A VERY RARE ETHER VAPORIZER DESIGNED BY JOHN SNOW

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Summary

An ether vaporizer designed by John Snow and owned by the Royal College of Physicians of London has been identified as the 'Mark II' model which he described on 12 March 1847. The facemask is a prototype of the design which he published in September 1847, and can be dated to between mid-May and mid-June 1847. The case contains a unique and previously undescribed thermo-etherometer. This is a thermometer which incorporates Snow's table showing the amount of ether taken up by 100 cubic inches of air at different temperatures.

At a time when the design of other anaesthetic vaporizers was based on empirical trial and error, this rare instrument is an important exemplar of Snow's uniquely scientific approach to the practice of anaesthesia. Its provenance is unknown but it appears to have been owned by Sir Benjamin Ward Richardson and may have been given to him by Snow's executors.

Design of ether inhalers by John Snow

John Snow first witnessed general anaesthesia by the inhalation of ether on 28 December 1846 in the Gower Street surgery and home of the London dentist James Robinson.[1] During the early weeks of 1847 the medical journals carried numerous reports of operations performed under ether, but the success rates were very variable and many attempts ended in failure.[2 3] Only Snow appears to have understood the reason for these inconsistent results; namely, that the process of vaporisation was temperature dependent and that, because vaporisation itself caused a drop in temperature, it was necessary to provide some means of maintaining an appropriate temperature if the proportion of ether vapour in the inspired air was to be maintained. Vinten-Johansen *et al* have explained how Snow would already have been familiar with the relationship between ether vapour and temperature because of experiments which he had conducted with ether as a 'diapnetic' to promote respiration in 1843.[4] By January 16 1847, just three weeks after the first etherization in London, Snow had also realised that it was essential both to know and to be able to regulate the concentration of ether vapour which was inhaled by the patient and that there must be no obstruction to respiration. He quickly appreciated that these

conditions were not provided by the vaporizers which had been described up to that time. Most of the early vaporizers were modifications of existing and readily available chemical apparatuses. All were made of glass, which is a poor conductor of heat, and most contained sponges soaked in ether, which constituted an obstruction to free inspiration. Snow explained these basic scientific principles, illustrated by a table relating vaporization of ether to temperature, to the members of the Westminster Medical Society on January 16 1847, and informed them that he was having an instrument made which would overcome the problems of existing inhalers. The instrument would be made of metal, a good conductor of heat, and would contain no sponges. [5]

In the event Snow was to describe a series of ether vaporisers. Each one embodied the same scientific principles which he had so quickly identified as essential for consistently successful etherization. However, in the light of practical experience, he made several modifications to the initial design. Some of the modifications were to correct technical problems and others were to simplify the use of the apparatus in clinical practice. The evolution of the design will be easier to understand once the vaporizer owned by the Royal College of Physicians [RCP] has been described. When examining the apparatus we gave particular attention to both the appearance and the dimensions of the instrument, in the hope that these would indicate the date of construction.

Description of the RCP Vaporizer

All measurements were made using an electronic digital calliper. The body of the vaporizer (Figure 1) consists of a black, japanned metal container, cylindrical in shape, 113 mm (4.4 in) in diameter and 60 mm (2.4 in) in height. Its base is constructed separately and, although slightly "sprung" at one edge, there is some slight rusting which prevents the removal of the base from the body without the use of unacceptable force. In the centre is a screw-tapped orifice to receive the breathing tube. At the circumference is an opening of internal diameter 13.8mm (0.54 in), protected by a gilt metal screw cap, through which a liquid could be introduced. Also on the circumference, and at 90° from the aforementioned opening, is an air inlet of internal diameter 17 mm (0.67 in). This is a hollow tube, also protected by a gilt metal screw cap, which descends vertically down the outside of the chamber and then coils around the full circumference of the chamber before rising vertically to enter at the top of the chamber. On the side of the body is a brass plaque inscribed "Ferguson/21Giltspur St/London".

The breathing tube is connected to the body by a screw-tapped brass connector which is 30 mm (1.2 in) in length and of 14.6 mm (0.57 in) internal diameter. Incorporated into the connector is a brass 2-way (quadrant) tap, the positioning

