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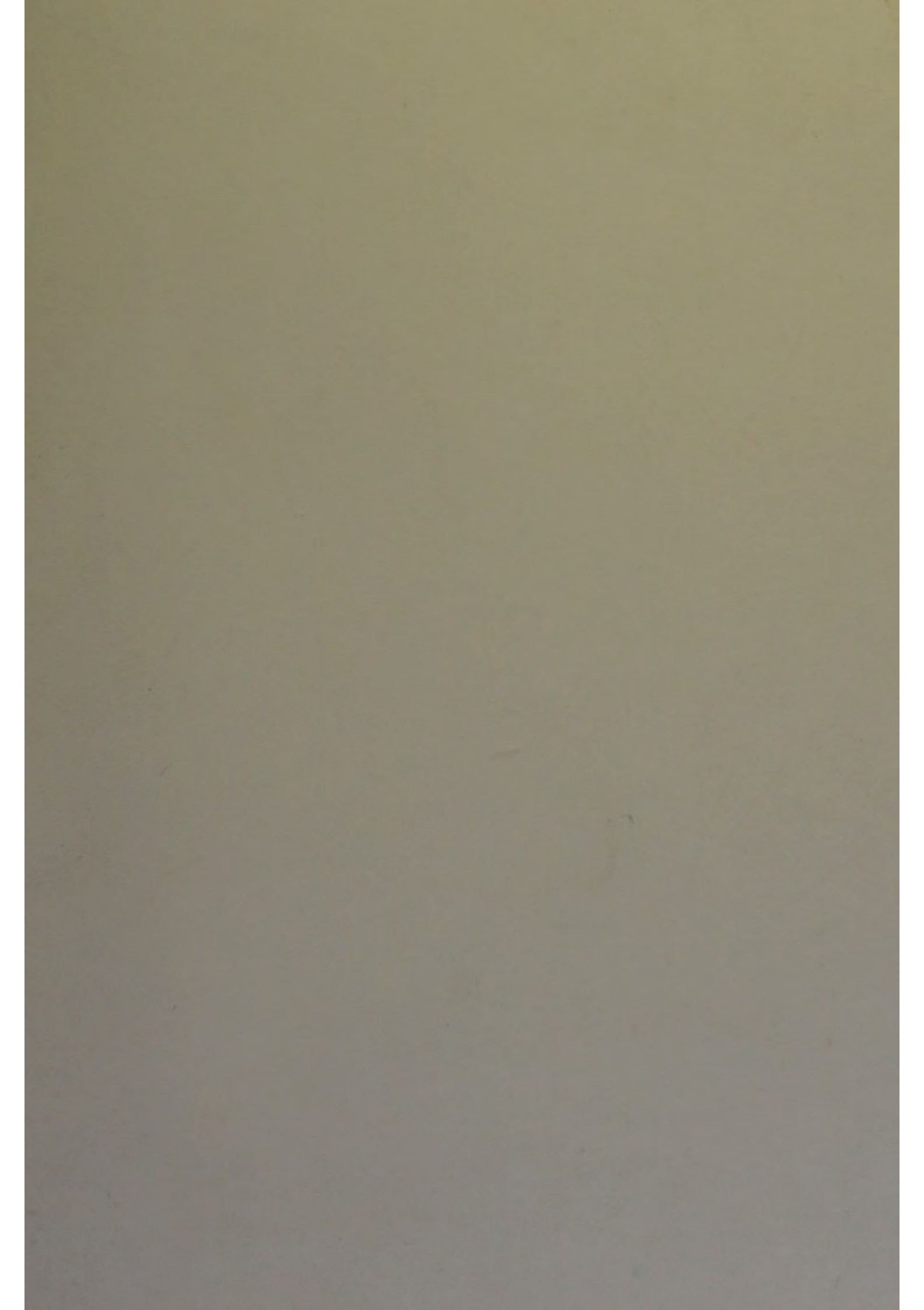
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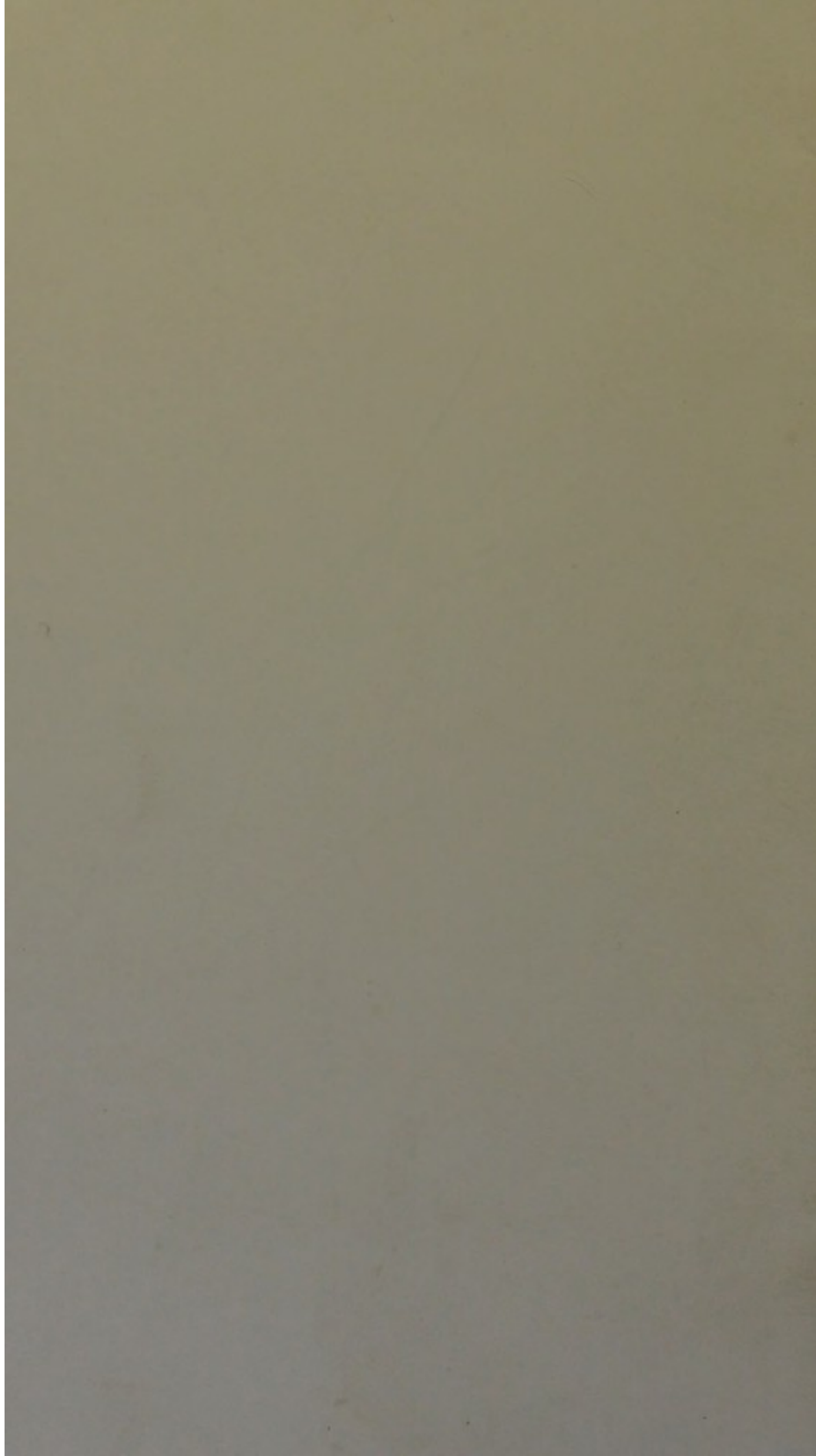
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ON

BY

Physician to the Hospital for Consumption and Diseases of the Chest,
Brompton.

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PLATE 1

THE COMPRESSED AIR BATH AND ITS USES
IN THE TREATMENT OF DISEASE

A TREATISE BY DR. J. H. HARRIS

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LECTURES

ON

THE COMPRESSED AIR BATH AND ITS USES IN THE TREATMENT OF DISEASE.

By C. THEODORE WILLIAMS, M.A., M.D., F.R.C.P.,
Physician to the Hospital for Consumption and Diseases of the Chest, Brompton.

LECTURE I.

THE use of atmospheric air, under different degrees of barometric pressure, in the treatment of disease, is one of the most important advances of modern medicine; and when we consider the simplicity of the agent, the exact methods by which it may be applied, and the precision with which it can be regulated to the requirements of each individual, we are astonished that, in England, this method of treatment has been so little used.

In therapeutics, air is employed in three ways.

1. Air at diminished barometric pressure, or rarefied. 2. Air at increased pressure, or compressed air. 3. Air mixed with other gases and compressed.

Rarefied air was first applied to the human body by Junod, who, in 1835, contrived a hollow copper ball, $1\frac{1}{2}$ metres in diameter, capable of holding a man, and, by an exhausting apparatus, reduced the barometric pressure one-third, producing distension of the membrana tympani, dyspnoea, chiefly in the form of quick short respirations, turgescence of the superficial vessels of the body, as seen in the eyelids and lips, and diminution of the salivary, renal, and other glandular secretions. Junod, not being favourably impressed by these experiments, betook himself to the localised application of rarefied air to various parts of the body, in which he had more success, for his inventions of cupping-glasses, and of Junod's boot, by which atmospheric pressure can be reduced over large surfaces of skin, have been, and are still, largely used with great benefit.

Another method of reducing atmospheric pressure locally, is Waldenburg's apparatus, in which a mask closely fitting the mouth and nose is connected with an exhausting aspirator, and air is thus drawn from the lungs, giving rise to the respiration of an attenuated atmosphere.

Another way of using air at reduced pressure is by balloon-ascents, in which any and every degree of diminution can be attained, from the slight reduction experienced in captive balloons, often sent up at

fairs and places of public amusement, to the extraordinary results of Glaisher's and Coxwell's adventurous voyages, where the reduction of the barometric pressure to $9\frac{3}{4}$ inches showed an elevation of 29,000 feet; and it is possible that even a greater altitude, and corresponding diminution of pressure, was reached by these aeronauts, after Mr. Glaisher had lost consciousness, and could no longer register observations.

