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FROM
THE MARYLAND MEDICAL JOURNAL,
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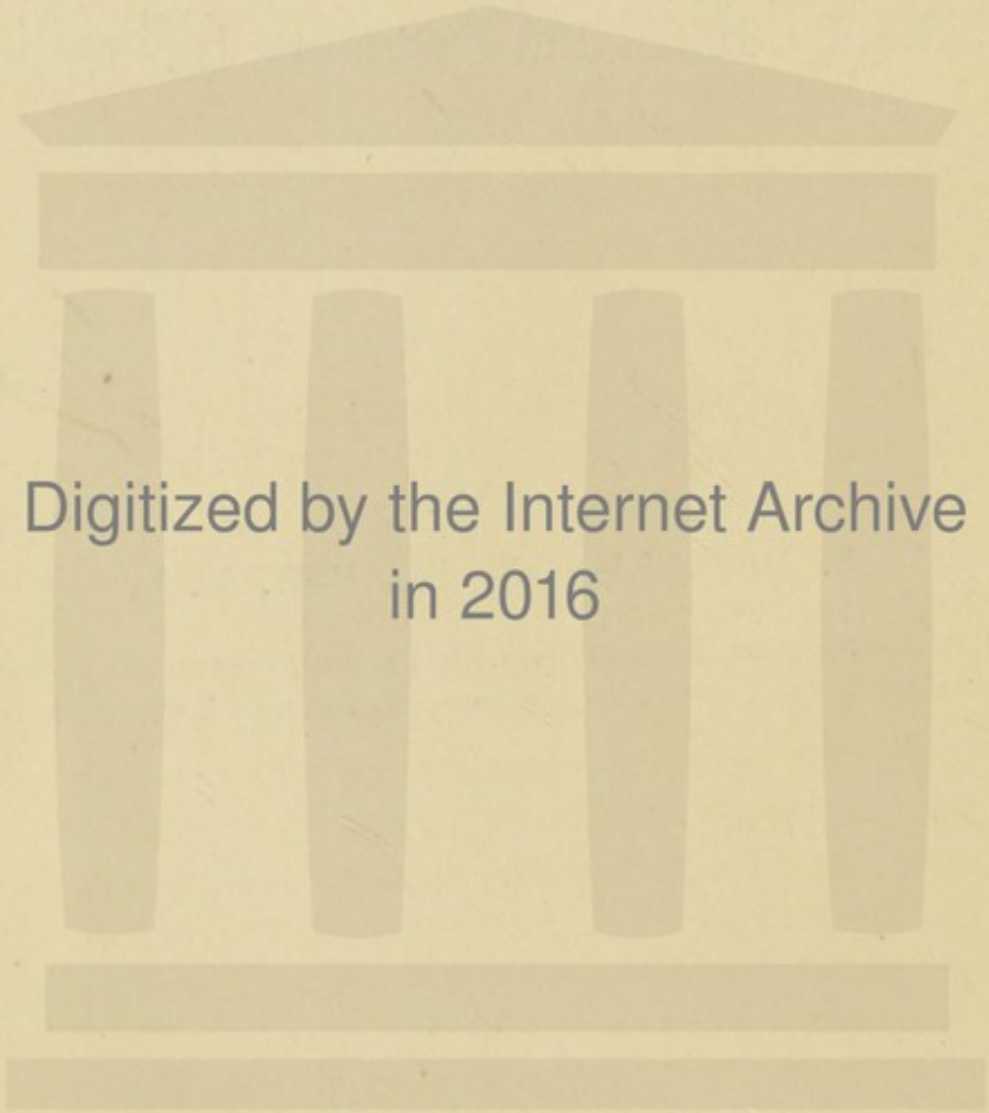

[*Read before Clinical Society of Baltimore, Feb. 5th,* 1886.]

THE PNEUMATIC CABINET AND PNEUMATIC DIFFERENTIATION.

