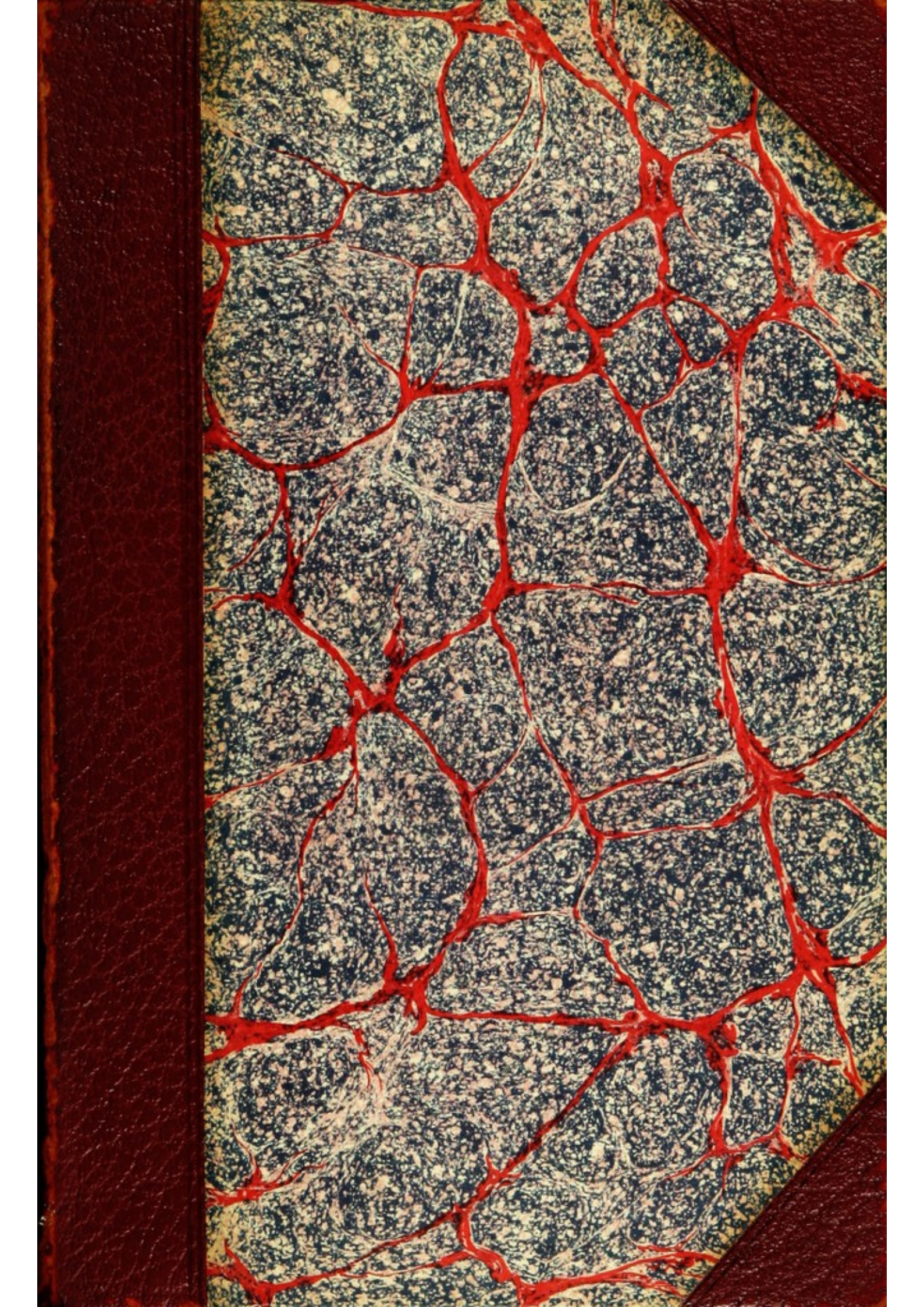

ON THE

INHALATION

OF THE

VAPOUR OF ETHER.

