# PHYSIOLOGICAL EFFECTS

OF

# THE INHALATION OF ETHER,*

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The Council of the Society having thought that the discussion of this subject might prove both interesting and useful, and having applied to me to bring it forward, I complied solely from the desire to render to the Society any service in my power; but certainly not from thinking my knowledge of the subject so exact, or my opinions upon it so matured, as to entitle me to bring it forward spontaneously; but I hope to meet with indulgence for the imperfections you may find in the performance of a duty not sought for, but imposed upon me.

It has long been a desideratum in the medical art, to lessen the pain of surgical operations—for as to removing it altogether, no rational man, even in his most sanguine moments, ever dreamt of it. It was at one time attempted to deaden the pain by means of opium; but the attempt was abandoned, because it was found impossible to administer the drug in sufficient doses to blunt sensibility without risk of more serious consequences. I need scarcely mention the more recent attempts, by means of animal magnetism; for I hold the abandonment of an object so important by the professors of the mesmeric art, to be a tacit acknowledgment that they know themselves unable to attain it—that their boasted power is a deception, or, at most, has no influence but over the minds of a few hysterical females. Were it otherwise, the charge I make against them is a light one, compared with the moral charge implied in their deserting so many sufferers, whom they have the power to relieve.

I confess that when I first heard of the marvellous efficacy of ether in deadening the sensibility of the nerves, I received it with distrust, and thought it was to turn out just such another imposition as animal magnetism. I am not ashamed to say this, because I think that every rational man

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ought to receive in a spirit of scepticism, statements made to him in opposition to all antecedent experience. But I should have thought myself a very unworthy member of this Philosophical Society, had I refused to inquire further, and shut my mind against the authority of facts. I have carefully examined the subject, by actual observation and experiment, and I have now to state as the result, that I am fully satisfied that the statements originally made to me were in no way exaggerated: that the inhalation of ether really has the power of suspending, for a time, the sensibility of the nerves; and that, during the period of suspended sensibility, the most formidable surgical operations may be performed—amputation of the limbs, the dissecting out of tumours, and cutting for the stone—without any perception of pain by the person operated upon, and without reason to apprehend any bad consequences, either immediate or subsequent. I can honestly declare that I have seen all these, and many other operations performed; and that the patients, when put fully under the influence of the ether, gave no indications of feeling pain during the operations, and declared afterwards that they had felt none, which is the whole evidence that the case admits of. So great a triumph of the medical art I never expected to witness; but it should not excite feelings of exultation merely, but should be received with gratitude and with thankfulness, as a great boon which it has pleased the Giver of all good to bestow, in his compassion for the sufferings of mankind.

When our wonder at results so unexpected has in some degre subsided, it becomes our duty to inquire in what way they are produced; because it is only when we come to understand the nature of this important agent, and the laws which regulate its action upon the human body, that we can expect to derive from it all the benefits which it is capable of imparting; to direct and modify it according to circumstances, and to avoid the dangers which, in the hands of the incautious and ignorant, it may, most unquestionably, occasion. It was to attain these important ends, and not to gratify a mere vulgar curiosity, that the Council of the Society started this subject; and I am not without hopes that good may be done by the mutual communication of opinions, and that even the collision of them may serve to strike out some useful light.

That we may be better able to appreciate the new facts recently ascertained, let us first inquire what was previously known of the action exercised by ether upon the human body. I could state this in few words, if I were addressing a body of medical men, fully conversant with the subject; but I am persuaded that, in addressing a general audience on such a subject, it will not be thought out of place for me to premise some general remarks as to the mode in which medicines operate on the human body, so that the place which ether occupies as a physiological agent, may be the more readily understood.

Medicines, then, may be divided into four classes, according to the mode in which they affect the human body:

Those of the first class act altogether locally. We have familiar

examples of them in mechanical agents applied to the surface of the body, in the diluted and strong acids, liquid ammonia, mustard, and cantharides, all of which produce inflammation and other local effects on the parts to which they are applied, but do not necessarily implicate parts at a distance. Ether, and many other substances, have a local irritant power of this kind, combined with a power of a more general nature.