I wish to bring to your attention this evening the pneumatic cabinet and the principle of pneumatic differentiation as perfected and applied by Dr. Herbert F. Williams and Mr. Joseph Ketchum, of Brooklyn. The subject of the pneumatic treatment of lung diseases is an extensive one, with the history of which I shall not now trouble you, but would refer you to a brief and comprehensive paper by Dr. Hudson in the *Record* for January 9, 1886.

There have been many forms of apparatus for the use of compressed air in respiratory diseases, but the one most familiar to the medical man is the cylinder of Waldenburg; and as I find that the pneumatic cabinet is supposed by many to be simply a modification of that of Waldenburg, I have brought one of the latter here to-night. As you see, it consists of one cylinder, with its open end downward immersed in water, within a second or larger cylinder. By a system of cords, pulleys and graduated weights the upper cylinder may be lowered or raised and the contained air condensed or rarefied. Connected with the interior is a tube with mouth-piece which

fits tightly over the patient's mouth and nose. In determining the indications for pneumatic treatment in different chest diseases, Waldenburg was "guided by the causes of dyspnœa, whether the product of inspiratory or expiratory obstruction, or of both"; for instance, he concluded that in emphysema retarded expiration was the immediate cause of the dyspnœa, and in phthisis that inspiration was chiefly impeded; and he made the patient inspire condensed air or expire into rarefied air, as the condition demanded. Both these methods were found to give considerable benefit when properly employed. In this apparatus, I would beg you to note that the increase or decrease of pressure is exerted upon the *lungs only;* that the amount of pure air is very limited, the patient constantly re-breathing the air in the cylinder, and that there is no possibility of medicating the air or of using a medicated spray or vapor. Modifications of the above apparatus have been employed by Cube, Schnitzler, Bierdert, Frankel, Oertel, and by Geigle and Meyer. Another method for the pneumatic treatment of respiratory diseases is by means of the *air bath.* This method is greatly in vogue on the Continent of Europe, where, according to Dr. Theodore Williams, fifty such establishments exist. These air baths are of various sizes and dimensions. They consist, speaking generally, of a chamber capable of holding one or a dozen people, so constructed that a person may spend days in them. Connected with the chambers is an apparatus for compressing or rarefying the air in it. The atmosphere of course can be changed at will, or impregnated with what medicament you choose. Dr. Theodore Williams has one of these chambers in constant use in the Brompton Hospital, London, and certifies to its great usefulness in the

various forms of lung diseases, anæmia, amenorrhœa, chronic catarrh of the ear, etc. This form of apparatus has the manifest disadvantage of great cost and size, and though the atmosphere may be medicated, there is no means by which we can direct a medicated spray or vapor directly and with force into the lungs.

As for the various forms of oro-nasal and oral inhalers now in use, we know how beneficial they may be in pharyngeal, laryngeal and bronchial troubles; of how little practical use in diseases of the lung alveoli themselves. The respiratory power in the very persons who are generally considered subjects for the inhalation treatment is, as a rule, much impaired, and their inspirations so weak and shallow that little, if any, of the medicament used is drawn into the lungs.

There are many other objections to be urged against the above methods, all of which are met in the form of apparatus which I am about to describe. The following description of the cabinet is taken verbatim from a paper by its inventor, Mr. Ketchum: "The instrument in question is a cabinet of proper size and shape to hold a man in the sitting posture, and rigid enough to withstand the superficial pressure when rarefaction is produced inside; strong enough to stand the jars and jolts of transportation. It is made of steel sides, bottom and top fitted to wrought-iron angle frame, with a heavy glass front and a door in the rear, air-tight when closed, but capable of being opened at an instant's notice. In front and below the glass is a projection which sustains the atomizing apparatus and medicine receptacle. In the centre of the glass an aperture is pierced, through which the breathing-faucet penetrates far enough into the cabinet to allow a soft