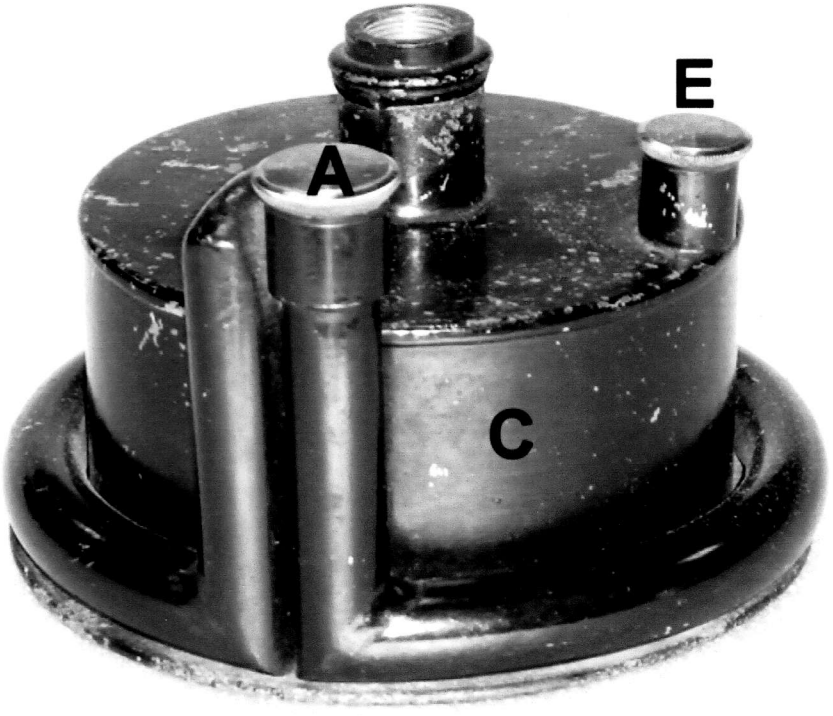

Fig. 1 Vaporizer Chamber. A = Air Inlet C = Chamber E = Ether port.
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of which would allow a variable amount of air to be mixed with the inhaled vapour. The breathing tube is fixed proximally to the brass connector and distally to a valve assembly, which is itself then connected to a face mask (Figure 2). The tube appears to be made of rubber and is closely covered with a fabric of either silk or cotton which is woven in a pattern of gold and royal blue. Internally the tube is stiffened by a closely coiled spiral of narrow wire. The tube is 835 mm (33 in) in length and has an internal diameter of 19.6 mm (0.77 in). The valve assembly is made of ebony and originally contained two small wooden (possibly cedar) balls, one of which is now loose in the carrying case. It is 16.1 mm (0.64 in or approximately ⅝ in) in diameter (see Figure 2).

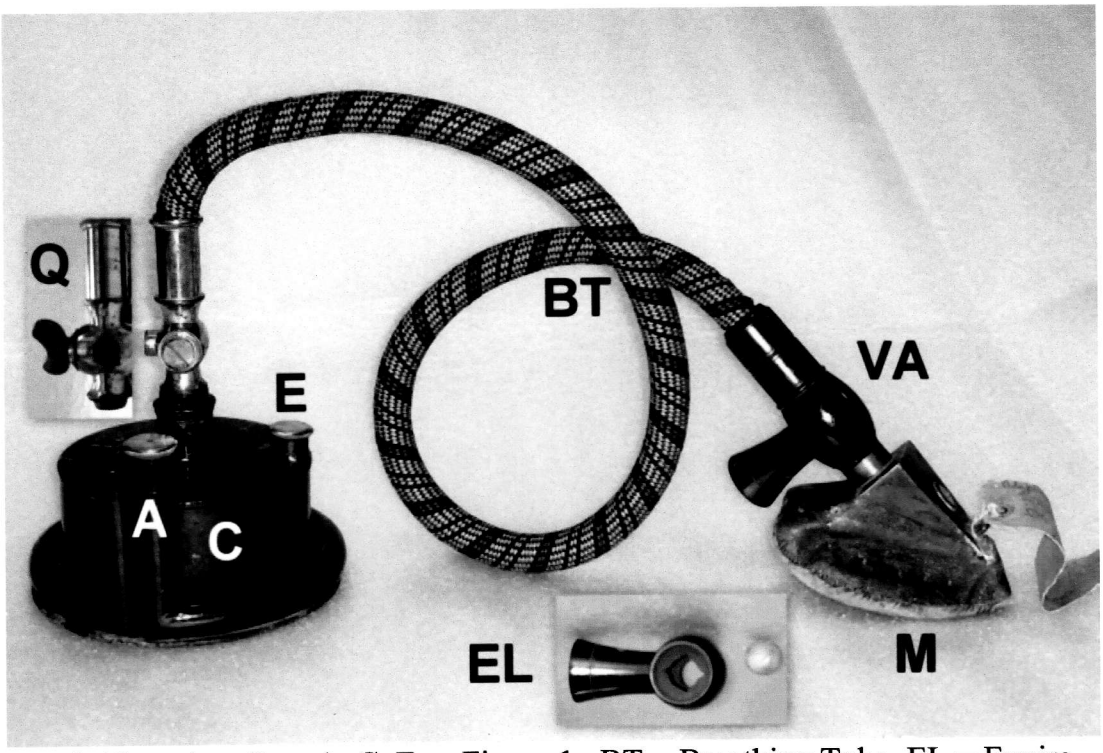

Fig. 2 Vaporizer Set. A, C, E as Figure 1. BT = Breathing Tube, EL = Expiratory Limb with Ball Valve, M = Mask, Q = Quadrant valve, VA = Valve Assembly. © Royal College of Physicians of London