The medicines of the second class operate by local sympathy. They are, in so far, local agents, that they must always be applied to the same spot; but the local impression influences distant organs sympathetically. Tobacco and other irritants applied to the nostrils operate in this way; the local impression they produce on the membrane of the nose is propagated, through the nerves, to the diaphragm and abdominal muscles, which are thus made to contract, and produce the act of sneezing: whence we name them *sternutatories*. Many important medicines operate in this way—many emetics, for instance, such as mustard, and the sulphates of zinc and copper, which, exercising an irritant action on the stomach, call into play, sympathetically, the muscles concerned in the act of vomiting. Almost all purgatives also, such as castor and croton oils, jalap, senna, and aloes, act in this way. They irritate the mucous membrane of the bowels, and the impression is propagated, by sympathy, to the expulsive muscles. It is a most erroneous idea, which some medical men entertain, that such medicines will operate when applied to the skin, for they can only operate when applied to the membrane of the bowels. Croton oil, for instance, when used as a liniment to the skin, or even applied to an abraded surface, never operates but as a local irritant.

The medicines of the third class require to be absorbed by the blood vessels, in order to produce their effects, which are thereafter exerted on the organs of nutrition and secretion. Iodine is a good example of the former; nitre, squill, and turpentine, of the latter. Such medicines produce the same effects, to whatever part of the body they are applied, provided it be an absorbing surface. Iodine and mercury act in the same way, whether applied to the skin or to the stomach.

The medicines in the fourth class act on the nervous system, either after absorption, or directly. The former may be said to be their general mode of action; but there are some substances, such as the prussic acid, of which the effects are manifested so instantaneously, that we can scarcely but suppose, that the nerves transmit the impression, with the rapidity of thought, to the heart and brain.

It is to this class of substances that ether belongs. They are readily distinguished from all other medicines, by possessing the four following characters:—They do not act locally, like the substances of the first class, but on parts at a distance. They act in the same way to whatever part of the body they are applied. They are thus distinguished from the substances of the second class. From the substances of the third class they are distinguished, by acting on the nervous system, and the organs

most intimately connected with it—the brain, the organs of sense, the heart, and the voluntary muscles. Lastly, they are all of them, with a few exceptions, poisonous substances, if improperly administered.

The substances belonging to this class are known by the name of narcotics, or stupefiants, from their producing confusion of intellect, and deadening sensibility. They were, at one time, supposed all to operate in one way; first, as excitants, and then as sedatives. But a more accurate knowledge of them has shown, that it is impossible to refer their multifarious effects to so simple a principle. There are, indeed, some of them to which the name of narcotics is altogether inapplicable, for instead of diminishing, they exalt the sensibility of the nerves. Such, for instance, are the nux vomica, and the other substances containing the alcaloids, strychnia, and brucia; for an animal, under the poisonous influence of these substances, instead of being rendered insensible, feels a touch of the finger like a shock of electricity.

But the great majority of the substances in question really act on the brain as stupefiants, but they affect other important organs too seriously to permit us to derive any advantage from the stupor they induce. Hellebore is the most powerful stupefiant we know, but it acts as a poison to the system. Camphor, while it induces stupor, brings on frightful convulsions of the muscular system, and prussic acid and fox-glove exert a deleterious influence over the action of the heart.

The section of the narcotics to which ether belongs, instead of exerting a deleterious influence over the heart, have for their character, to excite and sustain the action of the heart, while they produce upon the brain at first exhilaration, and at length stupefaction.

To this section belong, *first*, alcohol, the distilled spirits, the wines, and other fermented liquors; and *second*, ether, and some of the compound substances, now named salts of ether, such as the nitrite and the chloride of ether, more commonly called nitrous and muriatic ether. I say some of these bodies, for the effects of all of them on the animal economy have not been ascertained.

It simplifies our subject very much to observe that alcohol is the active ingredient in the first series of these bodies, and ether in the second; so that we have merely to consider and contrast the effects of these two agents, alcohol and ether, on the animal economy.