The rapid ascent of balloons, the difficulties of steering, and the impossibility of remaining long in them, render this form of reducing pressure of little use for therapeutics. The most usual method, and the one best adapted for our purposes, is residence at high altitudes; and fortunately, among the various mountain-ranges, we have, in all latitudes, an abundant choice of sites at various elevations and exposures, where we can try the influence of rarefied atmospheres on invalids. While at Davos (5,200 feet) we get a diminution of 5 inches in the barometric pressure, at La Paz, the capital of Bolivia (13,500 feet), it amounts to 12 inches, and we have examples of every intervening grade of elevation. The heights principally used for treatment range from 5,000 to 10,000 feet, giving barometric pressure of from 25 inches to 20.5 inches, and a diminution of from 5 inches to 9.5 inches. It is not the object of these lectures to consider the effects of rarefied air in the human organism, which has been dealt with elsewhere (*Treatment of Phthisis by Residence at High Altitudes, Transactions of the International Congress, 1881*), but rather to treat of the second subject, namely, air at increased pressures, such as is to be obtained in compressed air baths. We know that the air of mines is considerably condensed, and that, if a shaft could be sunk 45 miles deep into the earth, the air at the bottom of it would be as dense as quicksilver; but no mines have been made deep enough to modify barometric pressure to the inverse extent of that observed on mountains, and our principal results from compressed air come from the employment of diving bells and diving apparatus and pneumatic tubes, used in the construction of piers and bridges, of arches, and the like. In many of these enterprises men have worked, for hours at a time, at a pressure of from $2\frac{1}{2}$ to $4\frac{1}{2}$ atmospheres, and, when proper precautions were observed, apparently without harm. I am largely indebted to the great and masterly work of *Pression Barométrique*, by Paul Bert, for many of the facts cited in this lecture. The amount of evidence which these experiments afford as to the influence of compressed air on the human body is so extensive, and bears so directly on our present subject, that I make no apology for citing some of the leading facts, which we shall find useful in three ways; first, showing the limits of endurance of the human body; second, in demonstrating what steps of the process are dangerous, and what are not so; third, as indicating the means by which peril can be averted.

The pressure of air in diving bells depends entirely on the depth of water reached, which is sometimes considerable; but as the difficulty of renewing the supply of air was great, these instruments were soon replaced by diving dresses and pneumatic tubes.

The symptoms noticed on descending in bells to a depth of about 30 feet, were pains in the ears, noises and even deafness, a sensation of tightness, as if the head were bound with a band of iron. These phenomena only accompanied rapid descent, and ceased entirely when the bottom was reached. The ascent was generally described as more agreeable, but according to Colladon there was a feeling, as if the bones of the skull were separating; no changes in the pulse or respiration were noticed.

Triguet's invention of the pneumatic tube was soon applied largely for the construction of bridges, piers, etc.; and inasmuch as

by this means air could be pumped in to the extent of three or four atmospheres, a large number of workers were enabled to remain at their labours below the level of the water for several consecutive hours.

It appears that, in many instances, no special symptoms were experienced, but, in some works at Douchy, out of 64 workmen, 32 suffered more or less, of whom two died. On the other hand, one, an asthmatic, improved in breathing, and another, a chloro-anæmic individual, gained colour. Of 22 workmen who commenced labour at 4.15 atmospheres, one had slight hæmoptysis, eight experienced muscular pains in different parts of the body, some lasting for several days; and one, a man aged 40, of very robust appearance, who descended the tube only once, died immediately after leaving the tube, the pressure having been reduced in 20 minutes. *Post mortem* examination showed general cutaneous emphysema (not of decomposition), congestion of the lungs of a specially dark tint, the liver, spleen, and kidneys engorged, the blood fluid, and quite black in the heart. Nothing abnormal was observed in the brain, cerebellum, and meninges.

In another case, where reduction of pressure was too rapid, the workman, after exit from the tube, had a corpse-like aspect, with livid face and pupils enormously dilated. The pulse was not perceptible, and the heart-sounds could barely be heard. He became unconscious. Complete muscular paralysis followed unconsciousness, and urine was voided involuntarily. Under warm baths and friction he gradually recovered, but the sight remained affected.

In another case, these symptoms were still more marked, and the patient recovered with weak vision, and was stone deaf.

During the laying of the foundations of a bridge at Londonderry, in 1861, Messrs. Babington and Cuthbert reported accidents among the workmen; one, where a man, aged 18, during the reduction of atmospheric pressure, fell down unconscious. He remained in a half comatose condition for eighteen hours, and then, recovering consciousness, found himself totally paralysed below the level of the fourth rib. He lived for over five months, but never recovered sensation or motion.

Another had the same symptoms as the last, except that his paralysis commenced below the eighth dorsal vertebra, and he only survived eight days.

In another case, again, the paralysis was less extensive, being chiefly limited to the right side of the face, the patient was bled, and the blood found to be black and pitchy. The man died after twenty-four hours.

A great bridge was made at St. Louis, United States, the workings being at the depth of 33.70 mètres, at low tide, under a pressure of 4.45 atmospheres. Of 333 workmen, only 30 were seriously affected, of whom 12 died. The doctor of the works remained 2½ hours at a depth of 90 feet. The reduction of pressure was performed in from 3 to 4 minutes. Dr. Bauer noted in the slighter cases muscular pains with choreiform contractions, and hæmorrhage from the nose and lungs. In the grave cases, there was paralysis of different degrees, varying from slight paresis to complete loss of movement and sensation, paralysis of bladder, and urine sanguinolent. Death occurred by coma. The *post mortem* appearances showed hyperæmia of the cerebral and spinal meninges, some œdema of the arachnoid, with softening of the brain and spinal cord.

In one case, the softening occupied the anterior cornea and the lateral striæ throughout the whole cord.

Compressed air is employed also in the apparatus by which divers carry on operations at depths of 54 mètres and less, but it must be remembered that the conditions are not quite the same, owing to the additional pressure of the water on the bodies of these men, which, at

that depth, equals 6.4 atmospheres. Accidents seem more common, and deaths are far from rare. It was calculated that, among the sponge-divers of the Greek Archipelago, the mortality was ten per cent., and this does not include the minor accidents. They appear to suffer in much the same way as those working in pneumatic tubes, only more severely; prickings, muscular pains, and pains in the joints are complained of, the prickings (*les puçes*) never taking place where there is perspiration, and the muscular pains being most marked in the muscles principally used by divers. One diver had epistaxis at the bottom of the sea, which was repeated in a second descent, and accompanied by severe pain in the head. The serious accidents consist of paralysis of different kinds, and invariably occur after the diver has left the water. The general form is paraplegia, including paralysis of the bladder and of the sphincter ani. In some cases, the loss of power extends to the upper extremities, and is accompanied by loss of sensation over the whole body. Some of the deaths occur immediately after leaving the water, and appear to resemble those which took place at the works at Douchy. A *post mortem* examination after one of the deaths from paralysis showed extravasation of blood between the spinal dura mater and the arachnoid, and the greater part of the spinal cord itself in a condition of softening.

M. Bucquoy made observations on the circulation in compressed air-tubes, and, from a large number of instances, concluded that, in the first increase of pressure in the tube, the pulse rises about twenty beats; and that some increase is maintained during the whole stay, falling, at the end of an hour, to seven above the normal; and M. Gal's observations on the pulse of the Greek divers exactly corresponds, for he found, as a rule, an increase of from seventy to ninety beats. M. Bucquoy also found that the respiratory rate increased temporarily, but that such increase lasted only about fifteen hours after returning to ordinary conditions. We must bear in mind that, in both pneumatic tubes and in diving, the workmen are engaged in arduous labour, naturally involving an increase in the pulse and respiration rate.

On reviewing the accidents narrated, it would appear that they were much more due to the reduction of the high pressures than to the high pressures themselves. Very few symptoms appear to have been noted during high pressure in the tubes; and it is marvellous how well high pressures were borne; but most of the accidents occurred either during rapid reduction of pressure or subsequent to quitting the tubes after this. In many instances, pressure of 4.45 atmospheres was reduced in three to four minutes—a proceeding which has been proved by experience to be fraught with danger. The symptoms seem principally to be due to lesions of the nervous system, commencing with dyspnoea, quickening of the pulse, muscular pains of more or less intensity, and gradually increasing in severity; then come the different forms of paralysis, including loss of sight and hearing, paraplegia, stupor, loss of consciousness, coma, and death. The divers appear to suffer more intensely than the workmen in compressed air-tubes; but among them, also, the accidents were almost invariably due to rapid diminution of pressure.

It was found that young men bear compressed atmospheres better than the middle-aged.

The accidents appear to have been more common after long exposures to high pressures than after short ones, even when the rate of reduction of pressure was the same in both cases. There is another element of danger which we must not underrate; that is, the diminution of temperature which the rapid reduction of high pressure necessitates, and which must, by cooling the extremities, drive more blood

up to the central organs, and specially into those well protected from variations of atmospheric pressure, such as the brain and spinal cord. The experience of all authorities points to rapid increase of pressure as the best method of correcting any bad symptoms shown during the period of reduction.

The number of apparatus devised for condensing and rarefying the air is very large; for, in addition to air-baths to be described presently, there are many methods in which the air is inspired through a mask closely fitting to the nose and mouth.¹ Of these, Hauke's was, perhaps, the earliest, of which Waldenburg's, alluded to before, is a modification. This consists of a hollow metal cylinder or bell, containing a certain volume of air, which is plunged into a second and reversed cylinder, containing water. By means of pulleys and weights, an equilibrium is established, and a pipe is passed from the air-cylinder, through a drying box, to a mask fitting the patient's mouth, enabling him to respire the air, which can be either rarefied or condensed by raising or lowering the cylinder in the water. This is done in the first instance, by drawing off water, in the second, by placing weights on the cylinder. Schnitzler's is a further and simpler modification of the same system. Some, as Cube's, and Schnitzler's second form, are double apparatus, and consist of two cylinders, one for condensing and the other for rarefying the air; both are connected by pipes with the inhaling mask, and taps regulate the supply of one or the other to the patient's lungs. A third form is Biedert's, who arranged a species of leather bellows to compress or rarefy the air as required; but the most ingenious example of this form is Fränkel's, which consists of a kind of portable concertina, simple and cheap, and capable of being worked by the patient himself, the objections being the contracted attitude necessary for this purpose, and the impossibility of regulating the pressure. This little instrument is recommended by Oertel for the treatment of asphyxia by artificial respiration.

A fourth form is the apparatus of Geigel and Mayer, constructed on the principle of the centrifugal pump, by which air is stored up in a central reservoir, being compressed by the action of water.