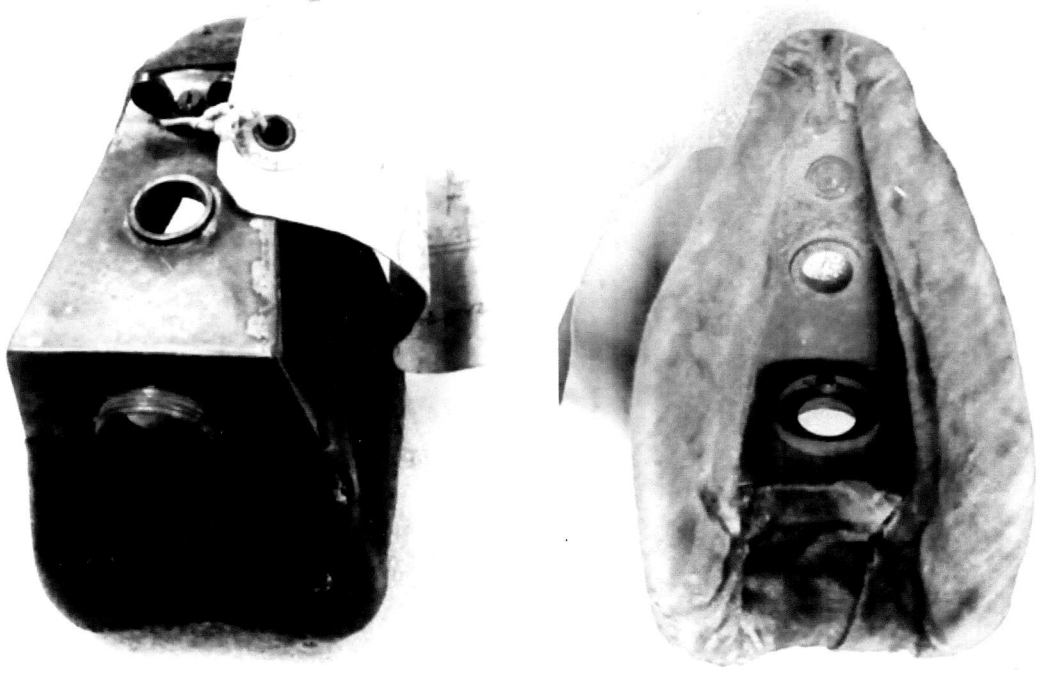

Fig. 3 Facemask. Exterior & Interior Views. © Royal College of Physicians of London

To the facemask is attached a luggage label on which is written "Adaptable mouthpiece for the inhalation of chloroform/By/Dr. Francis Sibson (The Late)". The facemask approximates in shape to that of a truncated pyramid, open on the side which is applied to the face (Figure 3). It is 107 mm (4.2 in) long and 51.4 mm (2.0 in) wide at its base. The front plate is made of brass or plated copper covered on its outer side by soft glove leather. The rear part, which fits to the face, appears to be made of a malleable metal, probably lead. The metal appears to be covered by some soft padding which, in turn, is covered by a soft material which may be silk or possibly velveteen and which is rather crudely stitched to the underlying padding. On the front plate of the mask are two apertures. The internal diameter of the lower aperture, which connects with the valve assembly, is 17 mm (0.67 in) and that of the upper aperture is 11 mm (0.4 in). On the internal circumference of the lower aperture is a small stud or pommel. The upper aperture appears originally to have been covered by a moveable flap. This was fixed by a wing nut, which remains in place above the orifice - see Figure 3.

With the vaporizer is a carrying case, made of a hardwood which may be mahogany. It is 250 mm (9.8 in) long, 140 mm (5.5 in) high and 175 mm (6.9 in) deep. It is lined internally with dark red velvet and has compartments for the vaporizer, a rectangular glass-stoppered bottle and a thermometer (Figure 4). A circular label on the inside of the lid is inscribed "Ferguson/Surgeon's Instrument Maker to St. Bartholomew's Hospital/21 Giltspur Street, Smithfield, London." On the outside of the box the initials "BWR" have been scratched on the brass base plate between the handle swivels. The words "Property of the Royal College of Physicians of London" are written on a tie label attached to the handle. On a stick-on label on the top of the box is written "Chloroform inhaler used by Dr. John Snow on Queen Victoria" and, in a different hand, "at birth of Princess Beatrice." On a torn scrap of paper inside the box is written "Box of chloroform inhaler used by Dr. John Snow when attending...Victoria..." and, in the same different hand as on the label, "...Beatrice". The thermometer is of the mercury-in-glass type and is inscribed at the top "Thermo-etherometer/after/Dr. Snow's Table". On the left hand side of the column is a temperature scale extending from 30-125 °F. On the right hand side is a scale labelled "Cubic inches of Vapour of Ether that 100 Cubic Inches of Air will take up". This scale extends from 34 to 476 corresponding to 38 °F and 90 °F respectively - see Figure 5. Written in ink on the back of the instrument are the words "Sir Benjamin W Richardson/25Manchester Square/London W".

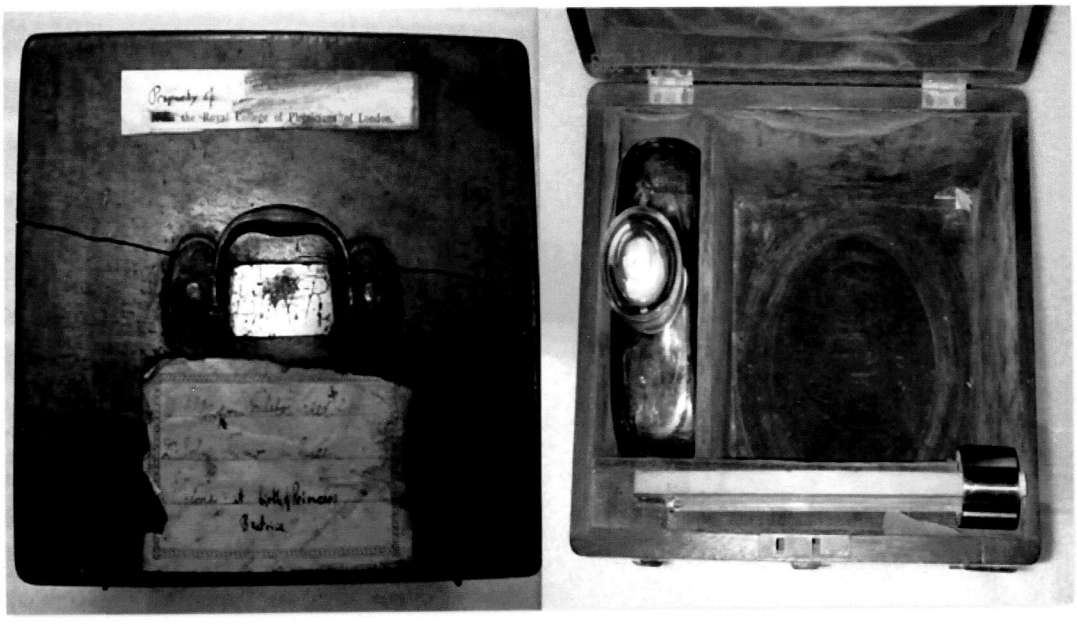

Fig. 4 Carrying Case. Exterior and Interior Views showing glass-stoppered bottle and thermo-etherometer in their compartments.