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ON THE

INHALATION OF THE VAPOUR OF ETHER,

&c. &c.

It will be at once admitted that the medical practitioner ought to be acquainted with the strength of the various compounds which he applies as remedial agents, and that he ought, if possible, to be able to regulate their potency. The compound of ether vapour and of air is no exception to this rule, although it might be supposed to form one, as the practitioner stands by to watch its effects. For, in the first place, these effects vary materially according to the proportion of vapour given with the air, and in the next place, there is a counter process going on with inhalation, viz. exhalation. This increases with the amount of ether absorbed into the blood, and there arrives a point at which the exhalation may equal and just balance the inhalation, if the vapour be very much diluted; and this may occur before insensibility is produced. It is to this circumstance that we are to attribute the origin of the opinion that there are some persons—hard drinkers, for instance,—who are proof against the influence of the vapour. There may be persons on whom it does not act favourably, but I believe that no sentient being is proof against its influence.

It occurred to my mind that by regulating the temperature of the air whilst it is exposed to the ether, we should have the means of ascertaining and adjusting the quantity of vapour that will be contained in it: for the proportion of vapour in any given volume of air saturated with it at any particular temperature, is to the whole volume as the elastic force of the vapour at that temperature is to the atmospheric pressure at the time and place. This is true of all vapours in contact with the liquid which gives them off. Now the elastic force of the vapour of ether has been investigated by Dalton and Ure. I made some experiments with air and ether in graduated tubes over mercury, and found that the quantity of ether vapour taken up at various temperatures corresponded with calculations made according to the formula for the elastic force of the vapour of ether, given by Dr. Ure in his paper on Heat, in the Philosophical Transactions for 1818. I accordingly made use of his table and formula, as I stated at the Westminster Medical Society, in constructing the table published in the Med. Gazette on Jan. 29. The ether I used was not altogether free from alcohol, and I conclude this must have been the nature of the ether used by Dr. Ure in his experiments on the elastic force of its vapour; for on making observations afterwards on washed ether, and on every kind of ether over water, (for it then becomes washed,) I found the quantity taken up by air somewhat greater; but the geometrical ratio of increase in the quantity, according to temperature, is the same, as I have ascertained by very numerous observations at all the usual atmospheric temperatures. To make the table I constructed correct for washed ether, which is always used for inhaling, it is necessary to subtract four degrees from the various temperatures; for instance, the numbers opposite 40° are correct for 36°, and so on. The ether I first used in my observations boiled at 104°. Washed ether boils at 100°, and if entirely deprived of its water by potash, at 98°. So long as ether contains no

alcohol its specific gravity does not much influence the elastic force of its vapour, nor consequently the quantity that will mix with air; for water, having a much weaker affinity for ether than alcohol has, exerts less influence over its volatility.

The quantity of vapour of ether which air will take up at different temperatures, may be readily seen by introducing some ether to a measured quantity of air in a graduated receiver over the pneumatic trough, and noting the expansion which takes place, and the temperature of the air within. The vapour may be washed out of the air by passing it through a quantity of water, and the air may be again measured, when the experiment will have been both synthetical and analytical. The most convenient and satisfactory way of investigating this subject, however, is over mercury, by means of a graduated tube, bent in the form of Dr. Ure's eudiometer, the open leg being the longest. Pass a portion of air into the sealed leg of the tube, about as much as will fill one fourth of it, the quantity being carefully noted, whilst the mercurial level is preserved in the two branches of the tube, and the required temperature attained by immersing the syphon over its sealed branch, in water contained in a tall glass jar. A great portion of the mercury being withdrawn from the open leg by a long narrow tube, a few drops of ether may be introduced by means of the same tube through the mercury to the air in the sealed leg, by inclining the eudiometer a little, and using a little pressure with the breath on the surface of the ether.