rubber breathing-tube to be slipped on. The breathing-faucet is constructed of hard rubber, and is of such shape and design that when in use the condensate collecting in it on the patient's side of the stop-cock flows out through a drip-hole in the latter, while the condensate formed in front flows back into the medicine receptacle and is re-used. At the side of the projection is another stop-cock entering the steel front of the cabinet, used for decreasing the rarity or pressure inside the cabinet without removal of the breathing-tube from the mouth of the patient. In front and immediately over the glass is a manometer gauge connecting with the interior of the cabinet, filled with mercury to the zero point and graduated to $\frac{1}{10}$ inch. On the top or roof is a bellows whose interior capacity is approximately one-thirtieth of the cubic capacity of the cabinet. The interior of the bellows, by a valve in its floor, communicates with the interior of the cabinet. This valve is operated from the inside of the cabinet. The bellows communicates with the outside air by another valve in its upper side operated from the rear of the cabinet. The bellows is operated by a rock-shaft running across the top of the instrument supported by shaft standards on each side, and to one end of which an operating lever is keyed. The saturation of the air is accomplished by the use of an atomizer and stand operated by compressed air or steam, and of such height as to deliver spray directly into the mouth of the breathing-faucet.

"The method of administration is so simple that, under the general instructions of the physician as to medication, length of time, and amplitude of force as indicated by the gauge, it can be and has been satisfactorily used by the invalid's ordinary attendant.

"The patient is first instructed in the method of respiring entirely through the mouth, and is told that, while the air will flow down into the lungs without any effort, a slight blowing force will be necessary to expel it preparatory to the next inspiration.

"He is next told that when the air of the cabinet is rarefied he may experience a slight swelling of the tympani, and to relieve which he is instructed to swallow, thus opening the meatus of the Eustachian canal, and allowing sufficient of the air enclosed to flow into the throat to produce equilibrium with the surrounding atmosphere. He is next seated in the cabinet on a chair adjustable for height, and raised or lowered until his mouth is on a plane of slightly higher elevation than the opening in the glass front, and a clamp is placed on the external nares to prevent the escape of air by that channel. The door is now closed, the valve-rods having previously been placed to indicate that the valves are set to produce rarefaction; the operator passes to the front of the instrument, and, having closed the breathing and auxiliary faucet, with his eye on his gauge, moves the lever operating the bellows toward the rear with a slow, even motion, until the difference between the levels in the two arms of the manometer indicates a rarefaction of, say, from one and a half to two inches.

"The object of this procedure, before beginning the treatment proper, is to expand the residual air in the lungs, and if any has been imprisoned behind mucus, or catarrhal plugs, or infarctions, to exert a pushing influence from behind and toward larger bronchi, and produce ultimate evacuation.

"The rarefaction is now allowed to run down by the use of the auxiliary faucet until the manometer indicates the amount deemed proper by the attend-

ing physician, and the spray having been adjusted to the breathing-faucet and turned on, the patient is instructed to take the breathing-tube and place the mouth-piece with which the end is fitted in his mouth, in front of and against his teeth, enclosing the rim with his lips to prevent displacement by the interior pressure. The stop-cock is slowly turned on. Nature asserts herself, and the inflation of the cheeks and the rise of the thoracic envelope indicate that the restraint first offered by thc stop-cock is now offered by the cell-walls, and the same influence that is distending the cheeks so markedly is distending the alveolar walls.

"This first inspiration has distended every cell and avenue, and the process of diffusion with the air charged with vapor of the medicament proceeds with a rapidity commensurate with its enlarged avenue of approach, and the act of expiration commences. This is brought about by the patient's forced muscular expiratory effort, and the pressure of the cell-walls on the loaded air reduces its hydrometric condition to a point where condensation is effected exactly in proportion to the energy of the effort, minus the effect of the increased temperature. Subsequent respiration is no greater in amplitude than normal, except in so far as the feeling of inflation may induce a greater expiratory effort; but after a time the patient becomes fatigued, notwithstanding frequent rests (during which he respires the air in the cabinet), and the expiratory act becomes labored. The door is now opened and the valves, inside and out, are set for vibration of the enclosed atmosphere synchronously with the respiratory act from plus to minus, the weight of the outside air. In other words, the top valve is closed and the bottom one opened wide. The door is again closed, and the

