

Smith, Andrew H

# OXYGEN GAS

AS A REMEDY IN DISEASE.

---

"He breathed into his nostrils the breath of life, and man became a living soul."

---

## CHAPTER I.

### HISTORY.

THE therapeutical history of oxygen dates almost from the moment of the discovery of the gas. A few months after he had succeeded in demonstrating oxygen as a separate principle, Priestley discovered its relation to animal life. He found that a mouse confined in a limited quantity of this gas lived at least twice as long as in a like quantity of common air. This fact led him at once to the suggestion that this agent might be usefully employed in cases of disease in which there was deficient vitality. At the same time, the effect of plunging a burning body into oxygen inspired him with a misgiving that oxygen could not be inhaled to any considerable extent without danger of exciting excessive action in the system, that the patient would "*live too fast*"—a phrase which, down to the present day, never fails to rise to the lips of the practitioner to whom this therapeutic measure is suggested for the first time. Thus early were the possible remedial uses of this

agent foreseen, and, at the same time, an erroneous idea advanced, which has maintained its hold upon the professional mind, and prevented much good which might otherwise have been attained.

During the fifteen or twenty years following the discovery of Priestley, attention was directed more to the physiological and chemical relations of oxygen than to its use as a remedy. The part played by it in the animal economy was made the subject of investigation by Spallanzani, Fontana, Barthollet, Lavoisier, and others. To Lavoisier belongs the credit of first demonstrating the composition of the atmosphere, and the changes produced in the blood by respiration. Following in his footsteps, Spallanzani showed that the consumption of oxygen was in direct ratio to the muscular activity of the animal. For instance, he found that the chrysalis consumed an exceedingly small amount, the caterpillar a much larger proportion, while the active *imago* demanded a very large quantity for its support.

These researches led to the grand discovery that the new element was the only one, a constant supply of which was necessary for the continuance of life. Food and drink could be withheld for days; even the nitrogen of the atmosphere could be excluded for hours, and yet no serious injury would result. But the animal *began to die* from the instant the supply of oxygen was cut off. No other element stood in this relation to life. No wonder, then, that it was called *vital* air, and that its discovery was thought to have begun a new era for humanity.

The first case in which oxygen was actually employed as a remedy was one reported by Caillens, in 1783. I can find only a reference to this case, which was published in the *Gazette de Santé*. But, in the year following, Jurine, of Geneva, published an essay, in which he cites, at some length, a case of phthisis in a young lady, which was very much benefited by daily inhalations of oxygen. In 1789 Chaptal, of Montpellier, reported two cases of phthisis, in one of which the gas produced great relief while its use was continued, but in the other the effect was not beneficial.

At about this period the French Government desired an

expression of opinion from the Academy upon the value of oxygen as a remedy, and Fourcroy was selected to prepare a report. In this report, and in other works which followed, he resigned himself to a current of speculation which drifted him far away from the truth. He saw the effect of oxygen in the action of every remedy, even of muriatic acid, the composition of which was not then known. He claims to have employed oxygen in a considerable number of cases of phthisis, and to have noted a rapid improvement for two or three weeks, after which a violent inflammatory action was set up, and the progress of the disease was greatly accelerated.<sup>1</sup> But his subsequent experiments on animals, in which he describes a state of fever occurring, which eventuated in gangrene of the lungs, lead to the suspicion that the gas which he employed contained some irritating impurity which the imperfect chemistry of the day did not enable him to discover. He became, nevertheless, the founder of a school which interpreted all therapeutical effects by the supposed relation of the agent employed to the oxygen of the system. But it was not until Beddoes began his observations that any valuable practical results were obtained.

In 1789 Beddoes published his book entitled "Considerations on the Factitious Airs." He was at that time Professor of Chemistry at Oxford, but none the less devoted to the practice of medicine, in which he had already attained a high position. To him belongs the credit of being the first to approach the subject without a theory to sustain. It was not until he had accumulated a large number of facts that he attempted to arrange and classify them. His attempts at generalization were not always attended with the happiest results; but the readiness with which he relinquishes a theory the moment it is found to conflict with fact, gives a rare impression of candor and impartiality to his work. The scope of the work includes observations upon several gases besides oxygen, especially carbonic acid and hydrogen.

His physiological experiments are of great interest. The principal results which he arrived at were the following:

Oxygen produces a remarkable power of resisting asphyxia.

