over the ether; and when the respiration is gentle, the whole of the air the patient breathes may enter by an outward opening that would only admit a third part of what he inspires when the respiration is forcible."  

In a remarkably short time Snow had achieved several very practical improvements.  

Snow stated that the rectangular metal box was added to serve "...as a waterbath when the apparatus is in use, and at other times containing the elastic tube and face-pieces." I performed a simulated trial which revealed another important, but unstated, advantage of the covered rectangular water bath; the lid held the vaporizer in a stable position. My test showed that earlier models, designed to float unrestrained in a basin of water, could tip unexpectedly if the patient should turn his head or the anesthetist shift position. A tug along the flexible tube might overturn the vaporizer which brought the risk of liquid anesthetic entering the tube. The concentration of anesthetic would then vary erratically with the potential of an even greater hazard — liquid ether flowing along the breathing tube to the patient. Snow not only pioneered the use of water bath to ensure that the anesthetic vapor pressure was constant but, by fixing the vaporizer in a horizontal position, also overcame the risk of erratic variations in anesthetic concentration precipitated by movement of the vaporizer.  

The monograph also provided a point of information which may explain why the WLM's unused vaporizer may be the only existing representative of its type. Snow commented, "This part of the apparatus (the vaporizer) was at first made of tinned iron, but it was found occasionally to become rusty by use." Because even the better grades of ether available in 1847 were contaminated by water, it is probable that every Snow vaporizer put in service to deliver anesthetics was destroyed by corrosion. Our WLM model may have survived only because it had never been used for anesthesia.  

Snow also described the origins of the components of the vaporizer. In January 1847 he had commented only that, "In the interior (of the inhaler) was a spiral plate of tin, soldered to the top, and reaching almost to touch the bottom... When the patient began to inhale, the air... would have to wind round three or four times before entering the tube going to the mouth-piece, thus insuring full saturation (with ether vapor)." In September he reported in the monograph that, "This spiral arrangement is adopted from the inhaler of Mr. Julius Jeffreys for aqueous vapour." Because no footnote or reference was provided, a new element was added to the mystery. Who was Jeffreys? Snow's acknowledgment did make clear, however, that the spiral plate was not of his own design.  

**The Jeffreys Inhaler**  

I learned no more about Jeffreys until I studied medical journals of 1840-1850 in Britain. The first entry that caught my eye was a February 1847 illustration of a Jeffreys inhaler with an unsigned commentary posing the question: "By a remarkable coincidence we find
that an instrument identical in principle with that invented by Dr. Snow, was invented some years ago by Mr. Jeffrey (sic) as an inhaler. The circumstance reminds us of the case of the new planet, in which two rival discoverers are in the field."15 (Neptune was first observed on September 23, 1846 in a position which had been independently predicted by two mathematicians, John Adams and Urbain Le Verrier.)

Although we do not know who challenged Snow for failing to credit Jeffreys' prior preparation of a coiled inhaler, an earlier entry in the literature revealed that Snow had previously recognized Jeffreys' claim. Any contemporary accusation that Snow plagiarized was refuted by Snow's first commentary on anaesthesia in which he identified his inhaler as being modeled on Jeffreys'. The London Medical Gazette recorded the meeting of the Westminster Medical Society of January 16, 1847, a session held seven days before Snow demonstrated his first vaporizer. The secretary reported: "He (Snow) was getting an instrument made which would enable the surgeon... to administer an atmosphere (of ether) of any strength he wished... The instrument... was on the plan of the inhaler of Mr. Jeffreys, with some alterations and additions."16 At the first opportunity Snow had acknowledged Jeffreys' invention.

Who was Jeffreys? A review of the London Medical Gazette led to a multi-part article, "On artificial climates and the restoration and preservation of health," published in 1842 by Mr. Julius Jeffreys (1801-1877).17 Jeffreys' thesis was that, based on his personal experience as a surgeon in India, the humidification and warming of air was of advantage both in the treatment of respiratory disease and in the prevention in cold climates of losses of heat and moisture in the exhaled breath. Jeffreys reported that the motivation for his invention came from a concern for his sister who was debilitated by paroxysms of severe coughing. He created an instrument that would warm and humidify the air she inhaled. The Jeffreys inhaler contained an internal coil positioned so that, as the patient inhaled, the inspired air could not simply traverse the short distance across the radius of the vessel but was channeled a longer distance to become fully humidified. This concept was incorporated later by Snow.18