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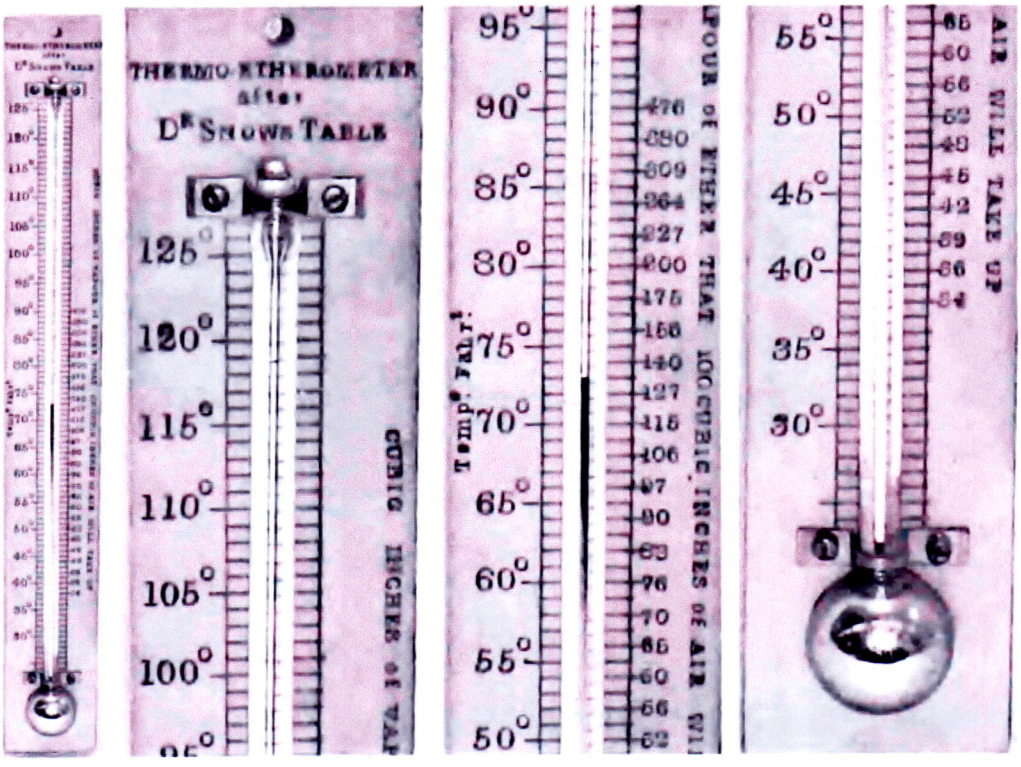

Fig. 5 Thermo-etherometer. Shown complete and as three enlarged segments.
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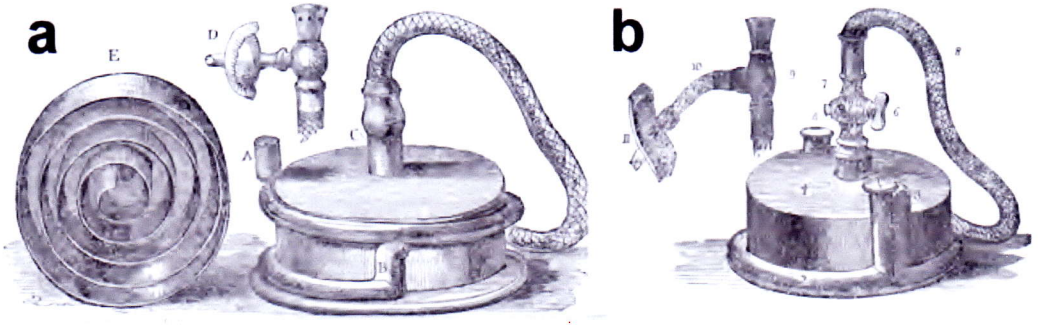

Fig. 6 a. Mark I, and b. Mark II Vaporizers from Snow's original publications [6 11]

Discussion

Snow demonstrated his first vaporizer to members of the Westminster Medical Society on January 23 1847, having already used it successfully in one case. The desired temperature was maintained constant by placing the vaporizer in a basin of water [6] – see Figure 6a. Richard Ellis described four types, or Marks as he termed them, in the evolution of Snow's ether vaporizers. The published abstract of his presentation to the History of Anaesthesia Society on this subject did not describe the criteria on which his classification was based,[7] but examination of his papers held by the Wellcome Institute for the History of Medicine shows that it was determined principally by the appearances of the chamber of the vaporiser. [8] In the first version, classified by Ellis as Mark I, the chamber was 2 inches deep, there was no separate aperture for filling the chamber with ether and the air inlet warming tube spiralled downwards around the outside of the chamber,[6] presumably because, at this time, Snow thought that the air must be warmed as thoroughly as possible before it entered the chamber.