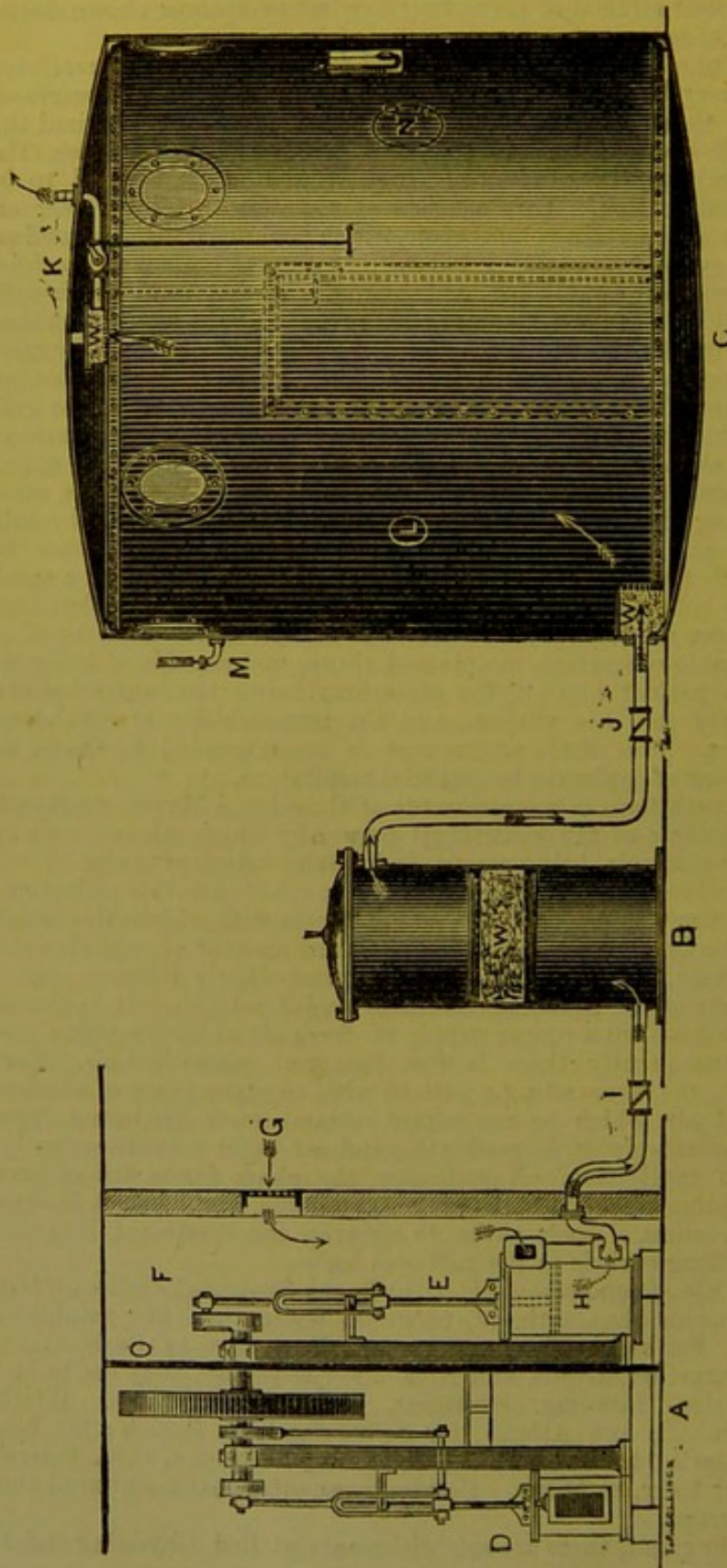
Ingenious as the above methods are, all have this objection, that their efficacy depends on the completeness with which the patient applies the breathing mask, and also on the amount of pure air available. As a rule, the use of the mask is exceedingly irksome, and many complain of its inducing faintness and headache. It is also impossible to keep up a proper supply of fresh air at the requisite pressure, and consequently there is the danger of rebreathed air. For these reasons, the surrounding a patient with an atmosphere of condensed or rarefied air, which he can respire without let or hindrance from artificial mouth-pieces, is preferable, and air-baths are consequently more easy of application. Nevertheless, the above forms are of great use when compressed air-baths are not available, and when it is advisable, after a course of such baths, to carry on the treatment by condensed air for long periods in the patient's home.

The use of compressed air-baths in the treatment of disease is greatly in vogue on the Continent, where no fewer than fifty establishments exist. For France there are two excellent ones in Paris, and others at Montpellier, Lyons, and Nice. For Germany, they are to be found at Berlin, Hanover, Stuttgart, Johannisberg, Ems, Wiesbaden, Reichenhall, and Altona; for Switzerland, at Zurich; for Belgium, at Brussels; for Sweden, at Stockholm; for Russia, at St. Petersburg; and for Italy, at Milan. Besides these, others exist scattered throughout Europe.

In England, there are establishments at Ben Rhydding and Ilkley,

¹ For a full list, see Oertel, *Respiratorische Therapie*.

and, till recently, one at Malvern; but there were no others, so far as I know, in England—not even in this great city, which ought to be



ever in the van of progress—until the Committee of this hospital con-

structed one, at great expense, in the new building; an example which, we trust, will be soon followed elsewhere.

The construction of these air-baths varies considerably; the size depending on the number of patients to be accommodated, but the following are the necessary elements.

1. *A circular or ovoid iron chamber*, much resembling an engine-boiler in appearance, constructed in wrought-iron, at least $\frac{3}{8}$ ths of an inch thick, strengthened by girders and ribs of iron, provided with windows of thick plate-glass, and a stout door not larger than sufficient to admit one person at a time. Both windows and doors must fit closely enough to be air-tight, though, as a rule, the centrifugal pressure of the air contained in the chamber renders this easy. The chamber is furnished with the following: (1) an inlet pipe for the supply of fresh air; (2) an outlet pipe for the escape of vitiated air, and for the reduction of pressure; (3) an air-tight cupboard, through which food and drink can be passed to the inmates; (4) other outlets, one in the form of a whistle as an alarm signal in case of bad symptoms, and another with a safety-valve attached to prevent the pressure being excessive. The thickness of the wall depends on the amount of pressure to be used. A thickness of $\frac{3}{8}$ ths of an inch sheet-iron easily sustains a pressure of 10 lbs. on the square inch, the amount most generally employed. The circular form of chamber, with an arched roof, is the one best calculated to resist pressure from within, and has, therefore, been adopted in this hospital. At St. Petersburg, one bath, consisting of two chambers, is constructed of stone, and fitted with double doors, after the fashion of the previously mentioned air-tight cupboard, allowing entrance and exit without alteration of the air-pressure within. There is also a water closet, and patients may, if required, spend several days in these two chambers. At Reichenhall, there is a large iron chamber holding nine persons; and in one of the Paris chambers six or seven may be treated at once; while at Dr. Fontaine's establishment each chamber or *cloche* can only hold two patients. Our bath measures 10 feet in diameter and 8 feet in height, and is constructed to accommodate four persons.

2. *Apparatus for compressing the air*. This is generally done by a steam-engine; the one used at this hospital being of 8 horse-power. At M. Fontaine's bath, hydraulic power is used, the ordinary water-supply pressure of the City of Paris being turned to account to work a very ingenious hydraulic pump, which compresses the air without materially raising its temperature. This method has some advantages, for the air escapes the chance of being heated and rendered unpleasant by contact with the boilers; but by using steam, the pressure can be more quickly increased and steadily maintained.

3. *A central reservoir*, to receive the compressed air, from which it can be drawn off, at will, into the separate chambers. This is the case at Reichenhall, where three baths are connected with a large anti-chamber, into which the air is pumped; and certainly the supply is likely to be more steady and the current more even, the puffs arising from each descent of the piston not being felt in the chamber itself. In most establishments the air is pumped directly into the bath, the supply pipe entering near the floor. In many, as at Johannisberg, Zurich, and Berlin, the pump is arranged to rarefy, as well as to condense the air, and this is done by a modification of the valves, or rather by reversing their positions. It is much to be regretted that some arrangement of this sort was not made here, but the initial cost, already very great, was an obstacle.

A receiver for filtering the air from the dust and mechanical impurity is often inserted between the compressor and the air-chamber. It generally consists of a small cylinder or box containing layers of cotton-wool, through which the inlet-pipe passes immediately before

its entrance into the bath. In hot weather this cylinder may be partially filled with ice, to reduce the temperature of the air. If this receiver be large enough, it also answers the purpose of a reservoir, and converts the puffs of air into an even current.

On page 8 is a drawing of the Brompton Hospital compressed air-bath, kindly made for me by Mr. Blake, the manager of Messrs. Haden and Sons' works, who were the contractors. It consists of three parts; the engine (A), the receiver (B), and the air-chamber (C). A includes a steam-engine D, which, by means of a fly-wheel and crank, works a second engine, E, in another and separate compartment, F. E is the air-compressing engine, with a cylinder containing an inlet-hole and an outlet-hole, and in this cylinder works the piston H, the plate of which is perforated by diaphragm-valves, which are not here shown, and which close during the descent of the piston and open during its ascent. The air from outside enters the compartment F through the inlet G, and follows the course indicated by the arrows. Entering the air-cylinder, it is driven forward by the piston, through the pipe, I, into the receiver B, containing layers of cotton-wool, W, into the air-chamber. Both I and J contain valves to prevent a return current. The air leaves the bath by an outlet-pipe in the roof, which is always open, the strength of the current through it depending on the rate at which the engine works. M is a safety-valve which opens wide and blows a whistle, when the full pressure of 10 lbs. is reached. L is a glass spyhole, through which the inmates can be watched. N is an airtight cupboard, fitted with double bolts to adjust the pressure, and to enable food and messages, and, if necessary, medicines, to be passed in. Apparatus to regulate the escape of air, which can be worked both from within or outside the bath, complete the chamber, which is lit from without by stout plate-glass windows, and fitted with a strong iron door. The air can be changed about five times in the two hours.

The chamber itself in all cases is furnished with chairs and tables, a water-bottle and glasses to meet the thirst and uncomfortable throat-symptoms, which often accompany increase of pressure; also with a pressure-gauge to record the variations, and a thermometer and a wet and dry bulb apparatus.

Care should be taken that the air be supplied from a pure source, like an open space, as a garden or court-yard, away from all machinery or drainage. It should be filtered through cotton-wool, and the temperature regulated as far as is possible. In some baths there is an apparatus for heating the air, but in our own the temperature has generally been too high rather than too low, and in the hot weather it was found necessary to pass the air through an ice-box, to reduce it sufficiently for the bath purposes. The dryness is seldom a trouble, and a saucer of water on the table will correct it by evaporation.

In some of the German baths, in winter, the temperature falls so low that it has been found necessary to pump in air specially heated. The amount of compression used for medical purposes is small, and varies from $\frac{1}{2}$ to $1\frac{1}{2}$ atmospheres. Here we do not exceed 10 lbs., that is, about two-thirds of an atmosphere, which is ample for the treatment of lung-diseases, and even before the pressure is reached complaints are made of headaches; as a rule, a pressure of $7\frac{1}{2}$ to 9 lbs. is sufficient to produce the ends we have in view.