<sup>1</sup> Annales Chimie, 1789.



It appears that, when the blood contains an unusual amount of oxygen, the animal is better able to support a deficiency of respirable air, or even the presence of an irrespirable gas.

Animals which have respired oxygen resist longer the action of frigorific mixtures.

The action of oxygen seems to be localized principally in the muscular system.

Oxygen is in the highest degree a stimulus to the irritability of the heart and blood-vessels.

The last conclusion is one which succeeding observers will scarcely indorse to the fullest extent. As a stimulant to the circulation, oxygen is certainly far inferior to alcohol; indeed, in many cases, its stimulating effect is scarcely perceptible.

A few isolated cases of success in the therapeutic use of different gases encouraged Beddoes to set on foot the project of a Pneumatic Institute, in which this mode of treatment could be tested on an extensive scale. The plan enlisted the coöperation of Sir H. Davy, who gave himself with ardor to the chemical part of the work, and of the eminent engineer James Watt, whose genius left nothing to be desired in the mechanical appliances for administering the gas. Probably a more brilliant triumvirate was never combined in the furtherance of a scientific object.

In pursuance of their plan, a building was erected by public subscriptions. It contained small compartments, the atmosphere of which could be charged with any desired gas. In these rooms the patients were allowed to pass a certain time daily.

The principal results obtained by the use of oxygen are summed up in the following table, from a review of Beddoes's work which was published in the *British Library*:

CASES TREATED.	Cured.	Relieved.	Not benefited.
Obstinate Ulcers .....	2	2	..
Leprosy (?) .....	5	..	..
Spasms .....	3	2	..
Gutta Serena .....	..	2	3
Chlorosis .....	5	2	..
Epilepsy .....	1	..	5
Asthma .....	10	9	3
Cancer .....	..	3	..
Dropsy of the Chest .....	2	1	1
Hypochondria .....	..	1	..
Dyspepsia .....	3	1	..
Dropsy .....	2	1	1
Hydrocephalus .....	..	1	..
Headache .....	2	2	..
Poisoning by Opium .....	1	..	..
Paralysis .....	2	1	1
Scrofulous Tumors .....	2	1	..
Deafness .....	1	..	..
White Swelling .....	1	..	..
Scorbutus .....	1	..	..
Venereal .....	1	..	..
Melancholy .....	1	1	..
General Debility .....	1	..	..
Continued Fever .....	1	..	..
Intermittent Fever .....	1	..	..
Coldness of Extremities .....	1	..	..
Total .....	49	30	14

It will be observed that no cases of phthisis are included in this table. The explanation of this is to be found in the peculiar views entertained by Beddoes as to the relation of oxygen to this disease. Accepting without question the reports of Fourcroy as to the ultimate acceleration of the disease by oxygen, he framed the theory that in phthisis there was a change, either in the constitution of the blood or in the substance of the lung, that favored the absorption of oxygen, which was therefore already present in excess. For this reason he considered oxygen as absolutely contraindicated.

In scorbutus, on the contrary, he supposed that there was a deficiency of oxygen in the system, which he thought should be supplied by artificial means.

The labors of Beddoes did much toward establishing the true position of oxygen as a therapeutic agent. They demonstrated, on the one hand, that the ideas at first entertained as to its curative power were extravagant, and, on the other, that it

was an agent capable of producing good effects in many cases not reached by ordinary means. The number and variety of diseases in which the treatment was found beneficial suggest at first sight a certain air of charlatanism, but subsequent observers have corroborated nearly all his statements. Nor, when we consider the physiological relations of oxygen, is it more surprising that its use should be applicable to a large range of cases than that modification of diet should be beneficial in so many diverse diseases.

It is very remarkable that results as satisfactory as those obtained by Beddoes should not have led to a more general adoption of the treatment. But, with the exception of Hill and Thornton, who were contemporaries rather than successors of Beddoes, scarcely any British physician seems to have become interested in the matter, and it was allowed to die out with its original promoters. This was doubtless largely due to the difficulties which then beset the production of the gas, and its transportation to the bedside of the patient. Chemical manipulations were then but little understood, and chemical apparatus was very imperfect. Caoutchouc was unknown, and this simple fact alone would have made that very difficult which is now extremely easy. Indeed, when we consider the part which this substance now plays in the manipulation of the gases, it is not too much to say that its introduction was a necessary preliminary to their general use as remedies.

