A NEW METHOD OF INHALATION

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FOR THE TREATMENT OF

DISEASES OF THE LUNGS.

BY

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PREFACE.

In the summer of the year 1887 I read a paper before the Bath and Bristol Branch of the British Medical Association on the antiseptic treatment of Phthisis, and the paper was published in the *British Medical Journal* in the following January. In that paper the method of treatment which it is my object now to unfold was foreshadowed. Although the Vaporiser was not expressly mentioned in the paper, it had then already been designed, and was in use in my own practice. It was first brought to the notice of the medical profession, and exhibited in its then form, at a meeting of the South-Eastern Branch of the British Medical Association held at Hastings in May, 1891.

Since then, both the method of treatment and the Vaporiser as a means to its practical application have been further developed and made, as it would seem, the better fitted for general use in practice.

It is the purpose of this book to set forth the principles and conditions upon which any Inhalation method for the direct application of antiseptics and other remedies to the interior of the lungs should be founded and conducted, and upon which the new method is based and proceeds. Then to describe how, by means of the Vaporiser, I have sought to give practical expression to the principles and to fulfil the conditions and to adapt the method to practical use.

This method and its means is no theoretical, no untried, suggestion for the more effectual treatment of diseases notoriously asking for and waiting for some such help to their cure. If, as I believe and as I here seek to show, the method is in full accord with well-established scientific facts and principles, it should not fail of its purpose. If, as has now been abundantly proved in practice, it answers well its purpose, this should be the test of its basis in scientific fact. And on this shall rest its claim to recognition and to usefulness.

WM. H. SPENCER.

ST. LEONARDS-ON-SEA,
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CHAPTER I.

CONCERNING THE PRINCIPLES OF THE METHOD.

1. *The older method of Inhalation—Its failure—And the cause—The new method contrasted with the older.*

It is an obvious condition of success in local treatment of any kind that remedies should be applied directly to the affected part and come into close contact with it. Wherefore, physicians have for a long time past tried in various ways to fulfil this condition in the local treatment of diseases of the lungs, and tó apply antiseptic and other remedies directly to affected parts in the interior of the lungs. Thus, antiseptics have been injected through the chest-walls directly into accessible cavities in the lung, and also into the lung tissue itself. Suppurating cavities in the lung have been cut down upon and drained, and treated antiseptically. More recently, liquid remedies—such as menthol and guaiacol in olive oil—have been injected in some quantity into the trachea through the larynx, the antiseptic solution finding its way here and there in the interior of the lungs. Such modes of proceeding—in strictness more surgical than medical—whatever may be their merits, and whatever may have been their success in cases for which they are suited, are not simple enough nor easy enough of management to be generally adopted for use in all cases.

Of all the methods devised for the direct application of remedies to diseased parts in the interior of the lungs, that method commonly known as Inhalation has been the most popular. This method found much favour from the first; there was much of promise about it for what, as it seemed, it ought to be able to do; it was simple and easy of management; it seemed to be the natural way by which to introduce remedies directly to all parts in the lungs.

By this method remedies have been presented in the form of gas or vapour or of very fine spray for admission into the lungs through the natural respiratory channels and by ordinary or by forced and deep inspirations, thus to pass (as has been supposed), just as the air does in the natural process of respiration, into the air-passages and thence to all parts within the lungs.

The method has been applied in practice in a variety of ways. Thus, it has been a common practice to mix the remedy with hot water, or with the steam from hot water, and then to cause the patient to inhale the so-called steam as it issued from one of the numerous contrivances or inhalers devised for the purpose. The remedy has been placed upon a sponge in an inhaler shaped like a respirator, and fitting closely over the mouth and nose, so that the patient might inhale the vapour arising by evaporation from the liquid on the sponge. The remedy has been spread out over large surfaces of cotton or other material and allowed to evaporate, so that the vapour thus diffusing in the atmosphere might be inhaled along with the air during natural respiration; and again, the remedy has been atomised by means of a steam spray-producer, and both steam and spray have been presented to the patient's mouth for Inhalation. These and other modes, devised with a like intent, have been more or less in use for the local treatment of diseases of the lungs by Inhalation.

Yet Inhalation, as practised in any of these its modes, has not hitherto fulfilled the early promise. Indeed, the method may be said to have failed completely as a method of local treatment for affections seated in the interior of the lungs. Inhalation has sometimes given good results when used to treat locally diseased states of the larynx and upper air-passages. But all attempts hitherto made to influence diseased conditions having their seat below the trachea and in the interior of the lungs by means of Inhalation in any of its modes have been barren of results. So that the treatment of diseases of the lungs by Inhalation has fallen a good deal into disuse and no little into disrepute.

This being so, is it to be concluded, then, that the principle of the method is at fault; that the object and purpose of Inhalation—to bring remedies into direct contact with diseased parts in any and every situation within the lungs by the aid of the natural respiratory mechanisms—is unattainable? By no means. There is an alternative explanation of the failure of Inhalation, as heretofore practised. The fault may lie, not in the object and purpose of the method, nor in any inherent difficulty in effecting these, but in the means by which it has been sought to attain that object and purpose. And so it is ; the fault does lie here, in the means employed both to prepare and to present remedies for Inhalation. When so many contrivances for preparing and presenting remedies have been devised, when so many modes of applying the method in practice have been in use for so long a time, it may seem strange if all have failed, and if no one amongst them all has hitherto succeeded in effecting the whole object and purpose of Inhalation. But careful inquiry into the matter will beget no surprise that Inhalation as a method of treatment has fallen into disuse and disrepute ; rather will it beget surprise at the amazing ignorance and credulity which could look for good results from any method of treatment whose mode of application violated or ignored the physical laws and conditions upon which its fundamental principle is based. It is, indeed, a strange fact that of all the numerous modes in which the method has as yet been applied in practice, not one of them fulfils the physical conditions (to say nothing of practical needs) which lie at the very foundation of Inhalation as a method of treatment for diseases of the lungs. The respiratory mechanisms act and work, atmospheric air passes into and circulates within the lungs, under circumstances and physical conditions which are well known and understood. It should not be difficult to imitate these circumstances and to fulfil these conditions, and to adapt the methods of Inhalation accordingly. If the conditions be known, as they are known, under which the mechanical mixture of gases constituting atmospheric air passes into and reaches every part of the lungs, even the air-cells, one would suppose that, at the very least, these conditions would have been recognised and an attempt made to fulfil them when devising means for the introduction of remedies in the gaseous form to every part of the lungs, even the air-cells. Yet the fact that there are any circumstances and any physical conditions at all as bearing upon the matter seems to have been ignored or overlooked, for some of the modes in which Inhalation has been practised ; and for most of the modes it seems to have been taken for granted that the mere fact of a remedy being in the gaseous state would secure its admission to and diffusion within the lungs ; and no other physical condition seems to have been so much as guessed at. Thus, when remedies in the form of fine spray, or mixed with so-called steam, have been presented for Inhalation in the expectation that they would reach the interior of the lungs, physical laws and conditions have been set at nought. The so-called steam is not the vapour of water at all, but water itself in the form of very fine spray—water atomised by condensation of the real steam or vapour of water. In the ordinary process of respiration no liquid, even in the form of very fine spray, can pass beyond the trachea ; it can be got into the trachea only with difficulty and by forced efforts of inspiration on the part of the patient when in a certain attitude. Even such true vapour of water as may be present cannot diffuse in the air within the lungs, saturated as this air already is, for the temperature, with aqueous vapour. Again, to take the oro-nasal respirator inhaler, which has been worn, and still is worn, by a number of consumptive patients in the vain hope of gaining benefit thereby. It has been shown by Dr. Hassell,* as the result of numerous experiments, that when such things as carbolic acid, creasote, and thymol are used with this inhaler four-fifths of the antiseptic is recoverable from the sponge of the inhaler after many hours' use. It was hardly necessary, indeed, to prove this by experiment in the face of the well-known fact that these substances are very low down in the scale of volatility. The same observer has also shown experimentally that even when such volatile liquids as eucalyptol and oil of turpentine are used with an oro-nasal inhaler the amount of vapour passing into the trachea is next to nothing, and this for the simple reason that the amount of vapour available for inspiration by this method is next to nothing. It is incredible that any one with the smallest knowledge of the physics of respiration could seriously expect any remedial results at all in the interior of the lungs from the evaporation of fifteen or twenty drops of a volatile oil placed on the sponge of an oro-nasal inhaler.†

Yet the principles and conditions which have to be taken into account and provided for in the practical application of any such method of treatment as that by Inhalation are few and simple, and to be found easily if only they be looked for where they lie—even in the facts and laws of chemistry and physiology and physics.