The effects of alcoholic liquids are too well known to require minute description, but their more prominent effects are, in the first place, an exhilaration and excitement of mind, which gradually passes into a state of narcotism or stupefaction: and in the second place, excitement and invigoration of the action of the heart, which seems to continue throughout; for the feebleness in the heart's motions, which comes on in deep intoxication, is, probably, the consequence of the narcotised state of the brain.

The effects of ether may be described in the very same words. This the identity of composition of the two substances might have led us to

anticipate; for alcohol is just the hydrate of ether, or ether *plus* an atom of water—the two bodies not differing in composition more than oil of vitriol does from anhydrous sulphuric acid. The moment the dry acid comes into contact with water, it is converted into oil of vitriol; and ether, when kept long in contact with water, (*Liebig*,) is converted into alcohol.

There is, however, a difference in the physical qualities of the two substances, which renders each of them only adapted to a certain mode of administration.

Alcohol is miscible, in all proportions, with water, and forms a palatable and too insinuating beverage. It is thus well adapted for administration by taking it into the stomach—while it is far less volatile than ether, and, therefore, is less adapted for inhalation.

Ether, on the other hand, is not miscible with water, unless the latter be in great excess (1 ether to 10 water.) Hence it is not adapted to be administered by taking it into the stomach; for its hotness cannot be overcome by dilution, and it acts as a violent local irritant. How much less alcohol would be consumed, if it could only be drunk in the form of a highly rectified spirit, and its fiery qualities could not be corrected by dilution! Physicians seldom prescribe more than from one to two drachms of ether—a quantity quite insufficient to develope any narcotic effects. I have known seven drachms of it taken; but it produced, at the pit of the stomach, a most uneasy sensation of heat and pain, which only the callous stomach of a dram-drinker could stand. As a dram, ether might answer very well; and it is for a similar purpose that it is usually prescribed in medicine—as a carminative, and not as a narcotic.

Ether, on the contrary, from its high volatility, is admirably adapted to be administered by inhalation. It boils at 96° Fahr. The heat of the hand is sufficient to make it fly off in vapour. Alcohol, again, is far less adapted to this mode of administration. Even when rectified to the uttermost, it only boils at a temperature of 173° Fahr.; and if less strong, the temperature must be higher. Still, however, the inhalation of the vapour of alcohol will produce narcotism, although with less rapidity than ether.

It is, I believe, to this difference of physical qualities, in the two substances, and in the mode of administering them which is the consequence of it, that the differences in the physiological effects of alcohol and ether are mainly to be ascribed; and not to any actual difference in their modes of action upon the human body.

The most remarkable peculiarities in the action of ether administered by inhalation are, 1st, the suddenness with which it induces complete narcotism; 2d, the transiency of the narcotic state; and, 3d, the very small quantity of ether necessary to produce the effect. I shall endeavour to show, that these peculiarities depend altogether on the mode of administering the ether, by inhalation; and would not be observed if it were administered in any other way: and in doing this, I shall assume as principles, that ether only acts as a stimulant to the heart, and as a narcotic on the brain, after being absorbed; and that the energy of its

action, is proportionate to the degree in which the blood applied to the tissues of the heart and brain is impregnated with it.

The suddenness of the effect produced depends, in the first place, on the volatility of the ether, and on its being thus brought, at once, into contact with a very extensive and highly absorbent surface—the mucous membrane of the lungs.