While Beddoes was carrying on his observations in England, the therapeutic use of oxygen was exciting no little attention in Germany. Numerous experiments and observations were made during the decade preceding the opening of the present century. Prominent among them were those of Girtanner, who, following in the footsteps of Fourcroy, gave arsenic dissolved in nitric acid for a large range of complaints, under the impression that the solution imparted oxygen to the system. He was charmed with the effects of *oxygen* given in this way in *intermittent fever*. In the midst of similar speculations and theories, which seem to have taken the place, for the most part, of observations on the practical use of the gas itself, it is not surprising that little real progress was made in determining the true value of the latter.



At Geneva, however, the use of oxygen fell into more practical hands. The results obtained by Jurine served to encourage others. Odier, then a prominent physician at Geneva, took up the new treatment with great zeal, and the *Society for the Advancement of the Arts and Sciences* caused the founding of an institution similar to that of Beddoes. But, as in the former case, this was short-lived, and with its decline the whole subject of the medicinal use of oxygen sank into oblivion. The frightful epidemic of cholera in Europe, in 1832, brought it again into momentary notice, but, as it failed to answer the expectations of those who employed it, it relapsed into its former obscurity.

It is only within the last fifteen years that any serious attempt has been made to bring this agent again into use. Dr. Riadore, it is true, published some observations upon its use in 1845, recommending it in cases of indigestion, debilitated conditions of the liver and kidneys, nervous affections, asthma, etc. But his cases were not numerous or striking, and failed to arouse the attention of the profession.

\* In 1857 appeared the first edition of a work on Oxygen, by Dr. S. B. Birch, of London. I have not been able to procure a copy of this edition, and the second, issued in 1868, seems nearly a new work. The writer claims to have presided at the *renaissance* of oxygen, and takes to himself the credit of having instigated all that has been done in the past few years to place its use on a solid foundation. His book consists of a selection of cases, preceded by some general remarks upon the properties and uses of oxygen, its *modus operandi*, etc. His ideas with regard to what he styles the *quasi-nascent* condition of oxygen are very peculiar, and are not borne out by the experience of others. Moreover, his style is singularly obscure, and his book lamentably lacking in practical directions for the administration of the remedy. While constantly insisting upon the necessity of *judiciously* selecting cases for treatment, of *judiciously* administering the gas, and of the *judicious* use of adjuvants, etc., he does not give a single practical rule for determining what is judicious in the premises. The cases which he publishes are very striking, one might almost say, marvellous; and the impression

which the work as a whole is calculated to make upon the reader is that, in the hands of the author, oxygen is almost a panacea, while at the same time it would be hopeless for the general practitioner to attempt to grapple with a treatment so intricate, and demanding such peculiar skill.

In sharp contrast with this work is the article on Oxygen in Demarquay's *Essai de Pneumatologie Médicale*, published at Paris in 1866. A little too diffuse, perhaps, it is still plain, simple, and to the point. The author tells his story as of one who has studied the literature of the subject, made some experiments himself, and treated quite a number of cases by the use of oxygen, sometimes successfully, sometimes not. With reference to its use in some diseases, while giving the experience and opinions of others, he states frankly that he has had no experience himself, and does not feel competent to judge of its merits. While it appears to me that some of his experiments on the physiological effects of the gas are defective, yet, others are novel and extremely valuable. His article is marked by perfect candor and frankness throughout, and is by far the best treatise upon the subject extant.

Dr. Hermann Beigel, in his work on Inhalation, published in London in 1866, presents a few considerations upon the use of oxygen, and cites a number of cases from his practice, in which he has used it with more or less benefit. He invented an apparatus for the production of the gas, according to Fleitmann's process, from the chloride of lime. His treatment of the subject is candid and unpartisan, and his conclusions demand respect.

A new era in the history of oxygen is being inaugurated by the invention of Téssie du Môtay, by means of which the gas can be produced in immense quantities from the atmosphere, and at an insignificant cost. Its possible future in relation to medicine and hygiene can as yet be only dimly discerned. When we shall be able to regulate the proportion of oxygen in the atmosphere of the sick-room as easily as we now regulate the temperature; when closely packed and ill-ventilated tenements can be supplied with this element, the free enjoyment of which is necessary to health; when by its use the contamination of the atmosphere by the furnaces of



factories and machine-shops shall be prevented or counteracted, who can tell what will be the sum-total of the result? Yet all this seems now attainable whenever the public shall become sufficiently awake to its importance.