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* "The Inhalation Treatment of Diseases of the Organs of Respiration, including Consumption," by Arthur Hill Hassell, M.D.Lond., &c. Longmans, Green, & Co., London. 1885.

† The vapour of most of the volatile oils commonly used for Inhalation is intensely odorous. A very minute quantity of the vapour from these oils will create an odour out of all proportion to the amount of vapour causing the odour. And this may lead to, and doubtless has led to, fallacies.

The new method takes its standpoint on these facts and laws. It is the object and purpose of the new method to apply remedies directly to the interior of the lungs. The method aspires to apply remedies in the gaseous form to every part of the interior of the lungs; to reach all affected parts, even the air-cells, and by means of the natural mechanisms of respiration and in the process of ordinary natural respiration. It claims to apply remedies so that they *shall* be remedial, to apply antiseptics so that they *shall* render intra-pulmonary cavities aseptic and promote the natural process of healing; and it claims to keep the remedies in contact continuously and indefinitely with the parts they are intended to influence. And all this by the simple expedient of recognising and working in accord with the natural physical laws and conditions which have been so woefully neglected or so unaccountably overlooked in the older methods of Inhalation.

2. *The new method described.*

This, our new method, may be thus described. We evaporate, or convert into the gaseous or vaporous state, certain volatile oils—such as eucalyptus oil and terebene—or these, together with the volatile constituents of solid bodies, such as iodoform and thymol, dissolved therein—by the aid of artificial heat. Evaporation is conducted at temperatures determined upon and fixed beforehand, and in such manner that evaporation shall be steady and uniform at the temperature decided upon —at temperatures within that range which, as chemistry teaches, ensures the conversion of the volatile oils into their natural vapour, a vapour retaining the antiseptic and remedial qualities of the oils and uncontaminated by deleterious matters, and a vapour of adequate tension. This vapour, being such, diffuses, as Physics teaches, easily and rapidly in the atmosphere, mixing with it intimately, uniformly, and permanently—thus forming a respirable mechanical mixture of gases, even as atmospheric air is a respirable mechanical mixture of gases. We place the patient in this medicated atmosphere and *keep him in it*—always, if needs be—and let him take the vapour into the lungs along with the air he breathes during ordinary quiet breathing. This vapour, so *inspired* (not *inhaled* in the popular sense), also diffuses, as Physiology teaches, easily and perfectly in that air which the fresh tidal air finds already in the lungs ; and thus it passes and penetrates in the interior of the lungs wherever the gases of the fresh tidal air can pass and penetrate. And, it may be added, this vapour, so introduced and so applied directly to all parts in the interior of the lungs, does, as a now long experience teaches and attests, so act as to bring about those antiseptic and remedial effects looked for by Pathology and Therapeutics and practical medical needs.

Further, we provide a continuous supply of the vapour, and practically without intermission, for any length of time—night and day, and for weeks and months—keeping the patient in the medicated atmosphere all the time, if needs be. And we regulate the supply of vapour (still continuous and uniform) to suit different circumstances of space and person and disease—so that the atmosphere of a large room may be charged with vapour to the same degree as the atmosphere of a small room, and so that in any room the amount of vapour in the air breathed by the patient may be uniformly and constantly more or less as desired. And further still, we do all this without the intervention of the patient, and requiring only, and at long intervals, that slight mechanical attention which is needful to replenish the oil from which the vapour comes and to renew the source of heat for evaporation.*

3. *The aims of the new method as a method of treatment—To apply remedies to all surfaces in the lungs—To keep them there—Absorption of remedies in the lungs.*

Now, to explain this method of treatment, and to give some account of the principles upon which it proceeds; as well, to speak of the physical laws and conditions that have had to be taken into account in adapting the method to practical use. This shall be set forth with plainness—even to repeating much that is well known and the very elements of common knowledge. For, as it seems to us, it is to neglect of such elementary detail that the older method of Inhalation chiefly owes its failure.

To begin at the beginning, and to clear the way, let us define the purpose and scope of this method of treatment—let us see what we want to do by means of antiseptics and remedies in the interior of the lungs; for so shall it be the better understood how the natural order of things may be made available to the doing of it.

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* The mechanical means whereby these various aims and ends are achieved will be described further on. See p. 40.

What we want to do we learn from Pathology; and it is shortly, this. We want to apply medicaments, of known and tried value for their antiseptic or remedial powers, to *surfaces* within the lungs—whether the surfaces be the seat of catarrhal or other inflammation, or be suppurating or ulcerating surfaces, or else, and along with these, the seat of bacterial and septic changes. We are not concerned to speak now of consolidations, tubercular or otherwise—albeit these are indirectly within reach by our method—but only of diseased conditions of the surfaces of the air-tubes and surfaces directly in communication with them. In bronchitis in all its forms we want to apply remedies directly to the whole interior surface of the affected bronchial tubes; and in the earlier stages of phthisis we want to apply remedies to the remotest ends of these, even to the air-cells. In the later stages of phthisis, when cavities have formed and ulceration is rife, we want to apply antiseptics to the surfaces of the cavities. And here we have to do with a state of things the same in all respects (save only in respect of situation) as that so often seen and treated locally with success in parts exposed to view. And since, in parts external, the mode of healing of a suppurating and ulcerating wound is always and only effected by organisation, or fibroid transformation, going on in the living tissue beneath the pus, and the local treatment is directed to promote and to bring about this mode of healing—so within the lungs we want to promote and bring about by the direct contact of our remedies the healing by this same mode.

Again, not only do we want to bring our remedies in actual contact with the surfaces we wish thereby to influence—we want *to keep them there*, and to maintain the contact indefinitely. Just as the mere contact of the small amount of oxygen taken into the lungs by a single inspiration with the moist membrane of all the air-cells in the lungs would not be enough to effect much in the way of aeration of the blood, just as it needs frequent repetition of the inspiratory acts and frequent renewal of the air, and the doing the same thing over and over again many times in every minute and continuously for the sake of life, so must we aim to ensure for our antiseptics and remedies a contact (with the walls of bronchial tubes and with air-cells and with the walls of cavities) that shall be a continuous contact, and a contact kept up without intermission, by night as by day, and for days and weeks, and prolonged until healing shall be complete.

And yet another and profounder want may be included in the scope and purpose of the method, and be met and satisfied by means of it. Not only do we want to influence diseased surfaces and to produce a local effect within the lungs in those diseases which especially affect these organs—the local affection has a general or systemic or constitutional concomitant condition or state, and other organs besides the lungs are often coincidently involved. This general and wider condition or state may be the aim and object of our treatment no less than the local. We want our remedies, or some of them and in some cases, to be absorbed in the lungs and to pass into the blood, and thus to find a wider field of remedial usefulness.

4. *The fundamental principle of the new method, that remedies be in the gaseous state—Deduced from the process of respiration—Diffusion of gases—Diffusion in the lungs—Practical needs support the principle.*

By this method, and to the end that these our aims in treatment should be reached by means of it, the medicaments are presented for admission into the lungs in the physical state of vapour. And this may be called the fundamental principle of the method. It is a condition precedent to all other conditions that remedies should be brought into the physical state of gas or vapour* (if they be not already in that state) in order that by means of the respiratory mechanisms and in the ordinary process of respiration they may be admitted into and circulate in or be absorbed in the interior of the lungs. This is made clear by consideration of what takes place in the normal process of respiration.