A bath, or sitting, generally occupies two hours; half an hour being spent in gradually increasing the pressure, which is maintained for a whole hour at the maximum, and half an hour in gradually decreasing it to the minimum. The rate of increase or decrease should be 1 lb. in two or three minutes. The number of baths to be given must depend on the case, but at least a dozen are required to produce permanent improvement, and sometimes 30, 40, or even 100, are needful.

During compression the air increases in temperature, and this is, of course, more the case when the bath is occupied. During reduction of pressure there is sometimes a slight fall; but what is most marked is the deposition of moisture, which is seen on the glass windows during this process, and which, when the door is opened, often amounts to a mist in the chamber. This is, of course, due to the quantity of moisture which the air was capable of holding in suspension at a high pressure being diminished when that pressure is reduced. The chief points to be aimed at in the management of compressed air-baths are:—

1. To increase and reduce pressure as gradually as possible.
2. To keep the temperature of the bath within reasonable limits, say between 60° Fahr., and 65° Fahr.
3. While increasing or maintaining the pressure, to provide for the escape of the used up and contaminated air.
4. If bad symptoms have arisen from increase or decrease of pressure, to reverse the process at once.

LECTURE II.

LET us now consider the effect on a man in ordinary health of a compressed air-bath; the pressure not exceeding ten pounds, and the bath occupying two hours, of which one half-hour is spent in raising the pressure, one hour in maintaining it at the same height, and the reduction of pressure occupying the last half-hour.

The first sensations experienced are noises in the ears, slight headache, and an unpleasant sensation in the throat, referred especially to the pharynx and immediately behind the tonsils, which is relieved by swallowing saliva, and still more effectually by drinking some fluid. Pain is sometimes experienced in the membrana tympani, which can be prevented by inserting cotton-wool into the ears. The reason of these unpleasant auditory sensations is to be found in the different calibres of the external auditory meatus and the Eustachian tube. As the channel of the latter is very much smaller than that of the former, the column of air penetrates with difficulty to the internal surface of the membrana tympani, and any change of pressure is but slowly communicated; whereas through the meatus the air passes freely, and its pressure being exercised on a larger surface gives rise to a convexity inwards of the auditory membrane. This is the case during increase of pressure, but during reduction the contrary effect is produced. The middle ear is then filled with air of greater density, the change being slow; whereas the external auditory meatus contains air of which the pressure is being reduced more rapidly. The membrane consequently becomes convex outward; hence the unpleasant sensations in the ear and throat during the commencement and end of the bath. Some people notice an impairment of the special senses, and state that touch, taste, smell, and hearing are all diminished in intensity; the voice sounds shrill; whistling becomes impossible. An instance is given by von Vivenot, where a professional singer gained half a note in her voice during a bath, and I can confirm this by another. It is noticed that the arched form of the abdominal walls is flattened, which Panum ascribed to compression of the intestinal gas.

The most important changes are in the organs of respiration and of circulation; the individual finds he breathes *slower, deeper, and with greater ease*. Physical examination demonstrates that the diaphragm descends lower, that the liver is displaced downwards, that the heart-sounds are less audible, the cardiac dulness is less perceptible, and the whole chest becomes more resonant. This diminution of the cardiac dulness does not appear to be mainly due to the displacement of the heart, but rather to the further expansion of the lungs; and the faintness of the sound, arises from the intervention of a larger amount of those badly conducting air-cushions. Measurements show a considerable increase to take place in the mobility of the thorax at various levels during inspiration. Von Vivenot found an expansion after one bath of 5.75 millimètres, and after seventeen baths of 9.47 millimètres. The respirations are diminished in number to a considerable extent; this seems to occur even in one bath, but after several it is still more marked, for they have been known to fall from 16 or 20

a minute to 4 or 5, or only to 3 or 4 a minute. The relation of inspiration to expiration is often, but not always, changed. Inspiration is easy, and expiration appears comparatively less so; and whereas the ratio at the usual pressure is normally 4 to 3, it becomes in compressed

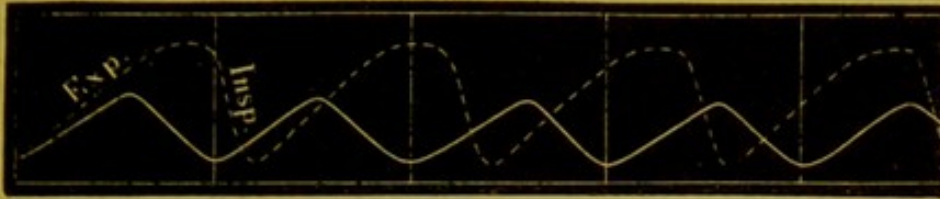


Fig. 1.

air 4 to 6, 4 to 7, 4 to 8, or even 4 to 11, according to von Vivenot, from whose work the annexed diagram is taken, which well illustrates the prolonged expiration, and the depth of the respiration in compressed air, which are indicated by the dotted line, as compared with the lower line, which is that of normal breathing.

The circumference of the chest increases considerably, though slowly, as will be seen by our experiment, to be narrated presently.

Spirometric observations show a marked augmentation of lung-capacity. Simonoff found in 11 persons a mean increase of 108 cubic centimetres after twenty minutes of the bath; after one hour and twenty minutes, 94 cubic centimetres; and at the end of the bath the increase was still 24 cubic centimetres. Von Vivenot's numbers are still larger for this increase. Our own showed in one case an increase of from 250 to 286, and in the other from 255 to 302.

There seems to be every reason to conclude that the inspiration of compressed air increases the lung-capacity, and it is probable that the effect is at first a mechanical one, more alveoli being brought into play than in normal breathing. The diminution in the number of respirations is the result of this, as we may conclude that their frequency is in inverse ratio of their amplitude; consequently we get, with an enlarged respiratory surface, fewer and deeper respirations, and this effect is more or less permanent.

The influence on the circulation is, that the pulse is slower, smaller in volume, but of increased arterial tension, the capillaries are smaller,

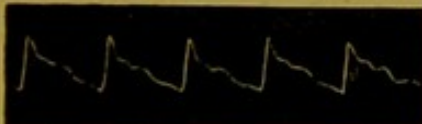


Fig. 2.—Before bath. Ordinary pressure.

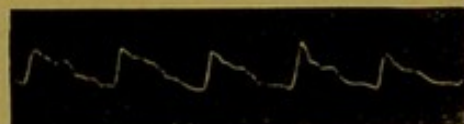


Fig. 3.—Pressure, 3 lbs.



Fig. 4.—Pressure, 6 lbs.



Fig. 5.—Pressure, 9 lbs.



Fig. 6.—After bath. Ordinary pressure.

and the veins are less full of blood. The amount of diminution varies from 4 to 20 beats a minute; and, if the pulse have been somewhat excited before entering the bath, the diminution may be still greater.

Sphygmographic tracings show a great lowering in the height of the pulse-wave, due apparently to contraction of the vessels, and also reduction of the dicrotic wave. But this change is only maintained during the bath, for tracings, taken immediately after leaving it, are precisely similar to those before entering. The subjoined tracings were taken from Mr. B., one of my clinical assistants, a very healthy young man, and indicate the influence of the different pressures on the pulse. The recovery, as shown in Fig. 6, is very complete. To the touch the pulse appears small and hard. The influence of compressed air on the circulation was admirably shown by von Vivenot's observations on a white rabbit in the bath. Under normal pressure, with the rabbit quiet and at liberty, the ears were full of blood, and the vessels of the conjunctivæ injected; the iris and the pupil were tinted deep red. During the increase of pressure, the vessels of the conjunctivæ became finer and more pale, and in one experiment they alternately filled and emptied. The iris and pupil became decolorised when pressure was kept up at the maximum; the ears, when seen by transmitted light, showed empty vessels, the larger ones were scarcely visible; a little later, the ears became quite pale and flabby, and the vessels completely disappeared. During reduction of pressure, the ears and conjunctivæ remained pale, and at the normal pressure, for one hour after the bath, the ears still remained bloodless and flabby.

These experiments and observations indicate that compressed air exercises an intropulsive influence affecting naturally those surfaces most exposed to it, such as the skin and the lungs; the blood is thus driven into the organs protected from air-pressure, such as the brain, the heart, liver, spleen, and kidneys. The pressure is exerted more on the capillaries and superficial veins than on the deeper veins and arteries, and its tendency would be to reduce pressure on the right side of the heart, and to increase it on the left. The retardation of the pulse is assigned by some to diminished heart's action, owing to the great obstacles the circulation meets with in the superficial vessels. A proof of the fulness of the arterial system is found in the colour of the blood, which is bright red, as has been seen during bleedings which have sometimes taken place in the bath.

Another proof is found in the sphygmographic tracings of the radial pulse, which indicate increased arterial tension. The diminution of the pulse-rate is explained by Dr. Burdon Sanderson (*Practitioner*, October, 1868) as follows. "The effect of the diminished fulness of the venous system is to retard the filling of the ventricles during their period of relaxation, and, consequently, to lengthen the diastolic period, and thus diminish the frequency of the pulse; for, as the time occupied by the heart in contracting is subject to little variation in the same individual, the interval between successive contractions depends on the duration of the diastolic pause."

Though this emptying of the veins is no doubt the principal cause of the slowing of the pulse, something must be assigned to the great obstruction which the increased air-pressure causes to the circulation, for instance, through the capillaries of the skin. The temperature is slightly raised, sometimes half a degree, in the mouth; that in the axilla is said to be diminished by Stembo; but in the rectum, according to the same authority, it rises considerably, a clear confirmation of the intropulsive influence before alluded to. The kidney-secretion is largely increased, another piece of confirmatory evidence. The saliva is also more freely secreted. To the same influence may be assigned the excitation of the menstrual function, which is often brought on during compressed air-baths; and defæcation is said by Oertel to be occasionally due to the pressure on the abdomen.

The compressed air-bath also produces physiological effects on the system. The introduction of a large amount of oxygen in each respira-

tory act causes increased absorption of that gas by the lungs and blood, and leads to further oxidation and tissue-change. This is proved, first, by the colour of the blood before alluded to, and, secondly, by the increased quantity of carbonic acid excreted by the lungs, in spite of the number of respirations being fewer than at normal pressure. The urine, too, contains more urea, and, in some cases, Hadra found the increase to amount to two grammes daily. The muscular power is increased, for Lange found two men could carry more in their hands with outstretched arms after the bath than before it. This is to be expected, when we consider that the blood is *determined* to the muscles, which are not under the influence of the direct action of the compressed air.