Although it may appear that Jeffreys' device represents only an eccentricity of Victorian medicine, a well-researched biography of Julius Jeffreys by Dr. David Zuck presents a different perspective. Dr. Zuck recognized that Jeffreys' concept of humidification had a modern application. Jeffreys marketed a portable humidifier which he called a "Respirator," a term which Dr. Zuck points out that the Editors of the Oxford Dictionary conclude was coined by Jeffreys. Jeffreys' "Respirator" consisted of a plate of finely soldered metal grids which formed a lattice work within a frame that could be worn over the lower face in cold weather. Dr. Zuck described its function as follows: "During exhalation warmth would pass from the breath to the lattices, and moisture would condense on them. During inspiration the cold air would be warmed, and humidified."19 A patient's testimonial read that the "Respirator" had the property of making all the air that goes down one's throat as warm as summer air. Jeffreys patented the "Respirator" and gained royalties from the sale of several thousand. Dr. Zuck was the first to realize that Jeffreys had prepared a humidifier identical in principle to the heat and moisture exchanger (HME) of Swedish design now often positioned between the endotracheal tube connector and the Wye-piece of an anesthesia circuit.

Read's Valves

While I now understood the history of the vaporizer, the origin of the non-rebreathing valves remained a mystery. Snow's phrasing that the valves were of the sort "in ordinary use" suggested that he had not invented them, but other questions remained: When had they been first designed and for what purpose? Had Snow been the first to use the valves in an anesthetic circuit? No one with whom I corresponded could answer the questions, but visits to British museums brought progress.
The rich collections of 19th-century medical devices in the Science Museums in Oxford and London featured two ether vaporizers, both of which antedated Snow’s first inhaler. The Science Museum in Oxford had a reconstruction of Peter Squire’s inhaler, which had been employed by his nephew, William, for the first public demonstration of ether in England on December 21, 1846, when Sir Robert Liston amputated a coachman’s leg. Squire’s inhaler featured a non-rebreathing valve, one closely resembling the valve of Snow’s vaporizer. The Science Museum in London had an original Tracy’s inhaler. It was an impractical design, having a narrow and elongated glass vaporizing chamber shaped like the bowl of a large Meerschaum pipe, but Tracy had precluded rebreathing by incorporating valves of the same type. Since the valve design used by Snow had also been selected by Squire and Tracy, it was certainly “in ordinary use,” but who had used it first?

The published descriptions of the vaporizers on display in Oxford and London gave more information. In a letter written January 18, 1947, for the *London Medical Gazette*, S. J. Tracy of St. Bartholomew’s Hospital reported that his Tracy inhaler had been prepared by Mr. Ferguson of Giltspur Street, soon to be Snow’s manufacturer also, and that, by the date of the letter, Tracy had already administered 20 anesthetics with it. He referred to the non-rebreathing mechanism as a “double-valved mouthpiece of the description in ordinary use.”

While two of Ferguson’s clients, Tracy and Snow, failed to identify the designer of the valves, a witness’s account of Squire’s first use of an inhaler on December 21, 1846, brought the answer. The reporter of the London Medical Gazette commented, “It (Squire’s inhaler) consisted of a Nooth’s Apparatus... and one of Read’s flexible inhaling tubes...” Once again, I had learned a name, Read, but knew nothing of the original purpose or history of the invention. Certainly, Read’s valve must have been in regular use because it had been chosen not only by Snow and Tracy but also by Squire. I was soon to learn that other anaesthetists had also selected Read’s valve.

On January 13, 1847, 23 days after Squire’s first public anesthetic and only a few days before Snow’s first vaporizer was marketed, the Pharmaceutical Society of London held an extraordinary meeting in which models of seven ether inhalers were displayed by their inventors. Five of these featured Read’s valves. Mr. Squire was joined by Messrs. Hooper, Clendon, Bell, and Gilbertson, all of whom shared in a spirited debate over the merit of their devices. The Society’s secretary noted, “Some discussion arose about priority of invention, caveats, patents, registration, etc. which the Chairman very properly cut short, as being foreign to the objects of the meeting.”

Read’s valves had such utility that they had been chosen by five of Britain’s first anaesthetists at least seven days before Snow’s first inhaler was marketed.