By plunging the eudiometer in water at various temperatures, making a correction for the slight expansion and contraction which takes place in the air itself, from the increase and diminution of heat, and keeping the surface of the mercury level in the two legs, a number of observations may be made in a short space of time; and by washing the ether out of the air afterwards, and observing that the quantity of air is the same as at first, the whole of the observations will be verified.

The following table is suitable for washed ether which boils at 100°, and is quite free from alcohol but not altogether free from water; this being the kind of ether which is usually, and I think very properly, used for inhaling. The barometer is supposed to be stationary, and at 30°. This table is formed on a different plan from the former, to shew the quantity of vapour that air will take up; and as the air is made a fixed quantity, and the variation of the ether all exhibited in one column, the influence which temperature exerts over it is rendered more apparent to those unaccustomed for a long period to arithmetical calculations. A table formed in this manner is the most correct way of exhibiting the subject, because, since the vapour of ether is absorbed as fast as it arrives at the pulmonary air cells, the quantity inhaled will be influenced rather by the volume of the air, than by that of the mixture of air and vapour, provided the patient's respiration is not obstructed, and it never should be, by the apparatus.

Table of the quantity of ether which 100 *cubic inches of air will take up at various temperatures.*

Temp. Fahr.	Cubic inches of vapour.	Minims of ether.
38°	34·4	37·8
40	36·9	40·5
42	39.4	43·3
44	42·2	46·4
46	45·3	49·8
48	48·6	51·4
50	52·2	57·4
52	56·2	61·8
54	60·5	66·5
56	65·2	71·7
58	70·6	77·6
60	76·4	84·0
62	83·0	91·3
64	90·1	99·1
66	97·6	107·3
68	106·1	116·6
70	115·4	126·9
72	127·2	139·9
74	140·3	154·3
76	156·4	172·0
78	175·4	192·9
80	200·0	20·0
82	227·8	250·5
84	264·0	290·4
86	309·7	339·9
88	380·8	418·8
90	476·1	623·6

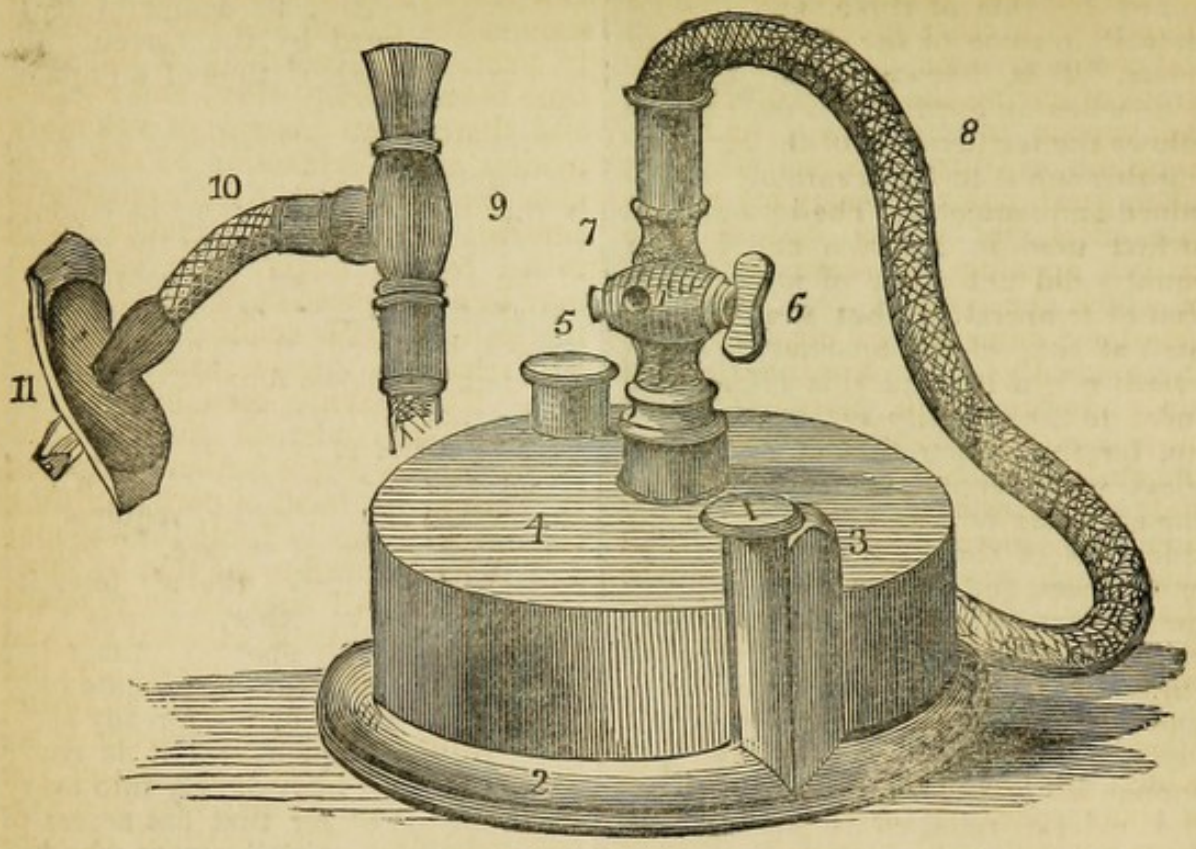
With the assistance of the above table we can determine the proportion of ether to air, and by measuring the