In ordinary quiet breathing a certain amount of air passes into the upper air-passages at each inspiration. The enlargement of the chest which follows every expiration causes a difference in pressure as between the air inside the air-passages and that outside the body, and the denser air outside consequently rushes in until equilibrium of pressure is established. The air thus

* "The words *gas* and *vapour* have no essential difference of meaning. A vapour is the gas into which a liquid is changed by evaporation. Every *gas* is probably the vapour of a corresponding liquid. The word *vapour* is especially applied to the gaseous condition of bodies which are usually met with in the liquid or solid state, as water, sulphur, etc. While the word *gas* generally denotes a body which, under ordinary conditions, is never found in any state but the gaseous."—"Elementary Treatise on Natural Philosophy," by A. Deschanel. Translated by J. D. Everett.

carried mechanically and forcibly into the air-passages at every inspiration is called "tidal" air. The amount of air so taken in at every inspiration is very small. It measures only 500 cubic centimetres, as against 5,200 cubic centimetres, the whole quantity of air contained in a pair of average human lungs after a full ordinary inspiration. That is to say, the amount of tidal air entering the air-passages in a single inspiration is less than one-tenth part of the whole quantity of air in the lungs after a full ordinary inspiration. Wherefore, when this small amount of tidal air has passed into the trachea and largest bronchial tubes it will occupy but a very insignificant part of the whole of the air space in the lungs; it will reach but a short way down the larger branches of the bronchial tree. The rest of the air space in the lungs is already full of air—the so-called "stationary" air—and at the end of an inspiration both the freshly admitted tidal air and the stationary air have a pressure equal to that of the air outside the body. Now, this small amount of tidal air, taken in at each inspiration, carries with it, as being of it, the oxygen needed for the work of conversion of venous into arterial blood, and this oxygen has to reach the very smallest branches of the bronchial tree, and the very ends of these, even the air-cells, here to be given up to the blood. But the tidal air does not itself pass bodily to the air-cells, carrying its oxygen with it. How, then, does the oxygen in the tidal air make its way from the upper part of the air-passages to the air-cells, and through the whole mass of stationary air already filling the lungs? It does this by virtue of the property possessed by all gases and vapours and known as "diffusive power," and by the physical process known as "diffusion of gases"; a process whose mode and laws are the same for diffusion of gases and vapours inside the lungs as for their diffusion outside the body. Let us explain for a moment what this diffusion process is.

If two bottles, each containing a gas—each gas different from the other, and each incapable of acting chemically upon the other—are connected together by a narrow glass tube, the gases will straightway overflow and spread out from their respective bottles, and the gas in the one bottle will pass into and fill the other bottle notwithstanding the presence still in this other bottle of its own gas. After a longer or a shorter time both bottles will be found to contain and to be full of the two gases, and these intimately and uniformly mixed. This result has come about by the diffusive power of the gases and the process diffusion. When two gases are presented to one another and are free to move, this process takes place inevitably; the two gases mix by diffusion against the force of gravitation even, and when once the intermixture has taken place it continues to be uniform and permanent, however long the gases may remain at rest. The same thing would happen if each bottle, instead of containing a single gas, contained several different gases; each individual gas would then overflow and spread itself out and diffuse on its own account and at its own rate, and with absolute indifference to the presence of any other gases—each bottle would be found ultimately to contain all the gases in uniform and permanent admixture. And the rate of diffusion, or the diffusiveness, of gases and vapours varies inversely as the square roots of their densities.

So it is in the lungs in the process of respiration. The inspiratory tidal air is a mixture of gases in one bottle, the stationary air is a mixture of gases in another bottle, so to speak. When the two mixtures are brought into communication, and the gases in each are free to move, as at the end of an inspiration—each individual gas or vapour in the inspiratory tidal air, although intimately mixed with other gases and vapours, spreads itself out and diffuses in the stationary air already in the lungs, on its own account and at its own rate, and according to the same law. And even thus does the oxygen in the inspiratory tidal air reach its destination at the air-cells.

The chief object and purpose of the respiratory process is the surrender by the inspired air of its oxygen to the blood—to be absorbed into the blood—and the reception in exchange by the air of carbonic acid from the blood—to be got rid of out of the lungs in the expired air. But nowhere in the lungs, not even in the air-cells, does the blood come into actual contact with the air; a membrane, albeit a membrane of exceeding tenuity, intervenes. Nevertheless, an interchange of the two gases, oxygen and carbonic acid gas, does take place in the air-cells, and by a process of diffusion analogous to that just now described. Although the diffusibility of carbonic acid into other gases and into air is very slight, carbonic acid will pass with the greatest ease into air through a membrane, even bladder, *if only the membrane be wet*; and this it does by virtue of its great solubility in the water which moistens the membrane. The air in the lungs being always saturated (for the temperature) with moisture, and the membrane intervening between the blood and the air in the air-cells being always wet, and both being normally and of necessity so, conditions are thus provided for the ready and rapid interchange of oxygen and carbonic acid in the lungs. This process by which oxygen passes out of the air into the blood, and by which carbonic acid passes out of the blood into the air, is called *moist* diffusion. And thus, if absorption of remedies in the lungs can take place at all (and we shall show hereafter that it can and does take place) it must be by the strictly physical process, gaseous diffusion through membrane which is moist.

The respiratory mechanisms are so fashioned and work on the condition that matters in the gaseous state shall alone be admitted to the interior of the lungs, or circulate therein, or there be absorbed into the blood. The process of respiration in all or any of its parts can be performed with matters in no other physical state. And thus it is plain that if remedies are presented in the state of gas or vapour for admission into the remotest parts of the air-passages in the lungs, they will, by virtue of their physical gaseous constitution, and the property of diffusiveness this physical constitution gives to them, be entitled to pass into the lungs and move and circulate by diffusion freely therein, and even to pass through the moist membrane of the air-cells. Supposing always, be it understood, that all other needful conditions be observed and fulfilled.

But more than this. It is a condition that remedies should be in the physical state of gas or vapour in order that, being present in all parts of the interior of the lungs, they may satisfy the practical needs of local treatment.

We want to apply remedies directly to, and bring them into actual contact with, the whole internal surface of tubes or of cavities or of both, and diseased surfaces, wherever situated, in the lungs. A remedy can only *surely* meet this need when it is in the physical state of gas or vapour.

Remedies in the solid state, when in the form of impalpable dust, may be got into the air-passages by accident or by force, but not otherwise. When in the air-passages, they may be carried hither and thither, but they will move only in obedience to gravitation and not against it. Eventually they will come to rest as foreign bodies in the lungs.

Remedies in the liquid state and in the form of very fine spray, may be got into the air-passages by accident or by force, and not otherwise; they cannot be inspired in the natural process of breathing. When in the air-passages, liquids will move only in obedience to gravitation; they cannot diffuse in the air, though they may absorb air and hold it in solution. A liquid, when injected into the trachea in quantity that can be tolerated, will flow down or trickle down the sides of the air-tubes, but will not necessarily come into contact with the *whole* surface of these, nor with the *whole* surface of a cavity into which it may flow; the route it will take in the air-passages and the extent of surface it will touch cannot *surely* be foreknown. Eventually, remedies in the liquid form, coming to rest, will choke and fill up the smallest air-tubes and the air-cells—if they reach these at all—displacing the air and thus interfering with the natural process of respiration.

It is otherwise with remedies in the gaseous state.