Another circumstance which favours much the speedy development of the narcotism is, that the blood, fully charged with the absorbed ether, is at once poured, undiluted, and in a continuous stream, on the heart and brain. The ether is no sooner absorbed, than the blood, charged with it, passes on to the cavities of the left side of the heart; and immediately thereafter it circulates through the coronary vessels, and the carotid and vertebral arteries, and thus pervades the tissues of both sides of the heart, and every part of the brain. It is far otherwise with respect to substances applied to the surface of the stomach, and absorbed by the stomachic veins; for the blood in these veins is necessarily diluted, by intermingling with many currents larger than their own, before reaching the heart and brain. Suppose, to take an extreme illustration, that the blood were capable of absorbing as much ether as water can combine with, or one-tenth of its own weight; if, then, we suppose that the blood in the lungs were impregnated to this extent, it would be applied in that state to the heart and brain, whereas, if the blood in the stomachic veins were impregnated with the same quantity of ether, before reaching the liver, it would have mingled with more than its own mass of pure blood from the splenic and mesenteric veins; the tenth would thus become a twentieth; and, on the blood leaving the liver, and joining the larger current of inferior cava, the twentieth would become a fiftieth or sixtieth. A further dilution would take place at the confluence with the superior cava, so that the blood, on reaching the heart and brain, instead of containing one-tenth part of absorbed ether, could not contain so much as one-hundredth. Whenever, therefore, the same quantity of ether, or of any other absorbable substance, is taken up from the lungs and from the stomach, it must, in the former case, be applied to the tissues of the heart and brain, in a state of concentration at least ten times greater than in the latter; and will, therefore, act on these organs with more suddenness and energy.

I would explain, also, by referring to the laws which govern the circulation of the blood, the evanescence of the effects produced, which is the most extraordinary part of the whole phenomena, and the most difficult to explain. During the inhalation, which is usually continued from five to seven minutes, blood, highly charged with ether, is applied to the heart and brain; while the blood, circulating in the lower parts of the body, contains a much smaller proportion of it. Now, on stopping the inhalation, the blood, circulating in the heart and brain, speedily passes off by the veins, and is succeeded by the comparatively pure blood coming from the lower regions of the body; and so the narcotic symptoms disappear.

It is far otherwise, when alcohol is absorbed from the stomach, for the

whole mass of blood must be impregnated with it, before a highly charged blood can be applied to the heart and brain; and then, the effect continues for many hours till the alcohol has been thrown out of the system by the skin and lungs.

It must not be supposed, with respect to the ether, that, on the subsidence of the narcotism, it disappears from the body; for it is merely weakened in its effects, by being diffused equably over the whole mass of blood; but, that it remains within the body is obvious from the smell of the breath for many hours afterwards, and from its frequently causing copious perspiration.

The small quantity of ether, necessary to produce narcotism when inhaled, depends on the principle above stated, that the ether is applied directly and continuously to the tissues of the heart and brain. It is difficult to determine the actual *dose* of the ether, or the quantity of it absorbed into the blood. The first step is to determine what quantity of it is inhaled into the lungs; and this inquiry is the more important as there is a necessary connection between the quantities of air and of ethereal vapour which are simultaneously inhaled, and by determining the one we determine also the other. Now, if at any given temperature, the chamber of the inhaler be saturated with vapour, since there is a free communication between the chamber and the external air, it is obvious that the tension of the ethereal vapour, added to that of the air within the chamber, must just balance the pressure of the external atmosphere. We know the tension of the vapour of ether at all ordinary temperatures from the experiments of Dalton. Supposing, therefore, the barometer to be at 30 inches, we have only to ascertain from Dalton's table the height of the column of mercury indicating the maximum tension of the vapour at any given temperature, and also the difference between that column and one of 30 inches high, and we then have two numbers which express the relative volumes of ethereal vapour and air existing in the chamber of the inhaler. Thus, at the temperature of 64°, the maximum tension of ethereal vapour corresponds to a column of mercury 15 inches high, and the difference between that column and one of 30 inches is also 15 inches, so that equal volumes of ethereal vapour and of air are contained in the chamber of the inhaler. At the temperature of 96°, again, the tension of the vapour is equal to that of the atmosphere, or to a column of mercury 30 inches high, so that the whole air is expelled from the chamber, which is entirely filled with pure ethereal vapour. But such an atmosphere could not be respired without immediately causing asphyxia from want of oxygen. Even at the temperature of 64° the proportion of air in the atmosphere of the chamber is reduced to one half, whence we may infer that during the inhalation of ether, the application of artificial heat is both unnecessary and dangerous, for by increasing the tension of the ethereal vapour the proportion of common air in the atmosphere of the chamber is proportionally diminished, and the risk of asphyxia made greater accordingly.