ether consumed in an operation, the quantity of air, as well as of vapour, breathed per minute, or throughout the inhalation, can be easily determined by rule of three, and I shall state it in some of the cases I have to relate. This, however, can only be done when an apparatus is used which allows the temperature of the air passing through it to be accurately determined and regulated. The instruments at first used in America and in this country did not allow of any regulation of temperature, but were always used at that of the apartment, whatever it might be, and this afforded no index to the quantity of vapour taken up, for the evaporation of ether in a glass vessel containing sponges cools the air, more or less, according to the thickness of the glass and other circumstances, and it leaves the apparatus many degrees colder than it entered, as may be ascertained by passing air through an apparatus of this kind, and noting the temperature with a delicate thermometer. Glass and sponge being bad conductors of heat, the caloric required to convert the ether into vapour is taken in a great measure from the air passing through the apparatus, its temperature being thereby reduced, and the quantity of ether which it will take up diminished. Instruments with compartments for warm or hot water, without the means of regulating the temperature of the whole apparatus, are still more objectionable than the former, for by them there is a risk of administering all vapour and no air. Hot water ought never to come near an apparatus for the inhalation of ether, nor even warm water, and when its temperature approaches to tepid it ought to be carefully regulated.

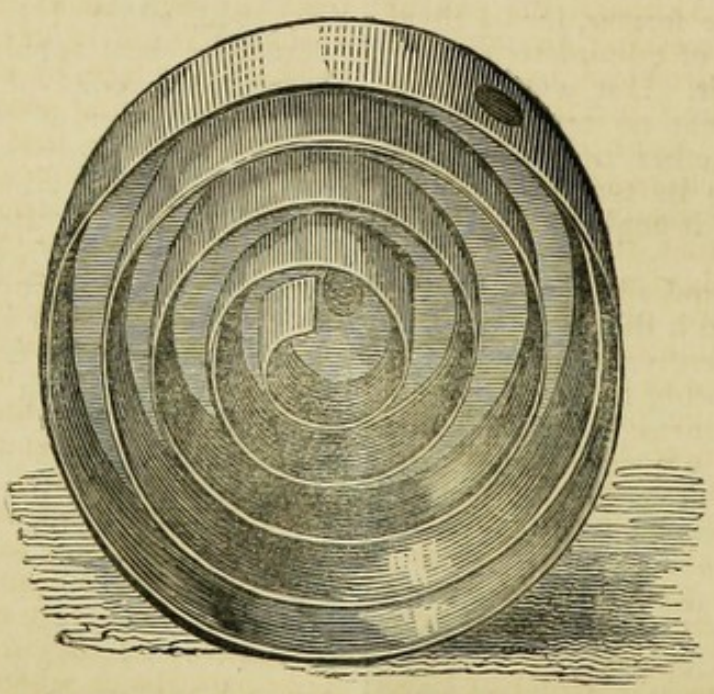
All that was required to regulate the temperature of both the ether and the air, and, consequently, of the resulting mixture, was to bring them into proximity with substances having a good capacity for, and a good power of conducting, caloric. The first we have in water, and the second in the metals; therefore, by placing the ether in a metal vessel, and that vessel in a basin of water brought to the desired temperature by mixing cold and warm water together, the object was attained. Two or three pints of water supply the caloric abstracted in the evaporation of an ounce or two of ether without being much reduced in temperature; and, as the water never requires to be many degrees either above or below the heat of the apartment, its temperature is but little altered by the surrounding air during the short time of an operation.

To ensure the saturation of air with the vapour of ether, all that is required is that the air should come in contact with the ether. The larger the surface of the ether exposed, the greater the evaporation, under ordinary circumstances, because it is exposed to more air; but the elastic force of the vapour of ether, at all temperatures above the freezing point of water, is such, that, to saturate the quantity of air which one person can breathe, requires no very great extent of surface. There is no necessity to make the air force its way through the ether, or pass with difficulty through sponges: the