By virtue of their physical constitution all gases and vapours tend naturally to expand. The power of indefinite expansion is the distinguishing physical property of a gas or vapour. Gases and vapours may be looked upon as being composed of minute particles of matter, or molecules, to which energy of motion in the form of heat has been imparted, whereby the molecules acquire a tendency and power to move as far away from each other as possible. A very small quantity of a gas or a vapour will expand indefinitely until it fills any space, however large that space may be. In consequence of this property, if a gas or a vapour be enclosed in a limited space it exerts pressure in all directions and equally —on the sides of a tube or any vessel containing it, and upon any liquid with which it may be in contact. Wherefore a gas or a vapour, expanding indefinitely and filling the whole of the space containing it and pressing equally in all directions, will necessarily come into actual contact with the whole surface of all the air-passages, and with the whole surfaces of cavities when introduced within the lungs. The degree of pressure so exerted by a gas or vapour, or, what comes to the same thing, the degree of closeness of contact of a gas or vapour with the boundaries of a space containing it, depends partly on the amount of gas or vapour in the space and partly on the temperature. So that by having enough vapour, and this being of a temperature to ensure a suitable tension or force of expansion, a remedy in the gaseous state can be brought to bear upon all affected surfaces in the interior of the lungs and with any degree of closeness of contact demanded by practical needs.

5. *Remedies in relation to the fundamental principle—Desirable remedies mostly in the liquid state—Change of state from liquid to vapour—Spontaneous evaporation—Volatility as a test of fitness in remedies.*

Bearing in mind that remedies can only pass into and be distributed in the lungs, and surely reach *all* surfaces therein or be absorbed in the lungs, when they are in the physical state of gas or vapour and by the physical process diffusion, there naturally comes next for consideration the question whether this fundamental condition can be met and fulfilled in respect of the medicaments and remedies we may desire to apply to diseased surfaces and air-cells and to keep in contact with diseased surfaces and air-cells in the interior of the lungs.

Not all things which, in proper place and rightly used, are good antiseptics or good remedies for this or that diseased state are fit for admission within the lungs, even in the form of gas or vapour. It is a prime condition that the lungs should be tolerant of the remedy, and that the remedy should neither disconcert the normal function of respiration nor endanger life. And this condition can be met easily, for the list of remedies suitable in this respect is long enough and to spare, and the choice therein is wide.

But even thus, the suitable and available remedies are not to be found ready to hand and already in the physical state of gas or vapour, they are mostly in the liquid state; whether solid or liquid, therefore, they have to be brought into the gaseous state. How, then, shall remedies be brought into the required physical state, and this in such manner as to meet other physical conditions which we are required to fulfil in order to effect the aims and purposes of our method ?

In nature, solids and liquids are constantly changing their physical state ; solids melt into liquids, or sublime and pass directly into the gaseous state without taking the intermediate state of liquid ; liquids evaporate and assume the state of vapour. This change or modification in the physical state of matter is effected by the agency of heat. Most liquids, when exposed in a shallow vessel to the open air, evaporate ; that is, they give off some portion of their own substance which assumes the state of gas or vapour. A liquid can only take the form of vapour and exist in that state by taking heat into itself, so to say. If a liquid be regarded as being composed (physically) of molecules of matter plus so much heat, the same body in the form of gas or vapour will be composed of the same molecules of matter plus so much more heat. This heat does not warm or raise the temperature of the vapour—it is said to be "latent" in the vapour; in whatever state or form this heat may exist in the substance, it is that which gives to a gas or vapour its distinguishing characters as a gas or vapour. Nor does this heat, except in a certain class of substances, change the composition of the liquid whilst, by means of it, the liquid is changing its physical state. A solid body or a liquid body not belonging to this class, is not altered as to its chemical or medicinal properties and qualities by changing it into the state of gas or vapour, provided the change is effected by physical means only ; an antiseptic will be antiseptic still, whether it be in the solid or in the liquid or in the gaseous state. For, the molecules are the same molecules, whatever the physical state; the physical state depends on the position and motion of the molecules relative to one another.

In the case of a liquid exposed in a shallow vessel to the open air, this latent heat of evaporation is abstracted from the liquid which is evaporating and from the surrounding air. And so long as evaporation is going on at the temperature (whatever it may be) of the liquid and the surrounding air, and without the aid of any other heat applied directly to the liquid, the process is called spontaneous evaporation or evaporation at ordinary temperatures. Most liquids, then, when exposed to the air at ordinary temperatures evaporate or pass into the state of vapour—more or less and in a longer or shorter time. The rapidity of evaporation is influenced, as is well known, by surrounding circumstances, such as dryness or humidity, and stillness or agitation of the air. But, apart from such circumstances, liquids vary much in the abruptness and readiness with which they change their state by spontaneous evaporation. Some, like ether, thus change their state immediately on exposure to the air; such are highly *volatile* liquids, and mostly also highly diffusible in the air—too highly volatile and diffusible—and withal too deleterious in their effects to be used as medicaments in the lungs. Some, like creasote and carbolic acid, are too little prone to change their state and take too long about it to be readily adapted to use remedially. But there are other things and liquids, which in volatility and in remedial powers are well suited and are readily adapted to our use. These, all of them, may stand on the list of remedies fit for the interior of the lungs—for choice. Amongst them stand out conspicuously the natural and volatile oils obtained from plants—eucalyptus oil and oil of pines, and others of a like sort; good antiseptics, all of them, and possessing good and various remedial qualities besides. The vapours from these volatile oils are, in respect of physical state and medicinal properties, suitable for our use as medicaments within the lungs. And, further, these volatile oils, some of them, are good solvents for certain other and solid things by nature volatile, like camphor and iodine—which, when exposed to the air, pass directly from the solid to the gaseous state. Such solid things, dissolved in volatile oils, pass into the state of vapour along with the oils in which they are dissolved, and thus into a state fit for use as medicaments within the lungs.

6. *Remedies being in the form of vapour, conditions relating to the vapour itself—The vapour to be diffused into the air before inhalation—And in good quantity—Facts of respiration as bearing upon quantity.*

But, whilst such medicaments as these vapours, so produced by evaporation from volatile natural oils, are of the right kind and in the right physical state for use as remedies in the lungs, there is something more than this required of the vaporous remedies in order that they may pass into and circulate in the lungs by diffusion, there to exercise their antiseptic and remedial powers. The medicaments being of the right kind and in the right state as vapour, there are certain considerations in respect of the vapour itself to be taken into account. It is not enough to have a vapour; the vapour must be of that tension which will ensure its diffusion rapidly. It is not even enough to have this; the vapour must be in good quantity. And still again, such a vapour must be diffused into the air beforehand, so as to be mixed with and to become a constituent of the air, and be presented in this form for admission into and diffusion in the lungs.

And first, of prior diffusion in the air and of quantity in respect of the remedial vapour. If, as in our method, the remedial vapour is presented to be taken into the lungs during ordinary quiet breathing, the vapour must be diffused into and mixed with the air beforehand. On no other condition would the vapour, if in sufficient quantity for practical remedial needs, be respirable. For the lungs, and most certainly the larynx, would not tolerate the remedial vapour unless it were sufficiently diluted; just as oxygen would not be tolerated unless diluted, as it is, by the nitrogen of the air. By generating a vapour of proper tension and allowing it to diffuse in the air of a room in quantity proportional to the size of the room and the degree of saturation of the air we desire, the vapour becomes a constituent of the air, even as atmospheric air itself is a mechanical mixture of gases. The air of the room thus becomes a uniform and permanent mixture of respirable gases, and this mixture we can offer to our patients to inspire in full certainty that the antiseptic and remedial vapour will diffuse in the lungs side by side with the other constituents of the air, and will penetrate and reach wherever these can pass and reach. And again, the vapour must be diffused rapidly in the air, so that in a short time, and thenceforth continuously, there may be a large quantity of it in intermixture with the air—as much as can be tolerated easily when the gaseous mixture is inspired continuously.

Here be it said, that although this last condition limits the amount of vapour which can be safely introduced to work its antiseptic or remedial effects in the lungs, yet this available amount is more than enough for all practical needs. The amount of vapour which can thus be stowed away by diffusion (at proper temperature) in the air of a room and still be tolerated is hardly to be realised without some reflection, and very little of this seems hitherto to have been given to the question. Perhaps, only familiarity with direct experiment undertaken for the purpose can give a just idea of how great this quantity is and how fully the quantity can be provided by appropriate and simple means.

As touching the quantity of remedial vapour present in the air to be breathed, there is this further consideration.