To determine the weight of the ethereal vapour we assume that the

relation of 1 to 2·583 between the specific gravity of atmospheric air and that of ethereal vapour is constant whenever they are at the same temperature and subjected to the same pressure. Taking, therefore, the weight of a cubic inch of atmospheric air, when the barometer is at 30 inches, to be ·310117 of a grain at 60° F. it becomes ·307695 gr. at 64°, and ·289595 gr. at 96°, whence we deduce the weight of a cubic inch of ethereal vapour at 64° to be ·797388 gr., and at 96° to be ·748023 gr.

To find the weight of the vapour inhaled in five minutes, we assume that 18 respirations are made in the minute, and that 15 cubic inches of gaseous fluid are taken into the lungs at each inspiration. We thus find by calculation, that if it were possible for any person to breathe, for five minutes, an atmosphere of ethereal vapour at 96° F., he would inhale 1010 grains of the vapour, or 2 *medicinal ounces* + 50 grains; and that at the temperature of 64° there would be inhaled, in the same time, 536 grains, or *an ounce* + 56 grains.

It thus appears, that at the temperature at which ether is commonly inhaled, if the air in the chamber of the inhaler were fully saturated with ethereal vapour, an ounce of it would be introduced into the lungs in five minutes; but of that quantity at least three-fourths would be again thrown out with the expired air, so that only two drachms would remain to be absorbed. There is, however, a still further reduction to be made, for during the inhalation, the atmosphere of the chamber is undergoing a continual renovation, and as the external air rushes into it with far greater rapidity than the ethereal vapour is generated, there is not time enough for the latter to attain its maximum tension. The deficiency thus occasioned may probably be estimated at about one-half. It must obviously be the greater the smaller the chamber of the inhaler, and we may therefore infer that there is an advantage in employing an apparatus of which the chamber is of large size.

Taking, then, into account the whole of the circumstances above mentioned, it appears to me probable, that by the inhalation of ether during the space of five minutes, not more than a drachm of it is introduced into the blood; and yet that quantity has been found to induce such a state of narcotism, that the most severe operations in surgery occasion no feeling of pain. Now it has been stated above, that a quantity of ether, seven times greater, has been administered by introducing it into the stomach. This dose, though largely diluted with water, excited a violent sense of heat and pain in the region of the stomach, and at length passed off by a profuse perspiration, without having occasioned any narcotic symptom, except a slight giddiness. It is obvious, therefore, that the recent important discovery of the influence of ether over the sensibility of the nerves, depends entirely on the mode in which the ether is administered, and not on any hitherto unknown power possessed by it as a physiological agent.

The preceding observations, with respect to ether, are confirmed by the fact familiarly known with respect to alcohol, that persons employed in

bottling spirits, if not habituated, are readily intoxicated; and that this kind of intoxication is almost immediately relieved by going into the open air.

The narcotic effects above described do not always follow upon the inhalation of ether. The operation, as at present practised, must be admitted to be uncertain and not devoid of danger. If too little ether be inhaled we fail in our object of stupifying the nerves; if too much be inhaled, excessive narcotism may be induced; and if atmospheric air be not supplied freely enough, or the same air be respired more than once, there is danger of asphyxia. The source of this uncertainty and danger, is the difficulty of determining the exact quantity of ethereal vapour which is inhaled, and the proportion of air which is mingled with it. To resolve these problems is, therefore, a matter of great importance, and fortunately the solution of them is not difficult. It only requires that the inhaling apparatus be of a proper size and structure, and that it be always employed at the same, and that a fit temperature. The proportion of ether and ethereal vapour is certainly known from the temperature, and if the chamber of the inhaler be of sufficient size that proportion will vary very little during the period of inhalation. If again the apparatus be so constructed, that there is no impediment to the free ingress and egress of the elastic fluid to and from the lungs, the quantity of air, and of course also of ether inhaled in a given time may be determined with considerable accuracy. Now, as the quantity of ether absorbed will, in the same circumstances, be always nearly in the same proportion to the quantity inhaled, we are enabled to measure, or at least adjust, the dose of ether by the sure and simple standard of the time during which the inhalation is continued. The only other criterion of the quantity of ether administered is the physiological effects resulting from it, such as the appearance of the eye and the state of the sensibility; but these, although worthy of being noted, are too vague and difficult of estimation to be relied upon alone.