ether lies imprisoned in the liquid state only whilst kept down by air already saturated with its vapour, and it is ready to project itself immediately into every fresh portion of air that has access to it, as every one is well aware who has made any experiments with it in jars over the pneumatic trough. However, to insure that the air should come in contact with the ether, and to prevent its being cooled by the contact, I had the interior of the apparatus constructed on the principle of the inhaler of Mr. Jeffreys, described in the Med. Gaz. Feb. 1842, which I had always considered the best inhaler for aqueous vapour. The coils of the tin volute are not so numerous as in the latter, but they are amply sufficient for so volatile a liquid as ether. The air has to pass through a pewter pipe before it enters the spiral chamber; by this means it gains the temperature we may wish, and the further advantage is attained, without the impediment of a valve, of preventing evaporation of ether into the room between the inspirations of the patient. In the other instruments that I have seen, there is either a waste of ether in this way, or else there is a valve to admit the air into the inhaler, which must be opened by means of the muscular effort of the patient. The vapour does not find its way in a retrograde direction through 18 inches of curved pipe between the inspirations of the patient; and, con-

sequently, whilst there is no impediment to the free passage of air through the apparatus, no ether escapes till it has been breathed by the patient. The mouth-piece I have adopted is furnished with the cushion and India-rubber described by Mr. Tracy in a recent number of the MED. GAZETTE. I use,



1, Cap which unscrews to admit the air to
2, Metal pipe.
3, Entrance of ditto into
4, Spiral chamber.
5, Star closing aperture for putting in or pouring out ether.
6, Two-way tap.
7, External opening of ditto.
8, Flexible tube.
9, Ebony tube, containing ball valves of cedar wood.
10, Portion of flexible tube to admit of change of position of
11, Mouth-piece, with soft cushion, &c.



Interior of spiral chamber, the bottom being removed.
N.B.—The spiral tin plate is soldered to the top, and reaches nearly to the bottom.

however, the common, and not the vulcanized, India-rubber, as I understand that the latter frequently, if not always, contains sulphuret of arsenic. As the sudden access of air highly charged with ether produces irritation and cough in some persons, I was desirous of having the means of diluting the vapour to any extent, and Mr. Ferguson, of Giltspur Street, who has taken great pains to carry my wishes into effect, got a tap cast of wide caliber, opening two ways, by means of which the patient can begin by breathing unmedicated air, and have this gradually turned off as the etherized air is admitted in its place. This tap offers the further advantage of enabling the medical attendant to keep up the state of insensibility during an operation by a more diluted vapour than that which was necessary to produce that state. All the passages through the apparatus are not less than five-eighths of an inch in diameter.