We have seen that the amount of air taken in at every inspiration is relatively and actually very small. It is clear that the amount of oxygen carried in at a single inspiration and diffusing to the air-cells is so small as to allow a very small share of oxygen for individual air-cells. But inspiration follows inspiration sixteen times in every minute, and thus there will be taken into the lungs in the space of one minute, by successive acts of inspiration, no less than 8,000 cubic centimetres of fresh air—an amount of air much greater than the lungs can contain when they are fully expanded. Now, one-fifth of this air consists of oxygen gas, so that the amount of oxygen passing into the lungs in one minute will be about 1,600 cubic centimetres (100 cubic inches). It may be taken for granted that not less than this quantity of any remedial vapour would have to pass into the lungs in the same space of time if any serviceable remedial effect is to be got out of it. And when the minutes are multiplied into hours, the amount of oxygen so represented or of vapour so required is very large indeed.

Not only so; every inspiration is succeeded by an expiration. At every expiration a quantity of air is got rid of out of the lungs about equal to that taken in at every inspiration. The gases and vapours taken in during inspiration are thus returned (less some oxygen) to the outer air along with carbonic acid and aqueous vapour; and the process by which these reach the surface to be expired is the same as that by which the oxygen of the inspiratory air was carried in. It is not to be supposed, however, that a gas taken in at one inspiration comes back again at the next and succeeding expiration. The gas remains in the lungs a certain time for diffusion. It has been shown by experiment that when hydrogen (a gas whose rate of diffusion is four times greater than that of oxygen) is taken in at a single inspiration in the same quantity as air—namely, 500 cubic centimetres—and instead of air, it is only after the sixth to the tenth following expiration that it has all left the lung (Gréhant). Thus, whatever may be the amount of oxygen or of remedial vapour taken into the lungs during one minute by successive inspiratory acts, the most of these gases are not retained in the lungs for long; they are returned to the outer air very soon and almost within that same space of time. The whole of the air present in the lungs at any given moment is completely changed in a very short space of time; so that the air present in the lungs, say, at the end of one minute, is not for the most part the same air that was present in them at the beginning of the minute. And so also will any remedial vapour the air contains be changed. Since this change of the respiratory air is repeated minute after minute, day and night and week by week, so also will the change of a remedial vapour be repeated in like manner. Wherefore, in order to keep a remedial vapour in contact with any diseased surface within the lungs, even for a few hours, a very large quantity of the vapour must be present continuously in the air breathed by the patient.

7. *Tension of vapours—Tension and temperature—Rapid diffusion depends on tension—Tension in vapour produced by spontaneous evaporation inadequate—Artificial heat required for right tension.*

We have seen that all vapours possess the property of elasticity or power of expansion. Speaking roughly, the tension of a vapour is the elastic force it possesses at different temperatures, or the pressure it is capable of exerting at different temperatures. The tension of vapours given off from liquids varies with the temperature at which they are produced; and the tension increases progressively as the temperature of evaporation is increased. The tension thus increasing, increases faster than the temperature, and very rapidly until the boiling point of the liquid is reached. At this point the tension or pressure of the vapour is at its maximum ; and although we may go on applying heat to the liquid neither the temperature of the liquid nor the tension of the vapour will rise so long as any of the liquid is left to boil. Up to the boiling point, then, the tension of a vapour depends on the temperature at which it is produced : the lower this temperature, the less the tension ; the higher the temperature, the greater the tension. Yet the tension of different vapours at the same temperature varies widely ; much depends on the boiling point of the liquid, and much also upon the nature of the liquid. Speaking broadly, the tension of vapours is relatively and actually very small at temperatures much below the boiling points of the liquids from which they are produced. Now, the volatile oils (with which we are here chiefly concerned) have mostly boiling points considerably above the boiling point of water ; and, although they evaporate, or pass into the state of vapour, readily enough at quite low temperatures, the tension of the vapours given off at these low temperatures is very small.

We have said that our vapour must be of the right tension for rapid diffusion. Let this be made clear. Suppose a small quantity—say half an ounce—of a volatile oil (such as eucalyptus oil) to be placed in a shallow pan in a small room and left to itself, the air of the room being at the temperature of the air outside at the time—say 60° F. The liquid will, of course, evaporate; the resulting vapour will expand and diffuse in the air of the room, and by-and-by the vapour will reach the furthest parts of the room and finally occupy every part of the room. This process will go on until the whole of the liquid in the pan has changed into vapour; but the process will go on slowly and take a long time about—a time to be reckoned in days.

Suppose, now, a like amount of the same volatile oil, in the same pan and in the same room, to be heated in such a manner that the temperature of evaporation shall be kept uniformly at 130° F., the temperature of the room being the same as before. The same things will happen, but with this difference—the vapour will fill the room much more quickly, and the liquid in the pan will disappear very much sooner (in exactly five hours, as we ourselves have determined by experiment), and in the end there will be more vapour in the room.

The difference is due to the difference in the amount of heat available in the two cases. The effect of the increased heat, besides changing the liquid into vapour more rapidly, has been to increase the volume of the vapour and also its distinctive physical property—namely elasticity or expansive force—in a word, to increase its tension, and therefore its diffusibility.

Wherefore, if we depend on spontaneous evaporation at ordinary temperatures of the atmosphere for the supply of our remedial vapour—as has been done in almost all the modes of Inhalation hitherto in vogue—not only is time greatly wasted but the vapour is produced so slowly and the tension of the vapour is so low that it will neither diffuse quickly enough nor be in quantity enough to satisfy the conditions required alike by the exigencies of natural respiration and the exigencies of our practical needs. Nor will it matter if we resort to such devices for the more speedy disengagement of the vapour as are open to us—short of applying artificial heat; we may dry the air, we may fan the liquid, we may increase the surface of evaporation, but we do not thereby increase the expansive force or tension of the resulting and still too small amount of vapour in the least.

On the other hand, by observing the principles relating to tension just now set forth, and producing our remedial vapour by the direct application of artificial heat to the volatile oil, the required conditions can be satisfied—as we next proceed to show.

8. *The right degree of heat required to generate a proper remedial vapour—Has to be determined by experiment—Degree needed to produce a vapour which is absorbed in the lungs a crucial test—Mode of application of heat.*

There is no difficulty in applying to a liquid heat of such degree as will evaporate the liquid as rapidly as we please, even to ebullition, and produce a vapour of any tension we please, even to its maximum tension at the boiling point of the liquid. The question is, what degree of heat is required to satisfy our conditions—that is to say, to produce quickly the full amount of vapour required and vapour of that tension which will cause it to diffuse rapidly in the air of an ordinary room ; and, be it said, a vapour whose remedial qualities shall not be affected by the heat employed. It is to enable us to meet these conditions alone that the heat is required at all.

In so far as concerns diffusion *in* the lungs, if we fulfil these conditions we have done all that is necessary. For the temperature of diffusion in the lungs is fixed, and it may be put down in round numbers as at 100° F. There is no object in presenting a vapour for inspiration at a higher temperature than this; the temperature of the vapour will be brought down or raised, as the case may be, to 100° F. when it gets into the lungs, as is the inspired air in which the vapour is diffused. We want tension in our vapour chiefly for diffusion in the air we make use of to carry the vapour into the lungs. And if only there be enough of the proper kind of vapour already in intimate and uniform and permanent admixture with the atmosphere, this vapour may be left to itself to diffuse perfectly within the lungs and therein to effect all our aims in treatment.

Reverting to the question, What degree of heat is required to satisfy our conditions—at what temperatures shall our liquid medicaments be evaporated?