Appetite is generally improved; increase of weight does not follow at once, but often a decrease is noted at the beginning of a course; and later on, however, after a course of twenty baths, there is marked increase of weight. The increase of appetite is probably a physiological effect of the larger supply of oxygen, and the first decrease of weight may be attributed to the more rapid tissue-changes which afterwards, with greater powers of digestion and assimilation, becomes surpassed by fresh production.

To illustrate some of the above conclusions, I will relate an experiment carried out under my direction, in the air-bath, by two of the clinical assistants of this hospital, aged 28 and 22, both healthy young men, who took observations on each other before, during, and after the bath. Notes were taken when the pressure had reached 3, 6, and 9 lbs. respectively; but, unfortunately, owing to the Turkish bath in the adjoining chamber being at work at the same time, the atmosphere was hotter than it should have been, and at one time a temperature of 78° was reached.

These gentlemen remained in the bath 3 hours 20 minutes. Both felt the heat, and perspired slightly; both said that, beyond slight fulness in the ears and forehead, not amounting to headache, nothing uncomfortable was experienced; Mr. B. also complained of slight oppression in the front of the chest; Mr. S. of temporary deafness. After the bath, they dined with great appetite, and each took 1½ glasses of beer and 3 glasses of wine, which probably accounts for the increased pulse and respiration-rate three and a half hours after the bath.

Pulse-rate.—Mr. S.'s was 84, two hours before the bath, of good tension; it fell to 78 in the bath, and rose to 96 after the dinner. Mr. B.'s was 64 before bath, rose to 70 under pressures of 3 and 6 lbs., but fell to 60 under 9 lbs. pressure. After dinner it rose again to 78. The tracings from Mr. B.'s pulse at the various pressures, and before and after the bath, have been given in Figs. 2 to 6. These show the gradual depression of the tidal and dicrotic waves, which is quite distinct at 6 lbs. pressure, but more marked still at 9 lbs. The influence of the stimulant, in addition to return to normal pressure, is shown, and the tracing taken on the following morning (6) is almost identical with the one before the bath (2), demonstrating the influence of the compression to have been purely temporary. In Mr. B.'s case the capillaries of the face were somewhat injected, but this may have been due to the heated air.

Respiration.—The number of respirations in Mr. S. was, before the bath, 16. Under 3 and 6 lbs. pressure, they rose to 18, but under 9 lbs. pressure, fell to 15. After dinner and wine they rose to 20. Mr. B.'s respirations, before the bath, were 15; under 3 and 6 lbs. of pressure they rose to 17, but at 9 lbs. fell to 16. After dinner they rose to 20. The relation of inspiration to expiration does not seem to have varied much.

Chest-Circumference.—Mr. S. decreased ½ an inch in girth at the nipple-line, noted during full inspiration and full expiration; while

Mr. B., on the other hand, increased an inch under both the above conditions.

The *spirometric observations* gave for Mr. S., before the bath, 250. Under each pressure there was a steady increase, reaching at 9 lbs., 286; after dinner, it fell to 262. Mr. B. also increased from 255 before the bath to 302 under the highest pressure, falling, after dinner, to 288. Undoubtedly, the overheated atmosphere interfered with some of the results, notably the pulse and respiration-rate; but the sphygmographic tracings and spirometric readings entirely agree with those made by von Vivenot on healthy subjects, and on the whole, confirm the conclusions previously arrived at.

Our principles of action in the treatment of disease by compressed air must be derived from its effects on the healthy organism; and we must bear in mind that its influence is by no means neutral, but productive of very decided results, beneficial or harmful as it is suitable or the reverse.

Now the action of compressed air on the human body is, mainly, twofold: mechanical and physiological—*Mechanical*, as shown first in its influence on the circulation. We have seen that it has an intro-pulsive agency, driving the blood from the surface of the skin and aërial mucous membranes into the deeper tissues, such as the muscles, bones, and internal organs, especially those wholly or partially protected from air-pressure by bony cavities, like the brain, the spinal cord, the heart, the liver, spleen, and kidneys, the uterus and ovaries. Now, it is obvious that its use is contraindicated in congestions, or hæmorrhages, or inflammations of any of these organs; and we have seen by the accidents occurring in the pneumatic tubes, and among divers, that very severe lesions of the brain and spinal cord follow excessive pressures, especially when quickly produced.

On the other hand, this intropulsion of blood may do good, by causing fulness and increased action of certain organs, such as the kidneys, the liver, the ovaries, the salivary and other glands, and by drawing away or deriving blood from the lungs and air-passages, when these latter are congested. Where there is fever, which means congestion of internal organs, this influence will aggravate it. Remembering the reduction of the number of pulse-beats, and the prolongation of the cardiac diastole, we may conclude that compressed air will benefit cases where congestion of the right side of the heart and of the liver is the chief feature.

Compressed air exercises a mechanical influence on the lung-tissue. Besides reducing the amount of blood in the bronchial passages and alveolar walls, it distends both the bronchi and the alveoli, especially those portions of the lung which, from not being penetrated in ordinary respiration, become partially blocked with secretions, and impenetrable to air at the ordinary pressures. This is proved by the appearance of the respiratory murmur, after compressed air-baths, in portions of the chest from which it has been absent for long periods; also by the diminution of dulness and the freer expansion of the chest-wall, and by an increased pulmonary capacity.

Physiologically, the introduction of more oxygen into the blood, thus supplying it with a richer combustion-element, may lead to more rapid tissue-changes, and is another reason against the use of compressed air in inflammatory affections; though it is, at the same time, a strong argument for its employment in all those affections where there is imperfect aëration of the blood, such as emphysema and chronic bronchitis. From these considerations we may expect benefits to accrue in old exudations of the pleura and lung, as in chronic pleurisy, chronic pleuropneumonia, and chronic pneumonia, where both the mechanical and the physiological influence of compressed air may be brought into play with great advantage. There

is another effect which I do not pretend to understand, which, nevertheless, has been noted in many of my cases, that is, a *sedative* influence on the nervous system, and especially on the nerves of the mucous membrane of the air-passages; compressed air subdues cough and bronchial spasm. From the mechanical effects, we should expect it to be beneficial in all catarrhal affections of the air-passages, such as laryngeal and bronchial catarrh and asthma, and it is in these affections that it proves most successful. As these are generally closely complicated with pulmonary vesicular emphysema, it will be convenient to consider the influence of compressed air on this disease, and then on the numerous conditions with which it is associated.

Emphysema.—We know that, in the tense or large-lunged variety of this affection, the thorax is distended to the utmost, the diaphragm is pushed down, the heart and liver are displaced downwards, the thoracic dulness of the latter generally entirely disappearing, and the impulse of the former being detected in the epigastrium. The breathing is shallow, and the dyspnoea great; percussion and auscultation teach us that the chest contains air, but that, owing to its being more or less stagnant, the blood does not get that perfect aëration which it requires, and consequently we see a dusky complexion, blue extremities, and sometimes a livid countenance. A course of compressed air-baths effects a wonderful change; after them the patient states he can breathe more freely, and can ascend steps and hills with greater ease. His cough and expectoration are decidedly reduced. The respirations are slower and deeper, the pulse is slower and firmer. Physical examination shows the thoracic distension to be diminished. The line of hepatic dulness, long absent, reappears, and rises to the normal level. Cardiac dulness is again detected, and the impulse is felt no longer in the epigastrium, but in the normal position between the fifth and sixth ribs. The excessive resonance gives place to something approaching the ordinary note; and, although prolonged expiration and wheezing sounds are heard, there is no longer the weird stillness formerly existing over large tracts of lung, for breath-sounds are audible in all directions, some healthy and some morbid.

Cyrtometric measurements show that the girth of the chest at various levels has diminished as much as from half an inch to two inches. Nevertheless, the vital capacity, as ascertained by the spirometer, is increased, and it would appear that most of these changes are more or less permanent.

Simonoff considers that the great improvement in emphysema is arrived at partly by raising the general standard of health and nutrition, and partly by preventing catarrh. He does not believe in opening up and developing healthy lung-tissue. It is not likely that actual development does take place, but some important change must occur to account for the above phenomena; and when we consider this result of the compressed air-bath, we can hardly regard vesicular emphysema as an invariably progressive disease, which is its usual description. The great improvement may be due partly to the presence of the condensed air on the bronchial vessels and muscle, whereby congestion and catarrh are reduced, and the muscular spasms allayed; but most of it must be owing to the healthy tissue being freed from obstructions, and rendered more available for respiratory purposes, and to the recovery of their normal dimensions by a large number of pulmonary alveoli, hitherto emphysematous; otherwise, how could we account for the diminished girth, the return of organs to their normal position, and the increased spirometric measurements?

Let us now take some illustrative cases.

CASE I.—William B., aged 41, bricklayer, admitted September 24th, 1884, fifteen years ago, had pleurisy, and had been subject to winter cough for many years, but enjoyed fair health till three years

ago, when he had severe bronchitis, and since then cough had persisted, accompanied, at first, by free expectoration, and dyspnoea on exertion. The breath had improved, but was still short; he had not lost flesh; cough was severe, expectoration scanty. Weight, 9 st. 6½ lbs; Pulse, 112; respirations, 24, shallow. *Physical Signs.*—Chest somewhat flattened, with little expansion, and superficial veins much enlarged. Excessive resonance in upper parts. Wheeze and sonorous rhonchi heard everywhere; some fine crepitation audible in the left interscapular region. No cardiac or hepatic dulness to be detected.

October 15th. Since last date, his cough had been more troublesome, and he had had nocturnal dyspnoea regularly. His breathing was always wheezy, and, although various forms of treatment had been tried, he was not relieved; he was ordered the compressed air-bath.

November 8th. After the fourth bath, felt his breathing much easier. Cough more moderate, and expectoration free.

		Pulse.		Respiration.		Temperature.
Before bath	...	108	...	18	...	98° Fahr.
After bath	...	86	...	12	...	98.4° Fahr.

November 12th. Sixth bath; pulse, respiration, and temperature records much the same as the last. Spirometric observations, before the bath, 159; after bath, 167.5; after the next bath (seventh) these rose to 181.5.

November 15th. Physical examination showed the chest resonant, but there was some cardiac dulness below the fifth rib on the left side, over a small triangular space, close to the sternum. Hepatic dulness was detected one inch above the lower border of the seventh rib on the right side. Inspiration was still wheezy, and expiration prolonged and musical. In the posterior regions there was more breathing, but still sonorous rhonchi. No crepitations were audible in the left interscapular region.

				Right.		Left.
Measurements at level of the						
third rib	...	...	...	18 in.	...	17½ in.
Measurements at level of the						
nipple	...	...	...	17½ in.	...	17 in.

November 24th. He had had ten baths. Cough not so distressing, and expectoration reduced since this treatment commenced; the patient felt he could take breath easier. Spirometer, 183. The wheezing sounds had ceased, and respiration was harsh, with prolonged expiration.