Snow quickly realised that he had no convenient way of adjusting the concentration of the vapour, so by February 4 he had arranged with his instrument maker, Ferguson, to include a 'quadrant' or 2-way tap between the inhaler and the breathing tube. [9] With the tap fully open to the atmosphere only room air would be inhaled. When the tap was fully closed to the atmosphere only air saturated with ether vapour at the set temperature would be inhaled. With the tap in intermediate positions the proportion of ether vapour to air could easily be adjusted. The administrator could, therefore, begin the process of etherisation with the patient breathing only air and then, by gradually turning the tap, he could introduce an increasing proportion of ether vapour. By March 11 Snow had replaced the original breathing tube, which was $\frac{5}{8}^{th}$ inch in internal diameter, with one of wider bore, ¾ inch in diameter, having found that the former could sometimes impede inspiration in an adult. [10] He also made changes to the chamber of the vaporizer. A separate aperture was provided for filling the chamber with ether and the air inlet tube, instead of spiralling down around the circumference of the chamber, now descended vertically and then encircled the lowest part of the wall of the chamber.

With these modifications Snow had arrived at the design which he described in detail in a paper published on March 12 [11] (Figure 6b) and which Vinten-Johansen and Zuck have shown was submitted between March 4 and 10.[12] Ellis designated this model as the Mark II. [7] The instrument now in the possession of the RCP is very similar to this second design but differs from it in two respects. Firstly the aperture for filling the chamber with ether and the air inlet are separated by 90° in the RCP vaporizer whereas in the illustration in Snow's

paper (see Figure 6b) they are diametrically opposite each other. Secondly the illustration in the paper shows a mouth piece coming off the side arm of the valve assembly whereas the RCP vaporizer has a facemask in direct line with the valve assembly, the expiratory limb of which is now the side arm.

Snow had originally used a valve assembly and mouth piece which had been designed by Samuel Tracy[13] who, by February 1, had modified his original design in an attempt to compress the nostrils. [14] Like Snow's vaporizers this mouthpiece was made by Ferguson, which would have enabled Snow to keep the whole manufacturing process within the same firm. Snow asked for one change to Tracy's modified mouth piece, substituting common rubber for vulcanised rubber because "the latter frequently, if not always, contains sulphuret of arsenic." [11] One of Snow's earliest research projects had concerned the use of arsenic as a preservative in the bodies dissected by medical students so he had first-hand experience of its toxicity. [15] Because Tracy's mouth piece did not include the nostrils these had to be compressed or occluded with a nose clip. This was not entirely satisfactory because, as Snow subsequently explained, "some 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..." [16] On April 3 Snow was still using a mouth piece [17] but by May 3 he had adopted Sibson's face mask. [18] However, Sibson's mask[19] was cumbersome and by June 17 Snow had designed his own facemask. He incorporated two swing (or flap) valves into the facemask itself, in place of the ball valves in Tracy's valve assembly. The expiratory valve was also made to turn on a pivot so as to allow admission of atmospheric air, thereby rendering the 2-way tap unnecessary. [20] This would have had the practical advantage that the proportion of ether vapour to air could now be controlled by the same hand which was holding the mask on the face rather than by the other hand which would have had to stretch to the 2-way tap on the vaporizer which was up to three feet away at the end of the breathing tube. There are two possible reasons for Snow's decision to change from ball valves to flap valves. Firstly, moisture in the exhaled breath might have caused the wooden balls to stick and, secondly, the flap valve was less cumbersome. For this second reason Snow had already introduced "flat" valves in place of spherical ones on a small portable inhaler which he described very briefly to the Westminster Medical Society on April 3 [17] and which Ellis designated as Mark III. [7]

The mask which Snow had introduced by June 17 and which contained two flap valves [20] was probably very similar if not identical to that which he described in detail in his monograph on ether and which incorporated both an inspiratory and an expiratory valve. [16] Sibson had used flap valves in his design but, like Tracy's ball valves, they were contained in a separate valve assembly between the mask and the breathing tube. They also required a lever and a spring for

their action and the position of the valve assembly had to be adjusted depending on the position of the patient. [19] Little is known about the 'flat' valves which Snow used in conjunction with the Mark III vaporizer. They must still have been incorporated in a separate valve assembly because this vaporizer antedated the introduction of Snow's mask and the inspiratory valve had to be "balanced with a weight". [17] In Snow's innovative facemask design the valves were not only incorporated within the mask but they closed of their own accord, without the use of counterbalancing weights, and whatever the position of the patient. [16] The mask attached to the RCP vaporizer is very similar to that described in Snow's monograph. [16] The expiratory valve is missing from the RCP facemask but its position is shown by the wing nut which held it in place (see Figure 3). The inspiratory valve, which is also missing, would have been fixed to the small stud which is located on the inside of the lower aperture, as shown in Figure 3. The attachment is shown in one of Snow's masks which is owned by the Science Museum (catalogue number A625284) and in which the inspiratory valve has survived *in situ* (Figure 7). The inspiratory valve in this mask appears to be made of latex rubber while the expiratory valve, shown beside the mask in Figure 7, is metal. It is not known if these valves are original. Snow probably experimented with different materials for the valves. They had to be heavy enough to fall back over the aperture but the inspiratory valve had to be light enough to have been lifted by a weak inspiration. Snow settled on vulcanized rubber in his published description. [16] At first sight this seems a surprising choice in the light of Snow's comments about the choice of vulcanised rubber for Tracy's mouth piece, but perhaps he considered that the surface area of the valves was too small to pose any risk of arsenic poisoning.