Those cases of administration of ether are generally most successful in which the insensibility is produced in a short space of time; for instance, from a minute and a half to three or four minutes after the process is fully begun. This we might expect for various reasons; amongst the rest, that no process of inhaling can be carried on without interfering somewhat with the natural state of the respiration and embarrassing to some extent the circulation; therefore the shorter the process the better. Although the patient may begin by breathing air, and the ether may be introduced by degrees, yet, by turning the tap a little at each inspiration, the transition may be effected in from a quarter to half a minute. It is necessary to the success of the process that the nostrils and mouth be carefully closed. The patient should have plenty of air, it is true, but it should all come charged with the vapour, otherwise there can be no certainty about the process, and the patient will be more likely to become inebriated than insensible. The temperature I have nearly always applied has been from 65° to 70°, between which points the proportion of vapour and of air does not differ much from equality.

In those instances in which I have watched the pupil of the eye narrowly, I have observed it to dilate, as the patient is getting under the influence of the vapour. This dilatation is, however, but transitory, and the pupil usually becomes somewhat contracted, and the eye turned up as in sleep, as soon as the patient becomes insensible to pain. The breathing at the same time becomes deep, slow, and regular, and there is an absence of voluntary motion and a relaxation of the muscles, the orbicularis muscle ceasing to contract again on the eyelids being raised by the finger. An operation may be commenced in this condition of the patient, with confidence that he will remain as passive as a dead subject. This having been found to be the case, in order to maintain the insensibility without further increasing it, I am in the habit of partly turning the two-way tap to dilute the vapour; and it has seemed to me that by turning it about half way, so as to admit an equal quantity of external air, and reduce the vapour to about 25 per cent., that object has been attained: but a more extensive experience is required on this point, and perhaps the proportion required may vary in different patients. This method of continuing a more diluted vapour I have found to keep up the insensibility better than leaving off the process and resuming it by turns. But if the respiration becomes too slow, or at all stertorous, or if the pulse becomes very small or feeble, the nostrils should be at once liberated, and the admission of fresh air will afford immediate relief. I should think it unsafe to fasten a mask on the face, by means of a strap and buckle going behind the head, or to use any means that would interfere with the instantaneous admission of air, for on one occasion I saw an animal killed by ether by a momentary delay. It was placed in a small glass jar, and when it appeared to have had as much of the vapour as it could bear, I attempted to take it out, but could not reach it with my fingers, and whilst turning round for some means of extricating it, it expired.

In nineteen cases out of twenty in which the pulse was carefully noticed, it increased in frequency during the inhalation, often very much, becoming as frequent as 180 in the minute in some patients in whom, from debility, it was frequent before the process began. Generally the pulse has also

become smaller and more feeble. In one instance, that of a lady reduced in strength by malignant disease, it became smaller, but not more frequent; and as soon as the inhalation was discontinued, it became fuller and stronger than before the inhalation began. The pulse generally recovers its volume almost directly the inhalation is discontinued; in several instances, as in the above, becoming stronger than before: but it remains frequent for some minutes. The immediate effect on the circulation, of the absorption of the vapour in the lungs, appears to be an impediment to the flow of blood through the pulmonary capillaries. Less blood reaches the left side of the heart to be sent into the arteries, which diminish in caliber, but the heart contracts more frequently in order to keep up a supply. The escape of the vapour from the blood again seems to exert a contrary effect on the circulation, as evidenced, in general, by the pulse. I may perhaps be allowed to make a quotation bearing on this subject from a paper of mine in the MED. GAZ., vol. xxxi.:—"Assafœtida, ether, various essential oils, camphor, and other volatile medicines, relieve difficult and impeded respiration..... They are all separated from the blood in the lungs, and escape with the breath..... increasing very much the quantity of vapour which exhales from the pulmonary capillaries, and thus giving additional impetus to the blood: in this way lessening congestion and relieving its distressing symptoms. As this class of medicines promote the function of respiration, I will venture to call them diapnetics, from δια and πνεω."