December 20th. The patient had had twenty-one baths; cough less, breathing easy; expectoration trifling. Breath on going upstairs was equal to what it was before the attack of bronchitis three years ago. He slept soundly, and there was no nocturnal dyspnoea. The pulse had generally fallen during the bath, and the respirations had diminished, occasionally to as low a number as 12. The temperature had not varied greatly, but had ranged between 97.8° and 99.6° Fahr., generally rising slightly in the bath.

				Right.		Left.
Measurements at level of the						
third rib	...	...	...	17¾ in.	...	16½ in.
Measurements at level of the						
nipple	...	...	...	17 in.	...	17 in.

This is a diminution at the upper level of one inch, and at the lower level of half an inch.

Chest is resonant; some cooing sounds were audible in both fronts; respiration was much freer, but sonorous rhonchus was present. Hepatic dulness 2 inches above the lower border of ribs on the right side; the heart's position the same as in last report. The patient was now suffering from a cold, caught four days ago, on going to the bath,

and his spirometrical standard, which had risen to 183, had fallen, since, to 156. Weight, 9 st. 12 lbs., showing a gain of $5\frac{1}{2}$ lbs. during his stay in the hospital.

The improvement in this case was steady and well marked. There was distinct diminution of the cough, entire disappearance of the nocturnal dyspnoea, and reduction in the amount of emphysema, as proved by the size of the liver and heart, and the diminution of the thoracic girth at various levels. The most remarkable feature was the rapid increase of the spirometric standard, unfortunately reduced later on by fresh catarrh; and, as the observations were taken very carefully, each result being the mean of three trials, they may be relied on as correct. Those taken before and after the sixth bath are also interesting, showing that a considerable increase of vital capacity may be due even to one bath. Judging by the above, and also by the patient's own statement, that his breath on ascent was as good as before the bronchitis three years ago, we may conclude that the improvement is likely to be permanent.

CASE II.—Frederick A., aged 10, was admitted November 5th, 1884. His father had phthisis; his mother suffered from chronic bronchitis; one brother died of bronchitis. The patient had whooping-cough seven years ago very severely, followed one year later by bronchitis, and had been subject to a winter-cough ever since, which continued all through last summer. He had lost flesh during the last two years. He complained of pain over the sternum, and had had attacks of vomiting lately. The cough was troublesome, chiefly at night, but there was no expectoration. The diagnosis was chronic bronchitis and emphysema.

Physical Signs.—Chest somewhat flattened under both clavicles. The cardiac impulse was felt in the epigastrium, and was altogether absent between the fifth and sixth ribs. Cardiac dulness commenced below the fourth rib on the left side. The whole chest was hyper-resonant, but breath-sounds were tolerably distinct everywhere; hepatic dulness was absent.

	Right.	Left.
Measurements at level of the third rib	11 $\frac{3}{4}$ in.	11 $\frac{3}{4}$ in.
Measurements at level of ensiform cartilage	11 $\frac{1}{4}$ in.	11 $\frac{1}{2}$ in.

November 11th.—He was ordered compressed air-baths.

November 12th.—He had had one bath.

	Pulse.	Resprtns.	Temp.	Spirometer.
Before bath	106 ...	28 ...	98° F. ...	82.5
After bath	80 ...	18 ...	98.2° F. ...	87.5

November 17th.—He had had three baths. Cough nearly gone. Hepatic dulness could be distinguished below the sixth rib, and, posteriorly, for a finger's breadth at the right base. On the left side, stomach-note was audible between the sixth and seventh ribs. The spirometer-observations gave 90. Pulse, respiration, and temperature about the same.

December 20.—He had had seventeen baths, and seemed greatly improved. He had lost cough and gained colour and one pound in weight. The pulse and respiration had steadily fallen in frequency, the former averaging between eighty and ninety, and the latter once reached as low as 14. After the seventeenth bath, they were as follows.

	Pulse.	Resprtns.	Temp.	Spirometer.
Before bath	90 ...	20 ...	98.4° F. ...	...
After bath	84 ...	16 ...	98.4° F. ...	90

	Right.	Left.
Measurements at level of the third rib... ..	11½ in.	11½ in.
Measurements at level of the ensiform cartilage	11½ in.	11 in.

showing a reduction of half an inch at the upper, and of a quarter of an inch at the lower level.

Physical Signs.—The chest was no longer over-resonant, and the note was fairly normal. Cardiac dulness could be detected as high as the third interspace; the impulse was felt in the normal position, and had disappeared from the epigastrium. Hepatic dulness could be detected, as at the last examination. The breath-sounds were fair everywhere, except in the lower posterior regions. The boy took two more baths, and left the hospital, January 5th, greatly improved.

REMARKS.—As no other treatment but the bath was used in this case, we may give it the credit of the reduction of cough, the large diminution of the emphysema, as evidenced by the smaller chest-measurements, the return of the organs to their normal positions, and the spirometric observations. Doubtless, the youth of the patient rendered him more susceptible to atmospheric influence.

CASE III.—C. D., aged 33, bricklayer, was admitted September 24th 1883. His father, mother, and brother died of phthisis. Three years ago, he was confined to his bed for six weeks with cough and expectoration, which had lasted ever since, and had lately been accompanied by shortness of breath on exertion. Expectoration had lately increased, and averaged about four ounces a day; and cough was troublesome, chiefly at night and on rising in the morning. Weight, 8 st. 5 lbs.

October 15th. Examination of the chest showed a well marked pigeon-breast malformation; great collapse of the lower portions of the chest beneath the mammæ. Heart's impulse visible in epigastrium on the left side of the ensiform cartilage. Cardiac dulness commenced below the fifth rib, about two inches from the line of the cartilages; hepatic dulness was altogether absent. The whole chest was over-resonant, and respiration was weak everywhere.

	Right.	Left.
Measurements at level of the third rib	17 in. ...	16 in.
Measurements one inch below the nipple-line	16½ in. ...	16 in.

Pulse 84; respirations 20. The diagnosis was bronchitis and emphysema.

November 5th. The patient had had two baths, and found his cough better, and the expectoration diminished. His breathing also was easier. After the second bath, the pulse fell from 108 to 96, and the respirations from 22 to 17.

	Right.	Left.
Girth at third rib	16½ in. ...	15¾ in.
„ one inch below nipple	15¼ in. ...	15¾ in.

Hepatic dulness could be detected below the seventh rib on the right side.

December 10th. He had had sixteen baths, and improvement continued. The measurements showed no great change; the right side, at third rib, 16½ inches; the left, 17 inches; at the ensiform cartilage, 15¾ inches at the right; and at the left, 16½ inches.

The patient continued to take baths until he had had thirty-eight, and always felt relief to his breathing during the bath and for some hours afterwards. For the last month of his stay in the hospital, he had no baths, on account of suffering from acute pleuro-pneumonia;

and complained much of the deprivation. The relief from them, though marked, was only temporary; but the prominent results—namely, reduction of pulse and respiration—were noticed throughout, although the chest-measurements gave a negative result. The rise of the diaphragm was shown in the increased area of hepatic dulness.

Chronic bronchitis is held by the Germans to be greatly benefited by the air-bath, the improvement being due to the increased pressure on the larger tubes causing diminution of the blood in the bronchial membrane, and consequently less exudation of serum into the coats of the bronchi; hence less pressure on the lymphatic system. Oertel finds this treatment to answer best in pure bronchial catarrh, but to be less effective when either emphysema is present, or the thorax is deformed, or again where the right side of the heart is dilated. My own experience is that the cough is quieted, and that the amount of expectoration is reduced. There appears to be an improvement in the muscular tone of the bronchial tubes; and this improvement may be due partly to the pressure on the vessels, and partly to the larger amount of oxygen supplied without effort. I do not hold with Oertel; for, in most of the cases of bronchitis under my care, emphysema has been present, and in some also, malformation of the chest, and yet all have considerably benefited by the compressed air-bath.

Subjoined is a case of chronic bronchitis and emphysema.

CASE IV.—Henry F., aged 48, shopkeeper, admitted September 19th, 1884. Sixteen years ago, he had sunstroke, from which he recovered in one year. He had had winter cough for fifteen years, which has been continuous during the last three, and had obliged him to relinquish work. In this period, he had been subject to nocturnal attacks of dyspnoea, occurring generally between 12 and 4 A.M. He had not lost flesh lately. The cough was exceedingly severe at night, and the effort produced sweating: the expectoration was abundant, thick, purulent, and contained no tubercle-bacilli. Breath was very short on exertion. Weight, 8 st. 9 lbs.

Physical Signs.—Chest over-resonant everywhere; no hepatic dulness to be detected; cardiac impulse perceptible in the epigastrium; and cardiac dulness was noted over a small triangular space, limited above by the upper edge of the fifth rib, and below by the seventh rib, and internally by the median line. Breathing was very feeble over the whole chest; some crepitation at the left base. Pulse 100, feeble, and at times irregular; respirations 24.

September 24th.—

	Right.	Left.
Measurements at level of the third rib	17 in.	16 $\frac{3}{4}$ in.
Measurements at level of the ensiform cartilage	16 in.	15 $\frac{1}{4}$ in.

The patient's cough was very severe, and in addition he had double inguinal hernia, and was so feeble that he was confined entirely to bed.

November 9th.—The cough had been reduced by treatment, but was still troublesome; he had a double truss for the hernia, which answered well. The expectoration was less. The appetite was very poor. Pulse about 100. The patient was now up and dressed. The nocturnal attacks of dyspnoea continued. He was ordered the compressed air-bath. Spirometric observations gave a mean of 67.5.

November 11th.—First bath:

	Pulse.	Respirations.	Temperature.
Before bath	100	32	99° Fahr.
After bath	80	30	98.6° „

Spirometric observations, 92.5° after bath.

November 15th.—He had had three baths, and no more attacks of nocturnal dyspnoea. He was improved in cough and breathing. After the last bath, the respirations were 28, and the temperature 98.6° Fahr. Pulse fell after last bath from 108 to 98. The patient was still too weak to walk to the bath, and was carried there and back. He had had phlebitis of the right forearm, which confined him to bed for one day. Since then he had been up, and had not missed any baths.

November 18th.—Spirometric observations had been taken twice since the 11th, and showed an increase, the last being 88 before the bath of to-day, and 94 after.

November 24th.—He had had seven baths, and during the last two had complained much of headache. The cough and expectoration had greatly diminished. The phlebitis was much better. There had generally been a reduction of pulse and of respirations after the bath, though the latter were always somewhat hurried.

Seventh bath :

	Pulse.	Respiration.	Temperature.	Spirometer.
Before bath	92 ...	32 ...	98.2° Fahr.	... 90
After bath	84 ...	28 ...	98.6° „	... 94

Strength was increased, and the patient could now walk to and from the bath.