From what has gone before it is plain that the degree of heat must be above the ordinary temperatures of the atmosphere, and below that point at which the heat might affect the quality of the vapour. This, however, is a somewhat wide and a too indefinite range. Chemistry teaches that at temperatures much above the ordinary temperatures of the atmosphere, and yet very much below their boiling points, the volatile oils contained in plants yield vapours of very considerable tension, and advantage is taken of this fact in the preparation of the medicinal oils. But Physics teaches that while the relations between vapour tensions and temperatures can be expressed in formulæ of sufficient accuracy for certain ranges of temperature, the formulæ cannot be relied upon for temperatures within that range with which we are now concerned. The question of temperature has, therefore, to be determined by direct experiment, and experiment conducted in view of and with direct reference to the exigencies of practice. Wherefore, we ourselves devised and carried out a long course of experiments directed to the determination of this question. Without going into unnecessary detail, it will be enough to say here that the experiments were made with a variety of different medicaments and in many different circumstances both of health and of disease.

It was comparatively easy to determine the lower point in the range of temperatures, and that point may be put down as being 100° F. The determination of the upper limit of the range was more difficult, and chiefly owing to the number of conditions—chemical, physical, and physiological, as well as practical—that had to be taken account of. Thus, to mention one consideration touching all conditions—what we want is the strictly volatile constituents of the volatile oils; but a temperature not nearly approaching that of the boiling-point of some of the volatile medicinal oils would give us more than this—certain resinous and other matters naturally in solution in the oils, to wit. Too high a temperature would spoil the vapour for some of its remedial properties; as, for instance, in respect of those properties upon which the production of ozone and peroxide of hydrogen depend—products of essential service in therapeutic applications of the vapours of volatile oils. Giving due place to such considerations and making due provision for such conditions, other and no less important things might have to be left untouched. Yet was there one consideration, touching more particularly physiological and practical conditions, which afforded at once an available guide and test—namely, the absorption of vapours into the blood in the lungs and the elimination of the medicaments through natural excretory channels. It is well known that oil of turpentine when absorbed into the blood is excreted by the kidneys and imparts to the urine a characteristic odour as of fresh violets. Pure terebene, which is isomeric with oil of turpentine, behaves in like manner, and its vapour is readily tolerated in the lungs. In the course of our experiments we found that when pure terebene was evaporated at a temperature of 176° F., in a room of 2,600 cubic feet capacity, the terebene was readily absorbed and soon appeared in the urine. In one experiment terebene vapour (produced by means of our Vaporiser and diffused in the air of the room) was breathed for the space of two hours (being well tolerated and not causing so much even as headache, although an ounce and a half of terebene was evaporated in the two hours), and the patient was then removed out of the terebene atmosphere. Nevertheless, and no terebene vapour being inspired after the expiration of the two hours, the urine still gave the characteristic odour when freshly passed ten hours later.

If, then, pure terebene is evaporated at such a temperature as to yield a vapour of that tension and quantity which, when diffused in the air of a room and taken into the lungs during ordinary quiet breathing, will cause a considerable amount of the terebene to be absorbed into the blood in the lungs and to be excreted by the kidneys, and to impart the characteristic odour to the urine, it may be fairly concluded that a point has been reached in respect of the temperature of evaporation high enough for all practical medical needs.

And, further, since terebene the liquid is absorbed in the stomach and passes through the kidneys and imparts a characteristic odour to the urine—and since terebene the vapour is absorbed in the lungs and passes through the kidneys and imparts the same odour to the urine—it is plain that terebene is unchanged as to its medicinal properties when in the form of vapour; in other words, is not spoiled for remedial use by the change of state at the temperature employed in the experiments.

Similar results as to absorption in the lungs may be obtained with iodoform dissolved in volatile oils. In fine, the results of our experiments went to show that a range of temperature lying between 100° and 180° F. should satisfy all conditions and all practical medical needs; and this conclusion has been abundantly confirmed by therapeutic results in actual practice. And in actual practice it has been found that the upper limit of the range is even some 20° higher than is needful for all ordinary purposes; for all ordinary medical purposes, a range of temperature between 110° and 160° F. is adequate.

Not only is it a question of degree of heat for evaporation, there is the no less important question of the mode in which the heat should be applied. It needs hardly to be insisted upon that the supply of heat should be constant and uniform, and that the desired temperature should be maintained steadily, to the end that the supply of vapour may be uniform and steady; and the mode of applying the heat concerns also the quality of the vapour. Now, there is only one way of applying heat to volatile oils so that these conditions be met and fulfilled—the application of heat, as in the operations of chemical and physical research in the laboratory, through the intervention of a medium such as water, the medium being interposed between the source of heat and the liquid to be evaporated. Wherefore, the water-bath is an indispensable feature in the mechanical appliance by which our method is adapted to practical use. But of this more anon.

So, then, have been set forth the principles upon which the new method of Inhalation is based, as well as the conditions to be met and satisfied in applying the principles to practical use. It has been shown that the method, claiming to reach all parts of the lungs affected by disease and to apply its remedies directly thereto, and even to produce systemic effects by absorption into the blood, works with remedies in the physical state of vapour and on the principle of diffusion of gases. The ruling principle of the method is founded upon the diffusive power of vapours (amongst other of their physical properties), and upon the laws governing the diffusion of vapours in the atmosphere outside and in the air inside the lungs. The method might indeed be termed appropriately, "the Diffusion Method."

It remains only to describe the mechanical means and device by which the principles have been expressed in practical shape, in conformity with the laws and conditions of science and the needs of medical art ; and also to describe how by this same mechanical device and appliance those other practical needs touching the continuity of the supply of vapour and the regulation of the supply and the automatic action of the apparatus, have been provided for and supplied.

CHAPTER II.

Concerning the Practical Application of the Method.

1. *The objects of the method from the practical side.*

Let us first, and by way of recapitulation, set down briefly and in order the essential features and practical objects of our method. So shall it be the better understood what any mechanical means for the practical application of the method must be designed to do and be competent to effect.

1. The conversion of volatile oils and substances dissolved therein into the physical state of vapour by the application of heat.

2. The application of heat in such manner that evaporation may be steady and uniform at fixed temperatures and at temperatures within a certain range.

3. The rapid diffusion of the vapour into the air of the room in which the patient may be placed, so that the vapour may be mixed uniformly and permanently with the air and form a constituent of the air, and thus a medicated atmosphere which can be inspired during natural quiet breathing.

4. The diffusion of the vapour, when carried into the larger air-passages of the lungs by the natural inspiratory

acts, through the air always in the lungs to every part of the air-passages, even to the air-cells.

5. The supply of vapour in considerable quantity continuously over long periods of time, and practically without intermission.

6. Regulation and adjustment of the supply of vapour to suit varying circumstances,

(*a*) Of space (size of room) in which the vapour is diffused ;

(*b*) Of disease and state and circumstances of the patient ;

(*c*) Of state of the atmosphere in respect of its temperature and its dryness or humidity ;

and accurate regulation, if needs be.

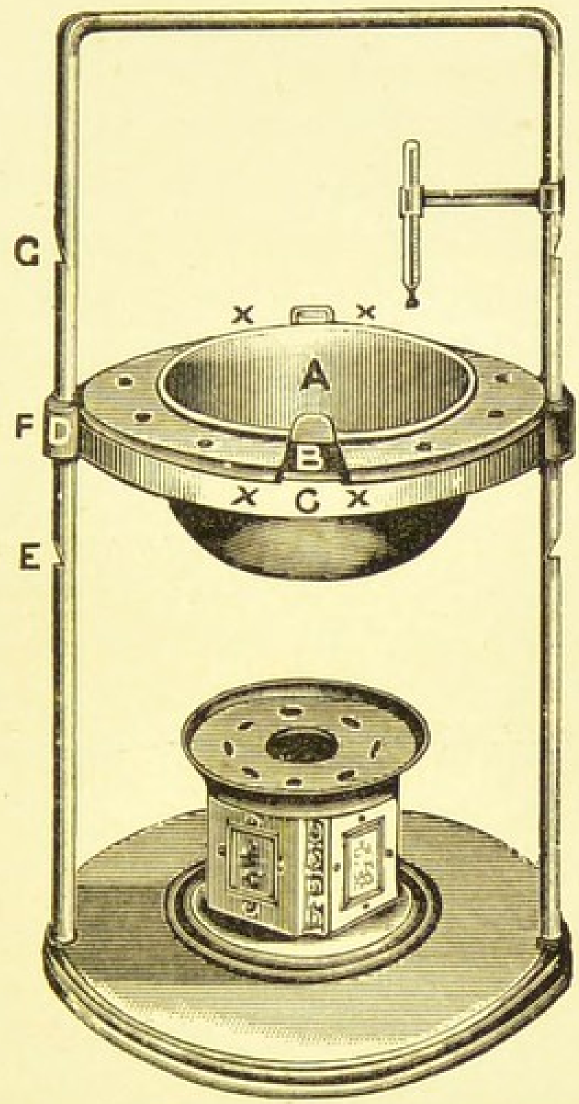
7. Automatic action of the apparatus employed to attain the foregoing objects, so that no assistance or effort on the part of the patient may be required.