I have seen two cases in which the depressing effect of the inhalation was considerable, and was not followed by reaction directly it was discontinued. As this appears to have been the case in the instance attended with a fatal result at Colchester, and related in the MEDICAL GAZETTE of the 5th inst., it may be desirable to enter into the particulars of one of these. A lady, 41 years of age, in pretty good general health, the patient of Dr. Frederick Bird, inhaled ether on the occasion of having a tumor removed connected with the external generative organs. She inhaled for eight minutes, during which time it was observed that the respiration was feeble and slow. The pulse, however, which had been about natural before the inhalation, became feeble and very frequent, and the patient began to struggle as if suffering from want of breath; the process was discontinued, although she did not appear insensible, and the operation was commenced. She flinched and cried out at the first incision, although she did not afterwards remember the pain. She became very faint during the operation, although there was but little loss of blood, and it was necessary to give brandy, and lower the head to the horizontal posture. Consciousness soon returned, and as some sutures were made in the skin, she spoke coolly of beginning to feel a little pain. The feeling of faintness continued more or less all night, but her recovery was very good. The apparatus in this instance was placed in water at 70°, being lower than the temperature of the room. Two fluid ounces of ether were put in, and three drachms remained; consequently 13 drachms were inhaled, equal to about 709 cubic inches of vapour; and as it was washed ether, each 115 cubic inches would be combined with 100 cubic inches of air; consequently only about 616 cubic inches of air were breathed, making 1325 cubic inches of air and vapour: but in eight minutes the patient ought to have breathed about 2400 cubic inches of air alone. The ether in this instance appeared to act as a sedative to the function of respiration, and the small amount of air breathed may perhaps account for the depressing effects.

In two or three instances there have been some struggling and a distended state of the superficial veins, the skin being rather purple, and the conjunctivæ somewhat injected. In one instance this seemed to arise from cough being excited by the vapour, on account of the bronchial membrane being in an irritable state, and in the others I believe it arose from obstructed respiration, which in future may be avoided, rather than from the direct effect of the vapour. By the kindness of the surgeons to St. George's Hospital, I have had the honour of giving the vapour of ether at thirteen surgical operations—most of them important ones—in the hospital during the last

six weeks, having the valuable advice of the surgeons, and occasionally also of one or two of the physicians to the hospital, to aid me in so giving it. It has been successful in altogether preventing pain in all the cases but one or two, and even in these there was but very little of the pain that there otherwise would have been; and there have been no ill effects of any kind following the inhalation of the ether. I allude to these cases to remark that five of the patients were children of various ages, from the fifth year upwards, and that they inhaled more easily than the adults generally did; that they were more quickly affected, generally becoming quite insensible in less than two minutes, and always without any of the struggling which sometimes occurred in the adults. For a variety of reasons, and from close observation, I have arrived at the conclusion, that this difference has not arisen strictly from a different effect of ether on subjects of different ages, but from a cause within our control. The same inhaler was used in all, consequently the tubes were wider in proportion for children than for adults. I have described all the passages of the apparatus as not less than five-eighths of an inch in diameter; but such is the description rather of what I wanted than of any instrument I have used. Valves and tubes such as were already in existence have been made use of, and the caliber in some part of its extent has always been contracted to half an inch, and this I consider only enough for a child, but not for the adult. As only half, and often not so much as half, of what is inhaled is air, it is particularly requisite that the tubes should be wide. I am now getting elastic tubes, valves and mouth-tubes, made purposely for the apparatus three quarters of an inch in diameter, as wide, in fact, as the barrel of a fowling piece, and intend to give ether as fair a trial in adults as hitherto, I believe, it has had in children only.* The pipe admitting air to the ether will be five-eighths, and all the passages for the air expanded by vapour, three-quarters of an inch in diameter. It may be supposed that there is no occasion to make the tubes larger than the trachea, but something ought to be allowed for the friction of the air against the interior of the tubes.