	Right.	Left.
Measurements at level of the third rib... ..	16½ in. ...	16¼ in.
Measurements at level of the ensiform cartilage... ..	15½ in. ...	15¼ in.

showing a decrease at first level of one inch, and at second of half an inch.

Physical Signs.—Chest less resonant generally. Liver-dulness was now perceptible along the upper edge of the seventh rib. Cardiac dulness was detected between the left nipple and the sternum; the impulse was felt between the fifth and sixth ribs, beating very feebly, but some pulsation was still detected in the epigastrium, this indicating that the heart had returned nearly to the normal position. Respiration was clearer, and the breath-sound was tolerably free. Slight crackle was audible just below the right nipple.

December 8th.—After the seventh bath, the patient suffered so much from headache, that the treatment was discontinued, and four days later the headache ceased. He was leaving the hospital improved in every respect, and had gained in weight. Measurements and spirometric observations gave the same result as after the last compressed air-bath.

REMARKS.—This was a well marked case of chronic bronchitis, in which acute symptoms had supervened; but the complication of the double hernia, and his great feebleness and extensive emphysema, rendered it doubtful if any benefit could be expected from the compressed air treatment. The return of his strength was, perhaps, as remarkable as his improvement in cough and breathing; and it was unfortunate that the headaches caused by the compressed air stopped the use of it. The increase in the spirometric measurements after the first bath was very great.

LECTURE III.

COMPRESSED air has been largely used in Sweden in the treatment of *whooping-cough*. Sandahl found that, in 102 cases among children, 88, or 86 per cent., were cured by a course of baths varying in number from nine to twenty, the only exceptions being cases complicated with phthisis; and Oertel confirms this experience, and assigns the beneficial effect to a reduction of the sensitiveness of the laryngeal nerves, and to the larger supply of oxygen to the lungs, enabling the sufferer to combat more successfully the suffocating cough.

Spasmodic asthma experiences great relief from this treatment; and some authors state that this is only the case in the catarrhal form, where the paroxysms are accompanied by swelling of the mucous membrane and congestion of the vessels; and that the benefit comes from the bronchi being dilated and the hyperæmia reduced. While admitting that the catarrhal form is greatly relieved, I strongly affirm that pure neurotic asthma often receives instant relief in a compressed air-bath, and that all cases of this malady benefit more or less largely. I annex a fair example, which was complicated with emphysema. The first effect of the air-bath is often transitory, and in some cases it is always so; but in most a series of sittings reduces the severity of the attacks, and lengthens the intervals of freedom. It is, however, from the diminution of the emphysema that the asthmatic patient obtains most relief, as it enables him to take more exercise, and to carry on the functions of digestion, assimilation, and respiration with greater ease and comfort, and thus to gain strength and colour. Out of six cases of spasmodic asthma submitted to this treatment, the number of baths varying from eight to twenty-four, four were greatly improved, two were improved, and in one—a case where the asthma was complicated with anterior sclerosis of the spinal cord—there was no improvement.

CASE V.—John H., aged 23, footman, was admitted into my wards June 4th, 1884, with a history of acute bronchitis five years previously. He had had winter-cough ever since. Four years ago, asthmatic attacks began, and had continued once a month ever since. These commenced in the middle of the night, and lasted three or four days, in the intervals the patient remaining tolerably free, and his breath not being short on exertion; cough and expectoration moderate; loss of flesh to the extent of several pounds before admission. On admission, the chest was found to be over-resonant, and sonorous rhonchi were audible everywhere. Weight, 8 st. 12½ lbs. The diagnosis was asthma and emphysema. He had an attack of asthma on June 16th, lasting three days.

June 23rd.—I carefully examined him, as he had been free from spasm for some days.

Physical Signs.—The chest was flattened on both sides to the level of the mamma. Below this point there was considerable collapse, and the lower parts moved more freely in respiration than the upper. Percussion-sound was hyper-resonant over the whole thorax. There was no hepatic dulness, and scarcely any cardiac. The heart was displaced

downwards, cardiac impulse perceptible at the epigastrium, but also between the sixth and seventh ribs in the vertical mammary line. The heart-sounds were normal; breath-sounds feeble everywhere. Measurements on deep expiration

	Right Chest.	Left Chest.
At level of third rib	17 $\frac{3}{4}$ in.	17 $\frac{3}{4}$ in.
At level of ensiform cartilage	15 $\frac{1}{2}$ in.	15 $\frac{1}{2}$ in.

Pulse 84, respirations 28. He was ordered compressed air-baths three times a week.

July 1st.—He had had four baths, at a pressure of 8 lbs. During each, the pulse and respiration had fallen; there was more movement of the ribs.

	Pulse.	Respirations.
Before bath... ..	96	32
After bath	64	28

July 11th.—He had had another attack of wheezing, and the bath had been omitted for four days. To-day he took his seventh bath, with great relief to his breathing.

	Pulse.	Respirations.	Temperature.
Before seventh bath	84	32	98.2° F.
After ,,	60	12	98.2° F.

July 25th. The last attack of asthma lasted a shorter time than usual. The patient had now had twelve baths; in each there had been reduction of pulse and of respiration. In one, the pulse fell from 72 to 56, and showed some irregularity; the pressure was 9 lbs. On examination of the chest, some hepatic dulness was detected in the last interspace on the right side. The heart's impulse was less perceptible in the epigastrium; chest still over-resonant, breath-sounds feeble everywhere. Measurements showed a diminution of girth at the level of the third rib of three-quarters of an inch, and, at the ensiform level, of a whole inch. After several baths, he complained of frontal headache, but this might be partly due to the temperature of the bath, which, owing to the hot weather, often rose to 76° Fahr.

The patient remained in the hospital till September 24th, and had altogether seventeen baths, with the same results. The influence on the respiration was to reduce its frequency, in one instance from 32 to 12 in a minute, and the patient stated that he always breathed deeper and more easily while in the bath, and for several hours afterwards. He has had no return of the attacks during the last six weeks, and says his breathing is 'greatly improved; no cough or expectoration. The reduction of the pulse on several occasions has been most extraordinary, and once it fell to 40, with a fair volume. As a rule, it is about 70.

Measurements taken September 20th showed a further decrease at the level of the third rib of three-quarters of an inch, and an increase of three-quarters of an inch at the ensiform level, giving a total decrease at the upper level of an inch and a half, and, at the lower, of a quarter of an inch. There was now more costal breathing, and the chest appeared somewhat less flattened. The area of hepatic dulness was the same, but some cardiac dulness was now perceptible below the sixth rib. The chest was generally less resonant, and respiratory sounds were more audible than on admission. The patient had gained five pounds in weight.

We may conclude that, in this case, the compressed air exercised a sedative influence on the pulmonary plexuses and bronchial muscle, and thus the asthmatic attacks became fewer. This enabled the lung-tissue to recover some of its normal tone, and much of the emphysema, being of a temporary character, disappeared, giving rise to freer respiration, smaller girth of chest, and the return of dis-

located organs to their proper position. The decrease of girth of the upper portions of the chest was very marked; but the decrease at first, and slight increase later, of the lower portion, seemed to point to a diminution at first, and afterwards a slight increase, of emphysema at that level.

The use of compressed air has been recommended to promote the absorption of *lung-consolidations and infiltration*, such as remain after pneumonia and pleuropneumonia. It is urged that these exudations may be partly resolved and absorbed under the combined mechanical and physiological influence of this agent, and that air may penetrate to the bases of lungs either consolidated or crippled by adhesions, and undergoing fibrosis. I have tried this treatment in several cases where pleuropneumonia, or pleurisy, have left such consolidations; and although I carefully investigated the patients while undergoing the course, I never succeeded in discovering any signs of the disappearance of these lesions under the treatment. Again, Simonoff recommends its use in *acute pleurisy*, after the inflammatory processes have disappeared; first, to expand the lung; secondly, to overcome the thoracic deformity; thirdly, to promote reabsorption. Oertel maintains that serous exudations are readily absorbed under the influence of compressed air, but purulent exudations more slowly. My experience is to the effect that it exercises no influence in expanding a lung compressed by fluid, and that, even during a course of air-baths, steadily persevered in, the fluid will reaccumulate, and will make its presence known both by physical signs, and by the diminishing amount of vital capacity, as tested by the spirometer; and I find that Sandahl's experience at Stockholm entirely confirms mine. The next is a case to illustrate this.

CASE VI.—John M., an engine-driver, aged 28, was admitted into Brompton Hospital, October 4th, with an obscure history of cough and shortness of breath of some weeks' standing. On examination, the right chest was found dull throughout, with entire absence of vocal fremitus and breath-sound. The dullness extended slightly across the median line to the left side, and the heart's impulse was felt beating about half an inch further to the left than normal. The chest-measurements were, at the level of the nipple, right, 18 inches; left, 16½ inches. On October 14th, the patient was tapped in the sixth space (mid-axillary line) with a Southey's trocar and tube, and 66 ounces of clear serum removed, the tube being left in nine hours. Six days after the tapping, the measurements at the nipple were, right, 17 inches; left, 16½ inches, showing a diminution of one inch. The heart returned to its normal position, and breath-sound was audible in portions of the right lung.

November 4th. The patient stated his breathing to be easier, and the measurements showed no reaccumulation of the fluid. The physical signs were, dullness diminished over the whole right front; vocal vibration present; and puerile breathing heard over the inner half of the same region. Posteriorly, dullness was somewhat decreased, and breath-sound was audible in the interscapular and suprascapular regions, vocal vibration being absent. Measurements as before. He was ordered the compressed air-bath. The spirometer indicated 107. The result of the first bath was as follows.

	Pulse.	Respirations.	Temperature.
Before bath...	140	28	100° F.
After bath ...	106	22	99° F.

After the eighth bath, on November 21st.

	Pulse.	Respirations.	Temp.	Spirometer
Before bath ...	110	28	98.4° F.	—
After bath ...	108	24	98.4° F.	99

November 24th. The dulness had again increased and the breathing diminished over the front and back of the chest; vocal vibration was entirely absent; oëgophony was audible in the scapular region. The measurements were, right side, $17\frac{1}{2}$ inches; left side, $16\frac{1}{2}$ inches; an increase of half an inch.

On November 28th, he was again tapped with Southey's tube, and 49 ounces of serous fluid withdrawn, and the measurements then showed a reduction of half an inch.

November 29th. The patient was relieved by the operation, and the physical signs showed resonance from the clavicle to the nipple, with a fair amount of breath-sound. Posteriorly, the resonance reached as low as the eighth dorsal vertebra; below there was dulness; breathing was heard more or less to the base. Spirometer, 111.5.