It follows from what has been just said, that the form of the inhaling apparatus is of the utmost importance, and should not be regarded as a matter of mere taste and convenience, as if there were no more stable principles to regulate it. Much risk is incurred by the diversity of instruments at present in use. It is, moreover, clear that no comparable results can be expected so long as an indiscriminate use is made of instruments differing so much, that one produces full narcotism in from five to ten minutes, and another can be employed from two to four hours with impunity. Admitting fully the influence of idiosyncracy, we cannot, without abandoning all faith in the uniformity of the laws of living nature, explain such discrepancies on that principle; and a little consideration will show that an obvious explanation of them is to be found in the mere difference of size and structure of the instruments made use of.

In constructing an inhaling apparatus, and in making use of it, every other consideration should be made to give way to the vitally important object of administering a definite quantity of ether in a given time, and

having it mingled with such an unvarying proportion of atmospheric air as may be sufficient to support respiration. Now, to attain that object, the apparatus should always be employed at the same temperature; the chamber in which the vapour is contained should be of large size; the apertures into it, and the tubes connected with it, should be at every point somewhat larger than the human wind-pipe, and kept carefully free from all obstructions; and, lastly, there ought to be valves, or some similar contrivance, to direct the course of the gaseous fluid to and from the lungs.

The temperature of 60° Fahr. is the most convenient that could be selected. At that temperature, if the size of the chamber be large enough to admit of the vapour retaining its maximum tension while the inhalation is going on, the gaseous fluid consists nearly of equal volumes of air and ethereal vapour; and experience seems to have shown that air of that degree of tenuity, or of one half its ordinary density, may be respired for a short period without any bad effects—although this cannot be considered as fully ascertained, since probably even the largest inhalers now in use are too small to fulfil the conditions above-stated. If the temperature be higher than 60° we must either lower it artificially to the proper standard, or we must admit air into the chamber so freely as to prevent the vapour from attaining its maximum tension, which it could not do without expelling so much air from the chamber as to render the remainder too highly rarified to be respired without danger of asphyxia. In cold weather again, the apparatus must be maintained by artificial heat at 60°, for it is only by a scrupulous attention to the influence of temperature, that the time of inhalation of the ether can be rendered a measure of its physiological effect.

The reason why the chamber of the instrument should be large has been already pointed out. The larger it is the more complete will be the uniformity between the successive quantities of ether drawn into the lungs at each inspiration. It should probably not be of less capacity than from 1300 to 1400 cubic inches, the volume of air consumed by respiration in five minutes. A cubic foot is a simpler measure, and, if adopted as a minimum standard for the size of the chamber, would render all observations made with instruments so constructed comparable with each other. It is true that such an instrument will not go into the surgeon's pocket, but this is probably no disadvantage, for an agent so energetic as the vapour of ether should not be employed on light occasions, but only after deliberate consideration.

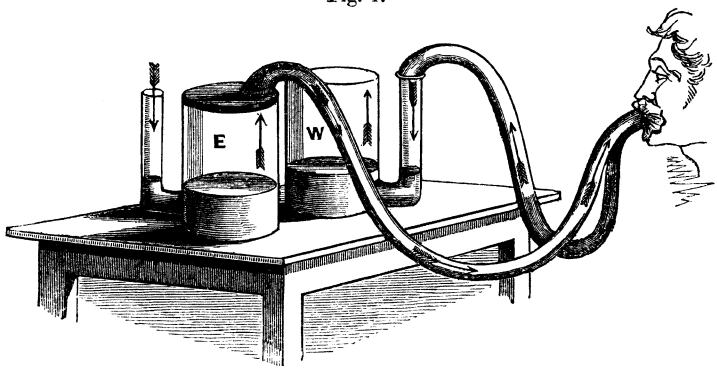
The tubes and apertures of the chamber should not be less than an inch in diameter, for when they are narrower, especially if the tubes be long, the difficulty of respiration is much increased. Care should be taken to keep the apertures perfectly free, instead of choking them up as is often done with sponges soaked in ether.