breathing-faucet is opened, and with the lever the bellows is raised until it has reached an elevation equal to one-half its height, and the patient is instructed to again place the tube in his mouth and make his first act one of inspiration. At the same time the operator raises the bellows to its full height and holds it during the interval preceding the expiration. Then allowing it to descend to the midway point, he forces it to completely collapse, thus compressing the air to the extent of one-half the contents of the bellows, and by this compression forcing the collapse of the thoracic walls and consequent compression and condensation. This method continues, if used as a pulmonary calisthenic, or as a 'means of topical application of remedial agents,' until in the judgment of the operator the dose or exercise is deemed sufficient. The influence of compressed air surrounding the patient while he is breathing at normal density, of course exerts its influence in a contrary direction, except in relation to condensation, where the outflow of air is retarded by the constricted condition of the glottis during expiration (Dalton, p. 233). This anatomical verification of the conclusion arrived at, independently, by logical deductions from the action of the manometer in estimating the dynamic value of expiratory energy, is as welcome as it is conclusive."

Such being the construction of the cabinet, it will be seen that it can be put to the same uses as the various forms of apparatus we have mentioned. The method of treatment, however, by this cabinet is entirely different from any ever used before—viz.: 1st, the diminution of atmospheric pressure on the thoracic walls and peripheral parts and the forcible inhalation of comparatively dense medicated atmosphere; 2d, the increase of pressure on the body

generally and forcible expiration into comparatively rarefied air; 3d, and most important, the alternate rarefaction and compression of the atmospheric pressure around the body, and the consequent involuntary increased inspiration and expiration.

It might be well, just here, to answer an objection which may be raised in the discussion of this paper, that no amount of spray will be carried to the person's mouth through so comparatively small an opening as that in the stop-cock. I have tried the experiment, and find that with twenty-five pounds pressure a large spray was projected about three feet from the opening into the cabinet.

What is the result when we rarefy the air in the cabinet? We remove pressure from the body generally, the chest-walls expand and the capacity of the lungs is increased, while the inspiration of the relatively dense air outside dilates the bronchi and vesicles, opens contracted tubes and atelectasic alveoli; and, to put it simply, we compel the patient to take an extraordinarily long and deep inspiration.

It has been found that the amount of air inspired at a vacuum of $\frac{1}{30}$ of an atmosphere was increased from 20 to 100 per cent., with, of course, a considerable increase in chest measurement. I found in my own case that outside the cabinet my chest expanded from $33\frac{1}{2}$ to 37, while inside the cabinet, with a rarefaction of $\frac{3}{10}$ of an inch of barometric pressure, or about $\frac{1}{100}$ of an atmosphere, I expanded to nearly 39 inches—an increase, you see, of nearly two inches. The greater expansion of the chest having been proved, then, what is the physiological effect of so long and deep an inspiration of a comparatively compressed atmosphere? To tell the truth, we are not at present in a position to answer this question, for as yet no satisfactory physiological experiments

have been conducted under these conditions. Speaking generally, however, we may state that the aspirating power of the thorax is much increased, the pressure within the thorax becomes less than normal, and there is a corresponding increase of venous-blood flow into the right heart; a greater amount of blood passing to the left heart, and a corresponding increase of arterial pressure results. The pulse rises from 70 outside to 80 inside the cabinet. We are somewhat in doubt as to the effect of so great an increase of the respiratory movements as we have under these conditions of rarefaction, on the capillaries of the lungs themselves; and it is an important consideration, in view of the possibility of producing hemorrhage. I have been asked whether the inhalation of comparatively dense air, with greater expansion of the chest, would not, particularly in weak chests, tend to produce hemorrhage from rupture of the alveoli and smaller capillaries. It is held by some physiologists that the increase in the area of the wall of each pulmonary alveolus tends to stretch and elongate the capillaries lying in the alveolar walls, and, in elongating, necessarily narrows them. This very narrowing of the capillaries presents an obstacle to the passage of blood through them.