By means of the apparatus, or Vaporiser, now to be described in detail, these several objects are attained, and in a manner to make the practical application of the method simple enough and easy enough of management to be adapted for general use and in all cases.

2. *The Vaporiser described.*

The construction of the Vaporiser will be readily understood by help of the illustration.

The Vaporiser consists of a stout wire frame attached to a circular and firm wooden stand. On the centre of the stand the source of heat is placed. Two pans are suspended on the frame over the source of heat. One



The "Arema" Manufacturing Co.,
27, High Holborn, London.

of these pans (A) is the evaporating or vaporising pan, in which the liquid to be vaporised is placed; this pan fits into a larger and outer pan (B), and so that a considerable space is left between the two, and in this space water is placed. Thus the evaporating pan is immersed in a water-bath.

The pans are suspended on the frame by means of a broad metal ring or "carrier" (C), into which they fit loosely; and the carrier is so fashioned as to pass round the wires of the frame and form guides (D). The guides are bent inwards at their lower edges so as to catch in notches (E, F, G) cut in the wires of the frame, and thus both the carrier and the two pans are supported and fixed in either of the three pairs of notches.

The heat is supplied from an oil lamp. The lamp consists of a shallow glass reservoir capable of holding about two ounces of colza oil, and fitted with a cork float and a small wick in the centre of the float. An ordinary night-light may be substituted for the oil lamp.

The carrier is so contrived as to be moveable up or down the frame, whilst still supporting the two pans, and even when the pans are full. The metal ring or carrier is in shape circular, and it is flexible. By placing both hands round the Vaporiser, so that the wires of the frame are in the angles formed by the thumbs and forefingers, then placing the thumbs and *second* fingers on the carrier, or spring band (C), where marked X X, X X, and squeezing or compressing the carrier between the thumbs and second fingers, the shape of the carrier will be altered from that of a circle to the shape of an oblong or ellipse. This action throws the catches of the guides (D) out of the notches, and now, whilst keeping up the compression, the carrier with its pans can be easily moved by the two hands up or down the frame. On ceasing the compression the carrier springs back into the form of a circle again, the guides (D) grip the frame again, and the catches will then engage in the notches.

A clip is provided to hold a small thermometer. This clip slides up or down one of the wires of the frame, and thus the thermometer may be lowered and its bulb immersed in the contents of the evaporating pan or be raised out of the way, as may be desired.

Such is the mechanical appliance and device by which the objects and purposes of our method are attained.

3. *How the objects of the method are effected by the Vaporiser.*

There is of course no difficulty in the mere volatilisation of medicaments by the aid of heat ; a pan for the medicament, supported over a spirit-lamp for the heat, is all the apparatus needed to effect this object. But science and experience alike demand something very different from such a rough-and-ready arrangement ; an arrangement that, in defiance of chemistry and physics, too often has done duty as a vaporiser in medical practice.

It has been shown already that the temperature of evaporation is limited by science and experience within a certain narrow range, and that the mode of application of heat is conditioned. A very small amount of heat suffices to meet all conditions in a scientific method ; the difficulty has been to find a source of heat that is small enough. A flame is practically the only available source of heat. The flame should not only be small enough, it should be constant in size and it should last without renewal for a considerable time. Though not an ideal source of heat, the flame of the little wick of our oil-lamp, or the flame of a night-light, answers these requirements well enough for all practical purposes ; the oil and the wick of the lamp last without renewal for twelve hours, and a night-light burns for several hours, and the size of the flame in either case is large enough. The flame is not required to provide much heat ; rather, the efficient working of the apparatus depends on the mode of distribution of a very small amount of heat. The flame is not required to heat the medicament directly, it is required to heat the water in the water-bath, and the utmost it is called upon to do is to raise the temperature of the water to 180° F. A very small flame placed so that its point shall lie an inch below the bottom of the water-pan will heat the water to 180° F. in a very short time. Less even than this is required, for if hot water be placed in the water-pan to begin with, the utmost the heat is then called upon to do is to maintain a temperature of 180° F., and if a very small flame will do this it is clear that it will provide heat enough for all other, and the lower, temperatures within our range.

The outer or water-pan first receives heat from the source. The water in the water-bath imparts some of its heat to the evaporating pan immersed in it, and thus the medicament is evaporated by means of heat conducted to it from the intervening water medium.

The effect of this indirect mode of applying heat is to ensure a steady and uniform supply of heat, and therefore a steady and uniform rate of evaporation and supply of vapour.

With any source of heat, and the heat applied *directly* from it to a vessel containing the medicament, it will be found impossible to keep the temperature of evaporation at the same point for even a very short time. The liquid gets hotter and hotter from the start, and as the quantity of liquid diminishes by evaporation it gets hotter still. The supply of heat is unmanageable and the temperature beyond control. But with the water-bath, due regard being paid to the amount of water in the bath and the extent of water surface and the free escape of the vapour from the water, the evaporation of the water carries off the excess of heat and the water thus acts as a regulator. In this Vaporiser care has been taken so to adjust the relative proportions of the evaporating pan and the water-pan and the amount of water space and the means of escape for the water vapour as to maintain a fairly accurate equilibrium between the gain of heat to the water on the one hand and the loss of heat to the water by its evaporation on the other hand. When the Vaporiser is in full action it will be found that the temperature of the water is uniformly only one or two degrees above the temperature of the medicament.

Again, this limitation of the amount of heat and this mode of applying heat ensures also the right kind of vapour both for medicinal use and for diffusion. The volatile oils generally supplied for medicinal use vary greatly as to their quality and constituents. Some, like eucalyptus oil, should leave no residue when volatilised at moderate temperatures—even at temperatures within our range; nevertheless, these are found sometimes to leave a residue, due to want of care in the preparation of the oils or to added impurities. Others, like a crude camphor oil imported from Japan (a bye-product in the distillation of camphor from the wood of the camphor tree), contain many ingredients besides those, known to be good antiseptics and remedies, which are volatile at our moderate temperatures. Balsams have long been in repute as remedies in affections of the lungs, and they are mixtures of resins with volatile oils. They owe their remedial efficacy to the volatile oils, and when the balsams are dissolved, as they may be to a considerable extent, in certain volatile oils, their volatile constituents pass into the state of vapour at moderate temperatures, leaving the resinous matter behind as residue. Now, whether the residues so left behind on evaporation at temperatures within our range be impurities or unavoidable constituents of the medicaments, they are more or less volatile, or at least are liable to be carried over mechanically along with the vapour, at temperatures not very much above our range.

It is the more readily volatile constituents of natural oils and of solid matters dissolved in them—constituents volatile at moderate temperatures—that we want for remedial use in the lungs. A proper vapour, a vapour fit for diffusion and remedial application in the lungs, should consist wholly and only of such volatile matters. What we want is a vapour that shall consist as nearly as may be of the molecules (however intricate in their composition) of the volatile portions of our medicaments plus only that heat which is requisite to hold them in the gaseous state and to give a due tension to the vapour. In our Vaporiser, the limitation of the amount of heat supplied to the water-pan, and the control over the conduction of the heat to the liquid in the evaporating pan provided by the water bath, effectually restrains the volatilisation and carrying over of those matters which are in the nature of impurities or of unavoidable yet undesirable ingredients, and which would spoil the remedial vapour.