The valves are a frequent source of difficulty. As they are fitted on narrow apertures, they impede the respiration to a certain extent, even

when they are in good working order; but they are very liable to derangement, and may then readily occasion asphyxia.

Having frequently witnessed how imperfectly the valves perform their office, it occurred to me that an apparatus might be constructed without any valves; or, to speak more correctly, substituting for the *solid valves* now in use, *liquid valves*, which require no contraction of the tubes, and, from their simplicity of structure, are not liable to go out of order. The principle of this contrivance will be understood by reference to fig. 1.

Fig. 1.

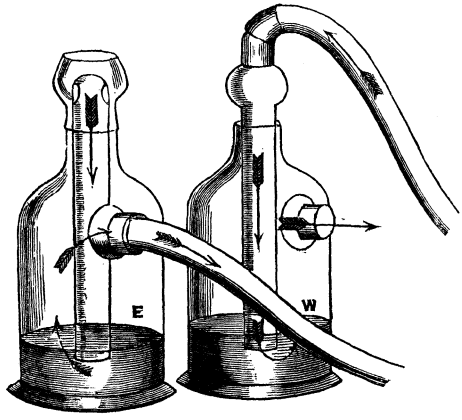



E and W are two glass vessels, the one containing a small quantity of ether, and the other of water. They are shaped somewhat like the letter U, having one limb or tube very narrow and the other wide. They are placed with these tubes in opposite directions—the one internal and the other external, in reference to the person who is to inhale the ether. In the vessel E, the narrow tube is external and open at the top, while the wide or internal tube is shut, and has an elastic pipe attached to it. In W, again, it is the wide tube which is external and open, while the narrow or internal one is shut, and has the pipe attached to it. The two elastic pipes terminate together at the mouth-piece. The effect of this arrangement is, that when the person begins to breathe, the air inhaled into the lungs can only gain admittance through the vessel E containing the ether, and the air expelled from the lungs can only make its escape through the vessel W containing the water. A current of air is thus kept up in the direction indicated by the arrows from E to W, and the air, as it enters at E and passes through the ether, is mingled with ethereal vapour, and carries it along to the lungs. The mechanism by which this is effected is of the simplest kind. The liquid in the vessels E and W stands at the same level in the tubes of each vessel, so long as the pressure of the air upon it is equal from within and from without. But no sooner does the person begin to breathe, than, by expanding his chest, he rarefies the air within, and thus diminishes the pressure upon the surface of the liquid in the internal tubes. The consequence is, that the liquid being forced inward by the pressure of the air from without, rises

in the internal and is depressed in the external tubes. But owing to the small diameter of the external tube of E, only a very trifling elevation of the liquid in the broad internal tube can take place before the whole liquid in the external tube is exhausted, and the air rushes in to restore the equilibrium. On the other hand, no air can enter through the vessel W, owing to the reversed position of the two tubes, the broad one being external, and the narrow one internal. These mechanical conditions are just reversed during expiration; for when the chest contracts, the air within is condensed and acquires a greater tension, so that the liquid in the two vessels E and W is now pressed more powerfully from within than from without. It therefore rises in the external tubes, and is depressed in the internal, till the whole liquid in the narrow internal tube of W being exhausted, the air rushes out in that direction, and the equilibrium is restored.

Mr. Young of this city * suggested to me an improvement on the apparatus just described,—that of putting the small tubes in the inside of the large ones,—and had the kindness to construct for me an apparatus of the kind. On trying it at the Infirmary, it was found to answer perfectly so long as the patient breathed calmly; but when he coughed, the ether spurted out through the narrow tube of E. To remedy this defect, the narrow tube was made shut at the top and with two apertures at the sides, and a round capital made to fit upon it at the level of these apertures, so that any liquid poured into the capital or projected upwards, might flow down thence into the vessel below. Mr. Young constructed for me an apparatus so improved, which is shown in fig. 2. It has been

Fig. 2.