Again, the rarefaction of the air removes pressure from the peripheral vessels and tends to draw blood from viscera and thorax to the surface, and consequently to lower capillary pressure in the lungs. Both these facts would seem to show that the tendency to hemorrhage would be diminished and not increased; of which point, indeed, Dr. Williams claims to have abundant clinical proof. As to the possibility of the diseased alveoli being torn by the increased pressure, it was found that no such results followed the use of Waldenburg's method where the increase

was from $\frac{1}{590}$ to $\frac{1}{400}$ an atmosphere, whereas in the cabinet we use a fall of $\frac{1}{10}$ to 1 inch barometric pressure, or a minimum rarefaction of $\frac{1}{300}$ and a maximum of $\frac{1}{30}$ of an atmosphere.

The next question of importance relates to the extent to which the medicated vapor or spray used in this method is carried into the ultimate alveoli of the lungs.

As we have shown, the tidal air is increased by differentiation to 40 cubic inches, and the relation between the tidal and residual air has been changed from 1 to 10, to from 1 to 5, or from 40 to 200 cubic inches, and a greater amount of diffusion in the interval between inspiration and expiration is the result. And so we see that the physical conditions of ordinary respiration are reversed. For, instead of having, as under normal conditions, 200 cubic inches of residual air diffusing its moisture into 20 cubic inches of comparatively dry tidal air, we have (owing to the inhalation of comparatively dense saturated spray) 40 cubic inches of tidal air diffusing into the residual air the moisture with which it is burdened.

Inspired air at 70 deg. F. has a tension of .733; when expired it is 90 deg. F. in temperature, and its tension has been increased to 1.410—that is, its capacity for water has been increased within the lungs; constant evaporation from the aërating surface is going on, which, according to Valentin, is about $1\frac{1}{6}$ lbs. daily.

"It is therefore clear that, with any method applied under natural conditions, respiratory air, charged with moisture at a temperature below that of the lungs, not only retains its moisture during the complete act, but acquires an additional quantity by evaporation from the pulmonary surface, in exact proportion as the pulmonary temperature is imparted to the inspired air.

"By what artificial aid can this process of evaporation not only be checked, but the natural process reversed, and the air compelled to deposit instead of acquire moisture when within the lungs?

"The two conditions hostile to the deposit of moisture are the contrasted temperatures, and their variations of aqueous tension.

"The former is beyond control, for no artifice can safely invade the lungs to sufficiently reduce their temperature. We can, however, compel condensation, by inter-pulmonary compression, to an extent that will not only counteract the increase of tension, but will leave a margin sufficient to effect this condensation. If a lung is surrounded by an atmosphere equal to a barometric height of twenty-nine inches, while its interior is exposed to one of thirty inches, a differential pressure equal to one-thirtieth of an atmosphere is exerted against the walls; and to effect expiration this pressure must not only be overcome, but muscular or other force must be exerted sufficiently to overcome its inertia, as well as the capillary and bronchial friction heretofore referred to as the second obstacle.

"Manometric tests show that in respiration, under the circumstances stated, the expiratory effort is equal to a difference of 4.5 inches of the manometer, and that a pressure five and a half times as great as that at which air enters is necessary to dislodge it. This increase in pressure reduces the carrying capacity, or hydrometric condition, and is equivalent to a reduction of temperature, and a resulting condensation of the vapor from the air respired.

"The usual remoteness of lesions from the larger bronchi is observed, and the connection between the cause and effect springs into prominence. Having demonstrated that wherever saturated air pene-

trates, its physical properties can be so changed that condensation ensues, it only remains to prove that these localities are penetrated by saturated air, and the topical application is demonstated. Spirometric tests show that while tranquil inspiration amounts to from fourteen to eighteen cubic inches, the initial inspiration, aided by the differentiation of the breathing and the surrounding atmospheres, amounts to from twenty-eight to forty cubic inches, dependent upon the differentiation; and this excess over tranquil respiration must penetrate to regions only partly used, or entirely disused, in ordinary respiration.