On December 10th, the air-baths were resumed, and he had five, making thirteen in all. The result of the thirteenth bath is seen below.

	Pulse.	Respirations	Temperature
Before thirteenth bath	64	22	98.8° F.
After ,,	58	16	99.4° F

December 20th. Physical signs showed that the fluid had again accumulated, and the dulness reached up to the third rib. Measurements: right, 17 inches; left, $16\frac{1}{2}$ inches; spirometer, 98.

January 2nd, 1885. He was again tapped, and 46 ounces were withdrawn; and, on the 12th, the measurements were, right, $16\frac{3}{4}$ inches, left, 16 inches. There was some flattening on the right side, and the right nipple appeared lower than the left. Breathing was again more audible, and dulness diminished.

January 26th. Much improved. There was dulness now only below the nipple, and good breathing above.

The course of this case plainly shows that the steady perseverance with the compressed air-bath exercised the usual influence over the pulse and respirations, both being considerably lowered: but that it had no effect whatever in preventing the reaccumulation of the fluid, which occurred twice while this treatment was going on, and showed itself, not only by the increase of the measurements, and the physical signs, but also in the diminution of the spirometric results. These gave an increased vital capacity after each tapping, but no increase during the baths.

Phthisis.—Some authors loudly extol the use of the compressed air-bath in phthisis. Oertel considers its proper use in this disease more important than climatic influence, and particularly advises its employment in the early stage. Simonoff states that absorption of the inflammatory exudations in the lungs of phthisical patients takes place in the baths, and has noted the distinct diminution of physical signs. He maintains that, where the maximum day-temperature does not exceed 100.5° Fahr., there is always considerable improvement, and complete recovery in about one-third of the cases. He admits that in cases where the maximum exceeds 102° Fahr., he has seen no instance of recovery; but, in a quarter of the cases, improvement takes place. This experience is far more favourable than what I have seen of the use of the bath in phthisis would lead me to expect. Considering that phthisis is a disease characterised by malnutrition, imperfect power of digestion and assimilation, and by a separate diminished number of red corpuscles in the blood, we may fairly expect that the physiological or chemical effects of compressed air will be beneficial, by stimulating these processes of sanguinification. The mechanical effects might act beneficially in reducing the amount of blood in the bronchial vessels, thus removing a certain amount of local congestion. Moreover, the pressure of the air may be the means of opening up portions of the lung not actually affected with tubercle, but simply collapsed, or with bronchi

stopped by mucous accumulations; but we can hardly expect compressed air to have any specific influence on the tuberculous masses themselves, nor can it, by its increased pressure, open up alveoli already invaded by tuberculosis. I have as yet submitted only six consumptives to the air-bath, but intend to make a trial on a larger scale. All six were cases of first stage, except one, in which there was a cavity. All manifested reduction of pulse and respiration rates during the baths; all showed general improvement; and in five there was gain of weight—one gained more than a stone in two months; in one (the cavity-case) there was decrease of weight. In two, the phthisis was combined with emphysema; in two others, with pleuropneumonia. In the cases of phthisis and emphysema, the circumference of the chest diminished, as in the other cases of emphysema. In the cases of phthisis and pleuropneumonia, the circumference of the chest showed no increase, in the regions affected by pleuropneumonia, under the compressed air-treatment, but rather the reverse, the natural collapse of the side which is noticed in these cases apparently taking place unchecked by the mechanical effects of compressed air. In one case (George E.), there was a decided enlargement, and the physical signs gave evidence of hypertrophy of the healthy lung, with some diminution of dulness in the affected one. Cough is usually lessened, and expectoration reduced; and the patient invariably reports that he can breathe with greater ease and more deeply. As I have avoided this treatment in pyrexial phthisis, fearing the increased oxidation, I cannot speak as to results in any but those cases where the temperature was either normal or subnormal; in these, the effect has been a slight rise of half a degree or so. In three of the patients, hæmoptysis of considerable extent occurred, all having previously spat blood. In one case, the bleeding came on five weeks after the last bath, and therefore can hardly be attributed to it; in another, it occurred twice during the course, with intervals of only forty-eight and of twenty-four hours after a bath; in the third case, two days after. In the last two, the bath seems to have had a causal relation with it. Considering this danger, therefore, the use of the bath appears to be contraindicated in cases of hæmorrhagic phthisis, and in all cases where cavities are present, as we know that it is common to have aneurysms of the branches of the pulmonary artery lying exposed on the walls of these, and thus, under the influence of changes of barometric pressure, rupture of the said aneurysms may take place. The great good we may expect from compressed air in phthisis is from the physiological influence, showing itself in improved nutrition, increased oxygenation, leading to augmentation of colour and weight, and from the mechanical effect manifested in the reduction of local congestion, and, above all, in the opening out and inflation of those portions of the lungs which are commonly the first point of tubercular attack—namely, the apices. In this aspect, we may regard compressed air-baths as a valuable prophylactic agency.

CASE VII.—George E., a labourer, aged 46, was admitted September 29th, 1884. His father and two brothers died of consumption; one surviving brother was consumptive. Gout commenced nine years ago, affecting the right great toe, followed by six attacks progressing in severity. Cough commenced eighteen months ago, and had continued ever since. He had had hæmoptysis several times; the first attack, which was profuse, three months ago. He had lost flesh for seven months. The patient was thin, and sallow. Conjunctivæ slightly yellow. Weight, 8st. 12lbs.

The physical signs showed consolidation of the left apex, with some friction-sounds at the base.

November 8th. During the last month, he had suffered much pain

in the lower left chest, where friction-sounds had been occasionally heard. The pain disappeared on the side being strapped.

Physical Signs.—Left chest: some dulness, with tubular sounds from the clavicle to the third rib; breathing and resonance good from the third to the fifth ribs, below which there was marked dulness and absence of breath-sounds. Posteriorly, there was some dulness, and tubular sounds were audible above the scapula; resonance and breath-sound were fair below. Measurements at the level of the third rib gave $6\frac{1}{2}$ inches on both sides; at the ensiform level, 16 inches on each side. He was ordered the compressed air-bath.

November 12th. He had had two baths.

	Pulse.	Respns.	Temp.	Spirometer.
Before second bath ...	100	... 36	98.2° F.	... 142
After ,, ...	96	... 30	99.2° F.	... 136

After the third bath, the spirometer rose again to 142.

November 26th. He had had eight baths, and felt better; cough and expectoration were less, and he had gained 12 lbs. in weight.

	Pulse.	Respirations.	Temperature.
Before eighth bath ...	112	... 36	99.4° F.
After ,, ...	98	... 22	98.2° F.

At 7.30 to-day, about twenty-seven hours after the last bath, he had hæmoptysis to the amount of three ounces.

November 28th. The hæmoptysis had ceased, but he brought up altogether eleven and a half ounces. No more baths were allowed. Beyond the bleeding, the patient did not appear any worse. There was no increase of cough or expectoration, and both pulse and temperature were the same as before.

He remained in the hospital till December 29th, and steadily improved, gaining up to 10 st., so that there was an increase of 1 st. 2 lbs. since admission.

On December 22nd, the measurements were as follows: at the level of the third rib: right, 17 in.; left, $17\frac{3}{4}$ in.; giving an increase of three-fourths of an inch; the measurements at the lower level were the same as before.

The right chest was more resonant than before; breathing harsh throughout; slight crackle was audible at the front base, where hepatic dulness was very manifest. In the left chest, the dulness had greatly diminished between the first and third ribs; tubular sounds were audible over the same area; dulness at the base was unchanged.

This case is instructive as showing (1) the large increase of weight under the baths; and (2) the danger of inducing hæmoptysis in cases where it has previously occurred. The result of the chest-examination is of great interest; for we learn that expansion of the upper portions of the lungs took place, the lower parts remaining unchanged. The increase of resonance in the right chest, and the diminution of dulness at the left apex, point to the conclusion that some hypertrophy of the right lung took place, and possibly some localised emphysema in the upper lobe of the left, the consolidation at the left base remaining as before. The spirometric observations gave negative results; but the air-bath seems to have had an excellent effect in quieting the cough and reducing the expectoration.

Anæmia.—Compressed air has been much recommended in this disease, with the view of its physiological effects in supplying a larger percentage of oxygen in the same bulk, and thus increasing the number of red corpuscles. I have tried it in two cases of chlorotic girls. In one, aged 21, a well marked anæmic murmur disappeared after twelve baths. In the second, aged 22, the pallor, short breath, palpitation, and rapid pulse, were accompanied by a very loud anæmic murmur. After a course of fifteen baths, the murmur nearly disap-

eared; the hæmacytometer showed a considerable increase in the number of red corpuscles, the patient gaining colour very perceptibly, as well as flesh and strength. All palpitation ceased, and the pulse and respiration fell in frequency. At the same time the chest became wider, and the spirometer showed an increase of vital capacity. In both cases, the dietary was the ordinary one of the hospital, and no special additions were made.

Amenorrhœa.—Sandahl cites several cases of long standing cured after a short course of compressed air-baths, and in both recent and chronic instances strongly urges their use, the principle being that the blood is determined towards the protected female organs of generation, and gives rise to the menstrual discharge.

Chronic Catarrh of the Ear has been often successfully treated by this method at Johannisberg and Stockholm. In many cases, the deafness disappears during the bath, but returns on leaving it. The benefit consists in the dilatation of the Eustachian tube by the pressure of the condensed air, and the reduction in the congestion of the pharynx and nasal passages. For the same reason, all catarrhs of the air-passages, whether of the nares, anterior and posterior, larynx or bronchi, are greatly reduced, and sometimes cured, by a few sittings in the air-bath.

The use of the bath seems to be contra-indicated in the following conditions, either by reason of its intropulsive effect on the blood, or by its physiological influence on the system: pyrexia, hæmorrhage, diseases of the brain, spinal cord, heart (except dilatation of the right cavities), kidneys, spleen, liver, intestines, uterus, and ovaries (except amenorrhœa). In this list I would except those conditions of organs which are due to simple anæmia, where the intropulsion of the blood may do good.

The number of baths requisite to produce a decided result varies with the disease, and generally with the length of its duration; and, although in some of my cases even a few baths have given relief, to produce lasting effects a course of from thirty to sixty, and even to one hundred, is often necessary. This is specially the case in asthma, emphysema, anæmia, and phthisis. It may be asked, Are the effects ever permanent, or are they only temporary? The short time the Brompton Hospital bath has been opened precludes my speaking with certainty; but the medical men at the large establishments of Stockholm, Reichenhalle, and Paris offer strong testimony to the beneficial influence lasting for years.

I am much indebted to my clinical assistants, Drs. Priestley and Slater, for the careful notes of the cases under treatment by the air-bath.