With respect to the psychological phenomena produced by ether, I have observed that consciousness seems to be lost before the sensibility to pain, and if an operation is commenced n this stage, the patient will flinch, and even utter cries, and give expressions of pain, but will not remember it, and will assert that he has felt none. Metaphysicians have distinguished between sensibility and perception—between mere sensation and the consciousness or knowledge of that sensation, though the two functions have, as they supposed, always been combined. Ether seems to decompose mental phenomena as galvanism decomposes chemical compounds, allowing us to analyse them, and showing that the metaphysicians were right. During the recovery of the patient, consciousness, which first departed, generally returns first, and the curious phenomenon is witnessed of a patient talking, often quite rationally, about the most indifferent matters, whilst his body is being cut or stitched by the surgeon. I have never seen this insensibility to pain during the conscious state except where consciousness had been previously suspended. In the paper on the capillary circulation, in the MEDICAL GAZETTE, to which I have alluded above, I offered the opinion that the pain of inflammation depended on a great increase of the natural sensibility of the inflamed part. Under the influence of ether we sometimes see the converse of this, viz. what would be pain reduced to an ordinary sensation; thus, some patients, whilst recovering their consciousness, feel the cuts of the surgeon without the smart. A nobleman, the patient of Mr. Tracy, of Hill Street, Berkeley Square, described the lancing of an abscess as the sensation of something cold touching the part; the manipulation of the abscess, which at another time would have been painful, he did not feel at all.

If the patient will remain silent during his recovery from the effects of ether, as he generally will, it is better not to trouble him with questions till he has perfectly regained his faculties, as conversation seems to increase the tendency to excitement of the mind

* Since the above was written, I have used these large tubes, and found them to answer my expectation.

that sometimes exists for a few minutes as the patient is recovering from the effects of ether. This kind of inebriation is sometimes amusing, but is not a desirable part of the effects of ether, more especially on so grave an occasion as a serious surgical operation; and therefore anything that may prevent or diminish it is worthy of attention. The children have all appeared to recover their consciousness very quickly, and without any kind of aberration of mind.

Any organic disease which impedes the flow of blood through the heart and lungs would seem to contraindicate the exhibition of ether by inhalation, and I should consider a hurried state of the circulation, such as that induced by strong labour pains, likewise to offer an objection to the process.

It was my intention to make some remarks on the probable way in which ether acts in suspending sensibility; but, as what I have already written is probably sufficient for one article, I will reserve that part of the subject for a future communication, and will be content, at present, to refer to a short abstract of some of my experiments and opinions which appeared in the number for Feb., 26.

In concluding, however, I should wish to observe that I am inclined to look upon the new application of ether as the most valuable discovery in medical science since that of vaccination. From what I have seen, I feel justified in the conclusion that ether may be inhaled for nearly all surgical operations, with the effect of preventing pain, not only with safety and without ill consequences, where due care is taken, but in many cases with the further advantage of improving the patient's prospect of recovery; the pain of an operation forming often a considerable part of what renders it dangerous, and many patients after ether, having seemed to recover better than might, without it, have been expected. In the amputations performed at St. George's Hospital whilst the patients were under the influence of ether, it has been remarked, as was stated by Mr. Cutler, on Feb. 11th, that there has been an absence of the painful spasmodic starting of the stump, which usually renders it necessary for a nurse to sit and hold it for some hours after the operation.

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