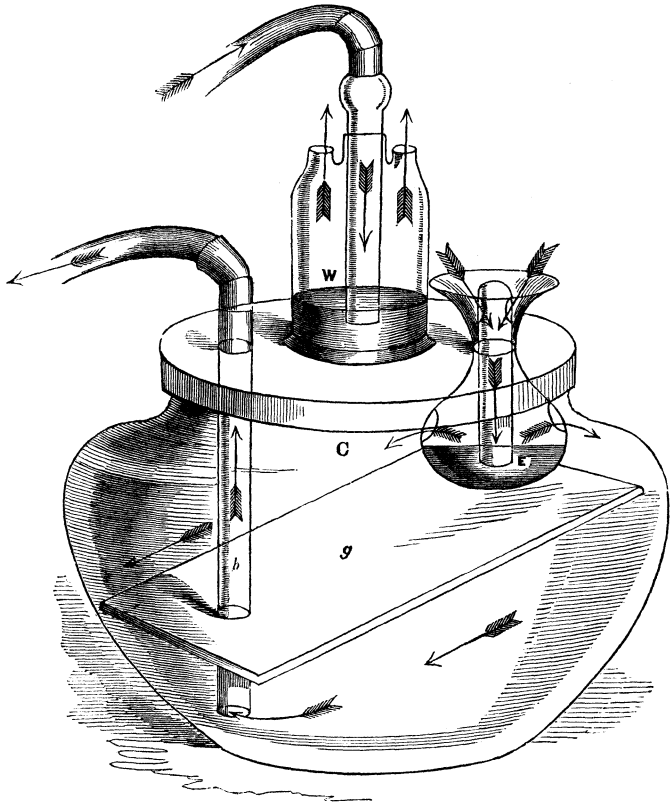



found to answer the purposes in view exceedingly well, inducing narcotism with great rapidity. It might probably, however, be still further improved,

* Now resident in Manchester, formerly assistant to Professor Graham, and well known for his ingenuity in the construction of chemical apparatus.

by enlarging the chamber containing the ethereal vapour; for, at the time it was made, I was not fully aware of the importance of having the chamber of large size. I would now prefer to it an instrument constructed in the following way, as seen in fig. 3:—

Fig. 3.




The vessel W is much the same as in fig. 2; but the vessel E has been converted into a mere valve, regulating the admission of air to the chamber C, which is a globular glass vessel of the capacity of a cubic foot, having a wide mouth, to which a wooden cover is accurately fitted, and on that the other pieces of the apparatus rest. E consists of a glass vessel, having a wide funnel-shaped mouth, a narrow neck by which it is attached to the wooden cover, and two openings below by which it communicates with the chamber C. To the neck of it there is fitted by grinding a tube, an inch in diameter, shut at the top, but having two lateral openings, through which the ether poured in at the wide mouth descends to the bottom of E, where there should be as much of it as to rise a little above the level of the lower orifice of the tube. Another tube

*h* conveys the ethereal vapour and air out from the chamber. It has attached to it an expanded linen cloth, *g*, placed obliquely, and serving to receive any drops of ether which may descend from above: and before commencing the inhalation a slight excess of ether should be poured into E, so that it may run over and moisten the linen cloth inside. An expanded cloth seems to me much better adapted to promote evaporation than the sponges now in use, for a sponge is more fitted to retain liquids that to promote the exhalation of vapours.

Lime water may be substituted for the common water in the vessel W, when the carbonic acid in the expired air renders the liquor milky. Whether the degree of decoloration produced will have any correspondence with the degree of narcotism I have not tried, but it is worthy of attention, as Dr. Prout's experiments on the effect of alcohol on the quantity of carbonic acid exhaled, render such a result not impossible. An apparatus of this kind might be advantageously employed in many physiological experiments on respiration.

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