The kind of vapour in respect of medicinal quality which the Vaporiser is thus designed to produce, and does produce, is also the kind of vapour in respect of physical quality fitted for diffusion—to diffuse rapidly and perfectly in the atmosphere outside and in the air inside the lungs. That this is so it needs no argument to prove; the demonstration is made clear by the experimental evidence already adduced. But in illustration of the fact that the conditions laid down by science in respect of the physical qualities of a remedial vapour have been considered and met in the construction of the Vaporiser, let this be remarked. The rate of diffusion of gases and vapours varies inversely as the square roots of their densities. This law does not affirm that the absolute diffusiveness of any particular gas or vapour can be deduced from the specific gravity of that gas or vapour; it affords only the means of determining the relative diffusibility of different gases and vapours. Thus, it enables us to say that the diffusive power of hydrogen is four times greater than that of oxygen, and that the diffusive power of chlorine is six times less than that of hydrogen ; or again, to say that whilst four volumes of chlorine gas will diffuse in a given space in a given time, six volumes of oxygen will diffuse in the same space and in the same time. And generally, the law affirms that a dense gas is less diffusible than a light gas, *et vice versâ.* Now, whatever may be the density of the vapour given off from a volatile medicament in our Vaporiser at a temperature within our range, it is clear that if the temperature of evaporation be raised to such a point as to volatilise or carry over resinous and other matters present in the medicament, these will add to and increase the density of the resulting vapour. And it follows that the diffusiveness of this denser vapour will be less than that of the lighter vapour produced at lower temperatures.

The dimensions of the apparatus and its several parts, especially with reference to evaporating surface and power, are such as to provide for an adequate *quantity* of vapour. This is obviously a practical detail easily determinable by actual trial and experience, and it has been so determined.

The continuity of the supply of vapour, in other words the continuous action of the Vaporiser, is effected by the combined action of several parts of the apparatus. The source of heat lasts a long time without renewal (twelve hours), and its renewal takes so little time about that evaporation is not materially lessened. The water-bath also assists, since the water is hot enough to keep up evaporation during the renewal of the source of heat. A comparatively short break in the process of evaporation is unavoidable when the time comes for the pans to be replenished. But this re-filling of the pans is needed at still longer intervals (twenty-four hours), and can be so quickly performed, including the necessary cleansing of the pans, that no appreciable diminution in the amount of vapour in the air is discernible. There is practically no intermission in the supply of medicinal vapour, through the inspired air, to the lungs.

And thus also a practically automatic action of the apparatus may be claimed for it.

The mode of effecting a due regulation of the temperature of evaporation and of the supply of vapour forms a special feature in the Vaporiser. The source of heat is fixed. It is plain that the pans, suspended over the source of heat, will receive the more heat the nearer they are to the source, and that they will receive the less heat the further away they are from the source. It is also plain that the more heat the pans receive the more vapour will be given off, *et vice versâ*. The regulation of the supply of vapour becomes, therefore, the same thing as regulation of the position of the pans relative to the fixed source of heat—higher or lower, as the case may be. The practical question then arises, What positions of the pans relative to the flame correspond to particular temperatures of evaporation within the range to which we are limited? The determination of this question involved a long series of experiments. Three temperatures were selected, namely, the extreme upper and lower points in our range, and an intermediate point, the mean between the two. The distance between the flame and the bottom of the water-bath, which gave a uniform and sustained temperature of evaporation corresponding to each of these three points, was ascertained (the apparatus being in full action, and working always under the same conditions). The pans being suspended on the frame by means of the carrier and its guides, these distances and their respective temperatures could be expressed in terms of height of the lower edges of the guides above the upper surface of the wooden stand on which the source of heat rests. So that if notches were cut on the wires of the frame at distances from the upper surface of the stand, thus expressing the distances between the flame and the bottom of the water-bath, the notches would severally represent the three several temperatures of evaporation. The three pairs of notches in the frame of the Vaporiser represent and correspond to these three definite and fixed temperatures—the lowest pair the extreme upper limit of our range, the highest pair the extreme lower limit, and the middle pair the mean temperature between the two—and these three temperatures suffice for all ordinary medical purposes.*

The pans are moveable by means of the carrier up or down the frame in the manner already described; wherefore the pans may be so placed, or " set," that evaporation may go on continuously and uniformly at any one of the three temperatures which may be determined upon beforehand, or the temperature and rate of evaporation may be altered and adjusted at pleasure and at any time. And although all this takes long in the telling, the

* We have also designed a form of the Vaporiser in which the distances are so graduated and the notches are so numerous as to allow of great accuracy of adjustment to temperature. In this form the carrier is rigid and attached to blocks sliding freely on the bars of the frame; to the blocks are attached catches, on the principle of the flute-key, by means of which very fine adjustments can be made rapidly.

mechanism of the Vaporiser is of the simplest, and the various operations required to the setting or adjusting or replenishing take but a few seconds in the doing.

4. *Mode of using the Vaporiser.*

Let us now describe how this apparatus may be set to work and worked to the best advantage, and kept working day and night for as many days or weeks or months as may be required. The pans must first of all be " set " ; that is to say, the pans must be placed in that position relative to the flame, which corresponds to that temperature and amount of evaporation desired. If, for instance, the room be large or the amount of vapour required be great, the pans should be brought down until the catches of the carrier engage in and rest in the lowest notches. For a very small room or for little vapour, the pans should be raised until the catches rest in the topmost notches. The middle notches are convenient for a medium space or a medium supply of vapour.

Next, the evaporating pan is charged with the medicament to be volatilised. One ounce of any liquid will be enough if the pans are set in the highest or in the middle notches, and this will last for twelve hours ; another half ounce will be required if the pans are set in the lowest notches. But it is impossible to give absolute rules in this respect. Much depends upon the nature of the medicament and its volatility ; much also upon the temperature of the atmosphere in the room where the vaporiser is in use. It will be found that in all cases regard should be paid to the temperature of the room ;

the Vaporiser is exceedingly sensitive and responds with extreme readiness to changes of temperature. The best results will be obtained when the temperature of the room is kept uniformly at about 60° F.

Then, the water-bath is charged—by pouring *warm* water into the water-pan, through one of the holes provided for the purpose, until the bath is nearly full. The evaporating pan (itself charged) should previously be adjusted into the water-pan, otherwise it will be difficult to estimate the amount of water required.

Finally, the lamp or the night-light is lighted and placed in its position on the stand and under the pans.

The Vaporiser having thus been set to work, in a short time the different temperatures (of the medicament and the warm water in the water-bath) will approximate, things will soon settle down and evaporation will go on steadily at a uniform temperature, and at that temperature represented by the position of the pans.

The Vaporiser may now be left to itself, and it will need no further attention until the lamp or the night-light has burned itself out. It works for twenty-four hours without need for renewal of the water for the water-bath. The intervals at which renewal of the medicament may be required depends upon what medicament is used—the volatile oils in common use may be renewed at the same intervals as the water. Renewal of the source of heat is a very simple matter. When the time comes for renewing the water in the water-bath, *i.e.*, every twenty-four hours, care should be taken then to thoroughly cleanse both pans.

In conclusion, let this be said: What is worth doing at all is worth doing well. In using the Vaporiser for the treatment of Phthisis and other diseases of the lungs, let it not be forgotten that the Vaporiser is but the means to an end, and that the end is only to be gained by using the means seriously and in the proper way—the head and the hand must work together in guiding and adapting any instrument to the purpose for which it is used. Let due and serious attention be given to all details of management, as just now set out; let watchful care be taken to apportion the supply of vapour to the size of the room and the state of the patient, and to provide enough vapour; let the temperature of the room be well attended to and maintained, with due regard to the external temperature and the season; let draughts and undue change and agitation of the air of the room (as by frequent opening of doors or leaving doors open) be avoided, whilst providing adequate ventilation; and, above all, let the application and influence of the antiseptic or remedial vapour be complete, continuous, and prolonged.

For so will good results be the better gained.