"We hold, therefore, that in this method not only is the enlargement of the chest and the capacity of the lungs increased, so that the tidal air is increased fifty per cent., but also that tubes are distended, air-sacs ordinarily inactive or but feebly expanded are brought into fullest action, increased oxygenation is produced, blood more fully vivified, and heart circulation stimulated; poorly developed, weak chests made stronger, pleuritic thickenings and adhesions stretched, and broken bronchial workings and contractions dilated." (Dr. Hudson.)

But, in addition to all this, we claim that the spray indicated is carried far into the lungs and deposited in the ultimate alveoli; and of this there can be no doubt, for, as Dr. Williams says:

"Cinchonism has been produced by inhaling quinine; mydriasis by inhaling a solution of atropia. In using the mercuric solutions we found it necessary to restrict their use. In one case, after three treatments, specific symptoms appeared. An experiment upon a full-grown rabbit was made as follows: Tracheotomy was done without the use of an anæsthetic. A cannula of one-tenth inch inside diameter

was introduced and tied; to this a rubber tube one-fifth inch in diameter and eight inches in length was made to connect with the outside of the cabinet. An assistant held the rabbit in position, and a mixture of China ink and water was sprayed into the tube. The point at which the animal's ability to expire against the normal atmosphere was reached was at seven-tenths of an inch; artificial expiration was resorted to, and the rarefaction was increased to nine-tenths of an inch. This was maintained for ten minutes. The spray was shut off, tube disengaged, and the rabbit allowed to run about the floor for ten minutes, which it did with no apparent discomfort. Its spinal cord was now ruptured and the lungs immediately removed. Microscopic examination shows pigmentation more marked at base of lungs, yet deep discoloration is seen at different points in the subpleural spaces on the periphery. Microscopic observation of fresh sections cut transversely from without inward from all parts of the lungs shows abundant pigmentation in the ultimate alveoli. China ink was selected because of its utter insolubility, fineness of its particles, and the length of time which it will remain in suspension."

But, as medical men, you will say, "The theory of this apparatus is all very well, but what are the clinical results of your treatment?" I can answer with truth that they are extremely satisfactory. I am unable to give you a tabulated statement of a series of cases, but I can say that in several cases of more or less advanced lung diseases there has been marked improvement—decrease of expectoration, lessening of cough, etc. In one case of asthma, from more or less chronic bronchitis, with some emphysema, the relief was very great. I hope soon to be able to present to you a series of cases which may show in detail the results of treatment.

In January, 1885, Dr. Williams reported 11 recoveries out of 16 cases of primary tubercular infiltration and softening. Of these, five were in perfect health in September, 1885; one of these, a man, had broken down, and a cavity with emaciation and night-sweats, and who was treated two years ago, is now a strong, healthy man, and has lost but one day's work in eighteen months.

Another, who had had severe hemorrhages and bad cough, regained his health and became a 'longshoreman. The remaining six are, at last accounts, in good health. Dr. Williams gives a long list of cases, including phthisis in all its stages, which showed a large proportion of marked improvement and cure. Dr. Jensen, of Chicago, has reported a number of cures of acute catarrhal phthisis, who were treated in the Ketchum cabinet; in all of the cases observed there was extraordinary and permanent relief. Dr. Houghton, of Chicago, also gives a long list of cases improved and cured of phthisis in all its stages; of asthma and emphysema also; and I myself can testify to the wonderful effect of differentiation in an acute asthmatic attack. Finally, the results gotten by this method are vouched for by Dr. Loomis and Dr. Darwin Hudson, of New York, and many gentlemen. Dr. Bowditch, of Boston, wrote to a friend that the pneumatic cabinet would work a new era in the treatment of lung disease.

Dr. Hudson says that, in addition to its great use in lung troubles, "many other therapeutic problems may be solved by the Ketchum cabinet. The withdrawal of peripheral pressure favors elimination by the skin, relieving venous engorgement and vascular tension in the kidneys and liver, and permits the depurative functions of these organs to be resumed —functions so often vitiated by interstitial deposit,

increased by the obstructive changes in circulation within heart and lungs, or, in common with them, the product of a rheumatic or gouty vice."