The crude stitching by which the silk or velveteen is attached to the Royal College mask suggests that this was a home-made prototype. If so the stitching may even have been the work of Snow himself, indicating that he did not seek the help of his landlady's daughter who, according to the census returns, was a skilled needlewoman. That the ball valve assembly is still associated with this mask could also indicate that the mask was a prototype because it would have allowed Snow to have used one or other of the ball valves in the assembly while he was experimenting with different materials for each of the flap valves.

The "thermo-etherometer", which fits snugly into its own slot in the carrying case, does not appear to have been previously described. When Snow first published on the relationship between temperature and the amount of ether vapour in air on 23 January 1847, he expressed the relationship as the proportions of ether vapour and of air in 100 cubic inches at various temperatures. [21] Thus at 70 °F the ether occupied 49.4 and the air 50.6 cubic inches. However, in a paper published on March 12, he used a different format

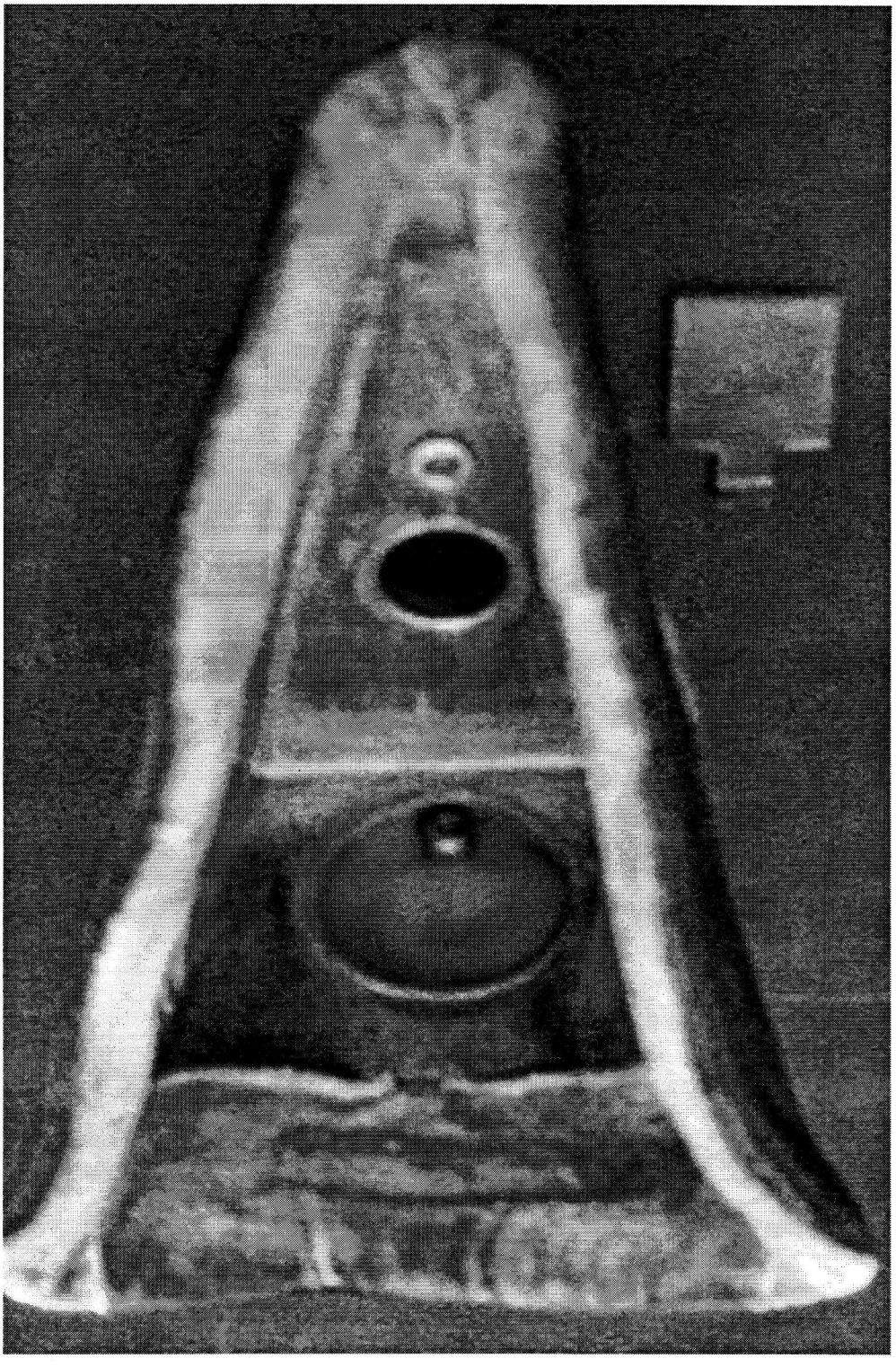

Fig. 7 A Snow Facemask owned by the Science Museum (A625284). Reproduced by permission of the Science Museum, London.

in a table which showed the amount of washed ether (the preparation most often used in etherisation) that 100 cubic inches of air would take up at different temperatures. Thus, at 70 °F, 100 cubic inches of air would take up 115 cubic inches of vapour, equivalent to 127 minims of ether. Snow tactfully suggested that this format was "more apparent to those unaccustomed for a long period to arithmetical calculations" [11] and it was this format which was used on the thermo-etherometer which probably therefore dates from March or later.