For some time my search was handicapped by too narrow a focus of interest. Because I had learned of Read’s valve through its medical application in inhalers, I attempted to find references to Read by searching among articles published by physicians of the period to identify the disease or diseases which a Doctor Read might have attempted to remedy by creating a non-rebreathing valve for inhalation therapy. The search remained unsuccessful even when British friends extended it to include alternate spellings of Read. Fortunately, I directed a request to Dr. Ghislaine Lawrence, the Assistant Keeper of the Science Museum in London, who initiated a broader search of the technical literature. To my good fortune, her associates came upon a remarkable document — Read’s patent. The patent (#4484) was awarded on July 11, 1820, to a Mr. John Read (1761-1847) for “An Improvement in Syringes.” The accompanying diagram showed that spherical valves within the chamber of a syringe provided unidirectional flow which permitted the syringe to be used as a pump. Read prepared pamphlets to describe the sizes of his valved syringes and their applications in activities which ranged from horticulture (spraying fruit trees) through veterinary medicine (medicating horses and cattle) to clinical practice (pumping the stomach.
or applying an enema. The anesthetists of 1847 had certainly been correct in describing Read’s valves as being “in ordinary use.”

I searched the medical literature for references to Read’s valves and found three. The first was written by a distinguished London surgeon, Sir Astley Cooper. The latter two were citations by a then little-known but now highly regarded physician of Soho, John Snow.

My literature search had begun with the first volume of *Lancet* when the journal was first published in 1823. Fortuitously, Reid’s (sic) syringe was cited in the Index. The relevant account described an experiment supervised by Sir Astley Cooper on Friday, November 21, 1823 in the operating theater of Guy’s Hospital. That afternoon, opium in water had been poured down the throat of a restrained dog. After an interval of 33 minutes, when the animal showed effects of the narcotic, the stomach was evacuated by Read’s pump syringe. The reporter continued, “The instrument succeeded very well in the dog, which appeared to be little worse for the experiment. Mr. Reed (sic) was in the theatre during the whole of the time, and superintended the use of the instrument; on quitting he received the unanimous applause of those present.”

While lecturing at St. Thomas’s Hospital the following Wednesday, Cooper lauded Read by stating: “This experiment, Gentlemen, delighted me; I do not know that I have ever experienced greater pleasure in my life than I felt in going home from the Hospital on that day. With respect to antidotes against the effects of poison, it is well known that they are, in a great degree, useless. . . . A few weeks ago, a nurse in this Hospital died in consequence of having swallowed opium. No relief was administered to her; but can it be said, after what we saw on Friday; that no relief could have been administered to her?” Soon thereafter, Read’s priority to the invention was challenged, but his claim prevailed.

While John Read’s stomach pump was a significant contribution to the general practice of medicine, two other applications of his equipment were reported by John Snow. Both papers suggested a cordial interactions between the two men and, on Snow’s part, a respect for Mr. Read, who at 80 years of age, was still actively designing equipment. In December, 1841 Snow read a paper, “On paracentesis of the thorax” to the Westminster Medical Society, in which he discussed the risk of the uncontrolled entry of air into the pleural space via a canula during paracentesis. To reduce this hazard, Snow added a stopcock to the canula. He remarked that the canula he had designed was one which “any member can get made by his own instrument maker” and added “It has since been manufactured, under my directions, with great accuracy, by Mr. Read of Regent Circus.”

The introduction of the stopcock was the second collaboration on instrument design recorded between Snow and Read. The first occurred earlier the same year. On October 16, 1841, precisely five years before Morton demonstrated ether’s anesthetic action, Snow read a paper before the Westminster Medical Society, “On asphyxia, and on the resuscitation of still-born children.” In that paper, which may be Snow’s first work relevant to anesthesiology, Snow recommended three actions now considered fundamental elements of resuscitation. These actions were: using supplemental oxygen, suctioning the airway and performing mechanical ventilation. Snow related that in 1838 John Read had prepared a syringe to ventilate adults. Quoting Snow, “So the matter rested, until a short time ago, when Mr. Read, knowing I took an interest in the subject, called to show me an improvement in his apparatus. . . . I then suggested that he should make a little instrument on exactly the same plan, adapted to the size of new-born children. It consists of two syringes, one of which, by a tube adapted to the mouth, and closing it, withdraws air from the lungs, and the other syringe returns the same quantity of fresh air through a tube fitted to the nostrils.” Read’s valves were essential to the action of the syringes. Five years later Snow again selected Read’s valves for his ether vaporizers and, in so doing, designed the first of a series of vaporizers that were the most functional of that historical period.
The single surviving Snow vaporizer will be on public display in the new Wood Library-Museum of Anesthesiology. All anesthesiologists who view it as it lies shielded behind walls of glass will be impressed by its attractive and functional design. For me it has been more than a museum-piece, it has been as magical as Aladdin’s lamp for it has led me on a study of the technology employed in the era in which anesthesia was discovered. By touching the vaporizer I have been led to a new appreciation of the skills of John Snow. When I first assembled and breathed through the inhaler, I could not have anticipated that my dust-driven cough would provoke a study of the components incorporated by John Snow in his first ether vaporizers.

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