There are many other points of interest in connection with this method of treatment, to all of which I have found it impossible to call attention in this article. My father and I are using the cabinet daily, and will be only too glad to explain its workings and any points I may not have made clear. Finally, all we ask for this apparatus is a strict but unprejudiced investigation. It is not a toy, it is not an air bath, it is not a modification of Waldenburg's cylinder. It is a piece of strictly scientific apparatus, about whose workings there is neither guesswork nor accident.

Since the reading of the above paper we have been using the cabinet constantly and with excellent results. In the course of this article I called attention to the possibility of stretching and breaking up pleuritic adhesions, which are so often the direct cause of consolidation and consequent destruction the lungs. The following case, resulting, after sixteen treatments, in cure, justifies the opinion there expressed:

G. L. W., æt. 24, bank officer, 5 feet, 11 inches, 145 pounds, mother living, father died at 50 of phthisis (?)., sisters and brothers living, in good health. The patient himself had been in good health until January 8th, 1886, when he was attacked with acute pleurisy on right side, with large effusion, which was only partially absorbed. When he presented himself to us we found want of expansion on left side, with some bulging of the intercostal spaces and absence of vocal fremitus. On percus-

sion, flatness along lower margin of lung, with more or less dullness as high as fifth rib, anteriorly and posteriorly. The apex beat of the heart was nearly an inch out of place, having been drawn over toward the left side. On auscultation, coarse pleuritic friction sounds, with jerky and impeded respiratory murmur, could be heard both behind and before, from the fifth rib downward to within an inch of the lung-base, where a small amount of fluid still remained. The patient was quite short of breath, complained of dragging pains on left side, and was considerably annoyed with a dry cough, increased by exertion. The patient was told of his condition, and at once consented to undergo treatment in the cabinet. Our desire in this case was to dilate the lungs as far as possible with safety, and by so doing to stretch and break up the adhesions which bound down the lung. We therefore used the method above described as differentiation—that is, alternate rarefaction and condensation of the air. In each treatment the rarefaction and compression were measured by an excursion of the manometer of from $\frac{4}{10}$ pressure to $\frac{6}{10}$ rarefaction.

The patient improved from the first, and when dismissed the lung expansion had become greater, dullness had gradually disappeared, the coarse, pleuritic friction-sounds had become less, the dragging pains in the side were no more, the cough had stopped, and there was no shortness of breath on exertion. Dr. Williams told the writer of a somewhat similar case, which he had never reported.

The second case of marked improvement was as follows: The patient, a married woman, æt. 27, of healthy German parentage, and with no history of family or personal defect, was in good health until June, 1885, when she had an attack of pleurisy. She

had made what her physician regarded as a good recovery. The sickness, however, left her with a cough, which had become gradually worse, her expectoration changing from a frothy mucus to a heavy, purulent sputa, which, with hectics, night-sweats and general emaciation, had continued up to the time she appeared at our office.

On examination we found a circumscribed spot of consolidation on left side, under the scapula, with all the signs of softening. She was considered a proper subject for treatment by pneumatic differentiation, and accordingly her treatments have continued every other day for the past six weeks. She remained in the cabinet fifteen minutes each day. During the first five minutes after she was put in the cabinet the air was rarefied $\frac{4}{10}$ of an inch barometric pressure; during the last ten minutes differentiation was used. The medicament used in the spray has been varied: benzoin, pine-needle extract with iodine (from which latter the results are not so satisfactory as Dr. Williams would lead us to believe), bichloride and ammonia, etc.

This patient has gradually improved. She has steadily gained in flesh. The cough and expectoration have lessened from week to week. The hectics and night-sweats have disappeared. At present the physical signs are in keeping with the symptoms as given, for on auscultation dry vales predominate with an occasional mucus-click only. The patient's complexion is indicative of her improved condition, for her color is bright and her skin clear. Her strength, too, is excellent.

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