As far as we know the only other surviving example of an original Snow ether vaporizer of any Mark is that purchased by the Wood Library-Museum [WL-M] of the American Society of Anaesthesiologists for £540 from a London dealer in antique medical instruments in 1979, although it was not until 1992 that its identity was recognised. [22] Calverley described the chamber as "about 5 inches in diameter and 2½ inches deep." The breathing tube is shorter and narrower than that of the RCP instrument being 28 inches long and ⅝ inch internal diameter. We are most grateful to Dr George Bause, Honorary Curator of the Wood Library-Museum, for providing us with accurate measurements and multiple photographs of the vaporizer. These suggest that it is virtually identical with the RCP instrument except that it is fitted with a glass mouthpiece which is very similar to one of those supplied with Gilbertson's vaporizer, as described in April 1847. [23] Its carrying case is almost identical with the one owned by the RCP but the thermometer and glass bottle are missing (personal communication, George Bause, Honorary Curator, Wood Library-Museum, 22/08/2008).

Snow stated that the vaporizer chamber in what Ellis termed the Mark I design was 2 inches deep, [6] but gave no equivalent figure in his description of the Mark II. [11] The chamber depth of the RCP and WL-M instruments, both of which conform most closely to the Mark II design, is 2½ inches. The reason for the change is not clear. Later in 1847 Snow wrote that he had experimented with several different depths, initially 2 inches, later 1 inch and finally 1¼ inches. [16] The last figure referred to what has come to be regarded as Snow's definitive ether vaporizer which he described in September 1847 [16] and which Ellis designated as the Mark IV. [7] Whether the other depths given by Snow referred to preliminary designs of this definitive vaporizer or to the earlier Marks is not clear. Ellis described the Mark II chamber as being only 1½ inches deep but gave no reference to support this figure [8] and we have been unable to find evidence for it in any of Snow's publications.

The antecedents of the WL-M vaporizer are unknown, (personal communication, George Bause, Honorary Curator, Wood Library-Museum, 22/08/2008) and the provenance of the RCP instrument is uncertain because the College has no record of it in its accessions register. No reliance can be placed

on the labels attached to the carrying case, because it is not a chloroform but an ether vaporizer and because on both occasions when Snow administered chloroform to Queen Victoria he used a handkerchief and not a vaporizer. [24] The label attached to the facemask is also misleading because, as discussed later, it is definitely not a Sibson mask. There is, however, presumptive evidence that the carrying case and thermo-etherometer (and therefore also, in all probability, the other items) were at one time owned by Sir Benjamin Ward Richardson (1828-1896), whose initials have been scratched on the handle plate of the case, and whose name and address have been written in ink on the back of the thermo-etherometer. Comparison with a known example of Richardson's handwriting [25] confirms that the writing on the thermo-etherometer is indeed that of Richardson himself. Moreover, in 1884, Richardson recorded that he had in his possession "an ether inhaler, with thermometer and reservoir invented by Snow, in 1846". [26] Richardson must have mistaken the year, writing 1846 which would have been impossibly early, instead of 1847, but he is clearly referring to an early ether vaporizer and, in all probability, the one now owned by the RCP. Richardson was Snow's friend and biographer. After Snow's death in 1858 his case books passed into Richardson's possession and remained in his family until presented to the RCP by Richardson's daughter, Mrs. George Martin on 8 February 1938. [27] It is possible that the case books were given to the College because it already possessed the vaporizer, or it may be that the vaporizer was given after the books but that the gift was not recorded. It was certainly in the possession of the College by 1946 because it and the thermo-etherometer were loaned in that year to the Wellcome Institute for an exhibition to mark the centenary of anaesthesia. [28] Richardson would certainly have considered the Royal College of Physicians to be an appropriate home for Snow's case books and vaporizer. Not only was Richardson an eminent and active fellow of the College [29] but he also thought of Snow as a physician and described him as such. [30] Snow had proceeded MD (London) in 1844 and had passed the licentiateship examination of the Royal College of Physicians in 1850. [24] Had he lived just one year longer he would, as a distinguished licentiate, have been eligible for election to the fellowship of the College under the new regulations which were introduced in 1859. [31] The Richardson connection is, at best, presumptive evidence that the apparatus had originally been owned by John Snow, but this presumption is greatly strengthened by the facemask. Snow acknowledged Sibson as the originator of the concept of a mask which encompassed both mouth and nostrils. [32] The RCP mask, however, is very different from the funnel-shaped design which was described by Sibson [19] and, despite the label attributing it to Sibson, it is very definitely a prototype of Snow's design. We can only speculate about who might have added the misleading labels. It would not have been Richardson, who would have known that the vaporizer was for use with ether and not chloroform and that Snow had

used a handkerchief to administer chloroform to Queen Victoria. It is perhaps possible that one of Richardson's children might have added the labels on the basis of some mis-remembered story. There was certainly much confusion in the 1890s about the origins of Snow's mask. Buxton, who thought that Snow had done little more than incorporate valves into Sibson's mask, had been told by Richardson's son that Sibson's mask was itself a modification of a mask which had been designed by Benjamin Ward Richardson. [33] Benjamin Ward Richardson himself gave a faulty recollection of the true sequence of events in his autobiography. Writing some fifty years after the events he described how he had made a "double-valved inhaler" with a leather mask. He showed this to Snow who made some alterations, one of which was to increase the bore of the breathing tube. According to Richardson it was Sibson who then substituted lead for the leather in the mask and "the change gave rise to the Sibson Inhaler with Snow's tube." [34] In fact Snow had already published the design of his facemask before he and Richardson had first met. Whatever the reasons for the incorrect labels it is surprising that the correct identification and description of the vaporizer in the 1946 exhibition catalogue did not result in comment on these inaccuracies.

The chambers of both the RCP and WL-M vaporizers incorporate a two-way tap, and they conform most closely to the instrument which Snow described on March 12 [11] and which was designated by Ellis [7] as Mark II, the only major difference being that the apertures in the top of the chamber are separated by 90° in the surviving examples and by 180° in the illustration in the paper. There are, however, significant differences in the breathing circuits, valves and mouthpieces. Ellis, who almost certainly derived his classification solely from Snow's published papers, assigned specific modifications in the circuits, valves and mouthpieces to each Mark, [8] but it is evident from the surviving examples that no such clear-cut distinctions can be made. It is of course possible that a purchaser might replace a mouthpiece with another of his own preference, but the WL-M apparatus is fitted with the narrower breathing tube and it is highly unlikely that an owner would have replaced the newer, wider tube with the older, obsolete one, even assuming that he had access to one. In the early months of 1847 all aspects of Snow's vaporizers appear to have been in a continual state of flux and each of these early versions, whether an illustration in a paper or a surviving example, should be seen as the transient manifestation of an evolutionary process rather than as a definitive version or 'Mark'.

The rapidity of the changes in design poses both difficulties and opportunities for the accurate dating of Snow's ether vaporizers. Both the WL-M and the RCP vaporizers include the two-way tap, and must therefore date from the time of its introduction on February 4 or later. The WL-M apparatus has the narrow bore

breathing tube and, assuming that this is original, should be no later than March 11, when the wider bore tubing was introduced. Its carrying case includes a space for a thermometer which is no longer present. If it had been a thermo-etherometer, as is present in the case owned by the RCP, then the case and its original contents are unlikely to have been sold much before the date on which Snow's paper containing the revised format of his temperature table had been submitted to *The Lancet* which, as previously noted, was between 4-10 March. The WL-M vaporizer may therefore have been constructed during the first eleven days of March 1847, before the design had appeared in print on March 12.

The dating of the RCP apparatus is more problematical. It is fitted with the wider bore tubing, which should indicate a date of March 11 or later. However if, as seems likely, this was indeed Snow's own instrument, and if it was the one which he was using to develop his facemask, it could also have been the one which he used to experiment with breathing tubes of different sizes. If so, the tube which is now with the vaporizer could be a replacement for an earlier, narrower tube.

We have no indication of the cost of Snow's vaporizers, but economic considerations would suggest that he was unlikely to have had a new model made simply to test relatively minor alterations in design. It seems probable that the production of vaporizers, like those owned by the RCP and the WL-M, which had chambers and two-way taps in conformance with Ellis's Mark II designation, would have ceased when Snow introduced what has come to be regarded as his definitive vaporizer. As previously noted, this instrument, which Ellis designated as Mark IV, [7] was first described by Snow in the monograph which he published in September 1847. [16] In this work Snow stated that he had used this vaporizer, which was incorporated within its own rectangular water bath, "for the last three months" which would imply that it was first used by him in late June or early July. It is certainly likely to have been after June 10th because a description of an anaesthetic given by Snow on that date included the words "...the inhaler being placed in water..." [20] which would not have been applicable if he had been using the definitive inhaler which was incorporated within its own water bath. How promptly Snow and Ferguson might have put the definitive inhaler on sale is not known, but it was probably soon after Snow had satisfied himself of its effectiveness and its advantages. The period during which the 'Mark II' vaporizer might have been manufactured was, therefore, probably only from early March until late June. This short time may explain the extreme rarity of known surviving examples. Indeed, it is remarkable that any should have survived at all. So far as we are aware, there is only one surviving original example (owned by the Association of Anaesthetists of Great Britain

and Ireland) of Snow's chloroform vaporizer and yet this instrument must have been produced in much larger numbers than any of the ether vaporizers.

An estimate can also be made of the period during which Snow was designing his facemask. It cannot have begun before May 3, when he first started using Sibson's mask [18] and it had been completed by June 17, when he used a mask of his own design at St. George's Hospital. [20] In a lecture delivered on May 12 and published on May 29 he wrote that he had found Sibson's mask to "answer completely". [11] However he also referred to spherical valves made of cedar wood, which suggests that he did not have complete confidence in Sibson's valve assembly and was still using Tracy's at this time. He made no mention of any re-design of his own vaporizer, but he probably would have started work on this project between mid-May and early June and he was using it in clinical practice by June 17. The unique RCP prototype can therefore be dated to between mid-May and mid-June.

The RCP and WL-M instruments, taken in conjunction with Snow's published papers, contribute to our understanding of the continuous and evolving process of Snow's vaporizer designs in what Vinten-Johansen and Zuck [12] have termed his *annus mirabilis.* The papers alone provide discreet snapshots, frozen in time, but the actual instruments add a dynamic dimension. Thus, we see the replacement of the mouth piece by a facemask, the tubing of increased diameter, and the process by which Tracy's valve assembly was replaced by the incorporation of valves into the facemask. We also see the incorporation of a 2-way or quadrant tap and its later replacement by a modification to the expiratory valve on the facemask and, although we do not know the precise chronology, Snow tells us in his 1847 monograph that he experimented with chambers of different depths. [16] All of these changes contributed to a continuously evolving design which culminated in his definitive Mark IV vaporizer.

Unless further evidence comes to light the definitive provenance of both the RCP and the WL-M vaporizers seems destined to remain an enigma but, in the development of anaesthesia in particular and of modern medical practice in general, they will always represent a major milestone in the triumph of scientific enquiry and evaluation over empirical trial and error.

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