## CHAPTER II.

### MODES OF PREPARATION AND ADMINISTRATION.

IN the preparation of oxygen for medical use, *purity* is, of course, of the very first importance. Undoubtedly many of the effects formerly attributed to oxygen, such as the production of bronchial irritation or inflammation, and even of pneumonitis, were owing to impurities in the gas employed.

The first substance from which oxygen was isolated was the peroxide of mercury, and in all the earlier experiments the gas employed was obtained from this source. It was not long, however, before cases of ptyalism occurring, warned experimenters of the danger of using the oxides of mercury for this purpose.

Chaptal showed, by carefully-conducted experiments, that oxygen so prepared contained an appreciable quantity of the metal. The peroxide of manganese was then substituted, and finally chlorate of potash.

Recently quite a number of processes have been added to the list, so that it now embraces a large range of procedures by which oxygen may be obtained with more or less facility. I will touch briefly upon the more prominent of these, only one having been found by experience to be really adapted to the use of the physician :

1. Decomposition of binoxide of manganese. This is accomplished by heating the oxide to a red heat in an iron retort, or by treating it with sulphuric acid. In the first case a high heat is required, and in the second the acid is disagreeable, and dangerous in general practice. Moreover, the gas contains four or five per cent. of nitrogen from the impurities usually contained in the manganese. If commercial acid is used, it also imparts its impurities to the gas, and among them usually a certain proportion of arsenic. These considerations

have led to the complete abandonment of this method in practice.

2. The decomposition of sulphuric acid, or sulphate of zinc. This process depends upon the decomposition of sulphuric acid by heat into oxygen and sulphurous acid, or that of sulphate of zinc into oxygen, sulphurous acid, and oxide of zinc. It is probable that oxygen could be produced in large quantities in this manner at a very small cost, so that it would be available for industrial purposes; but, for the use of the physician, the complexity and cost of the apparatus required render it an undesirable method.

3. Process of Boussingault. This consists in procuring oxygen from baryta, in utilizing the property which the latter possesses of fixing the oxygen of the air at an elevated temperature, and giving it off again when the temperature is raised still higher. It is difficult to manage, however, and the results are not satisfactory. The apparatus, also, is bulky and expensive.

4. Reaction of sulphuric acid upon bichromate of potash. This reaction results in the production of oxygen and chrome alum. About sixteen per cent. of oxygen is yielded by the bichromate. This yield is too small to render the method desirable, aside from the objections belonging to every process which requires a powerful acid to be placed in unskilled hands.

5. Decomposition of chloride of lime by cobalt. The oxide or any of the salts of cobalt have the property of inducing a species of catalytic action between chlorine and lime, from which free oxygen and chloride of calcium result. An extremely minute quantity of cobalt only is required. If a stream of chlorine gas is passed into warm milk of lime, containing a little of a salt of cobalt in solution, the chlorine is absorbed, and oxygen is given off, and at the close of the process chloride of calcium will have taken the place of the lime. This method of procuring oxygen is known as Fleitmann's process. Now, by using chloride of lime, we have the chlorine and the lime united in one substance, and, by merely adding the cobalt, and pouring on a little hot water, the process is greatly simplified. The gas, however, contains



considerable chlorine, and the yield is small in proportion to the quantity of material employed. This process is the one recommended by Dr. Beigel for preparing oxygen for medical use, and his recommendation is sustained by Birch, who, however, prefers compressed oxygen when it can be obtained. I have given the method a trial, but, in my hands, the quantity of gas was so small, and the quality so inferior, that I abandoned its use. However, as the cost is very slight, it might be used with advantage in office practice, where a large stationary apparatus could be employed, and where arrangements could be made for washing the gas through an alkaline solution to remove the chlorine. But, for use at the bedside, an apparatus, small enough to be portable, would not yield the gas in sufficient quantities.

It remains to consider the method of obtaining oxygen by the decomposition of chlorate of potash. This substance, having the formula  $\text{KO}, \text{ClO}^3 = \text{KCl} + \text{O}^6$ , is broken up by heat into oxygen and chloride of potassium.

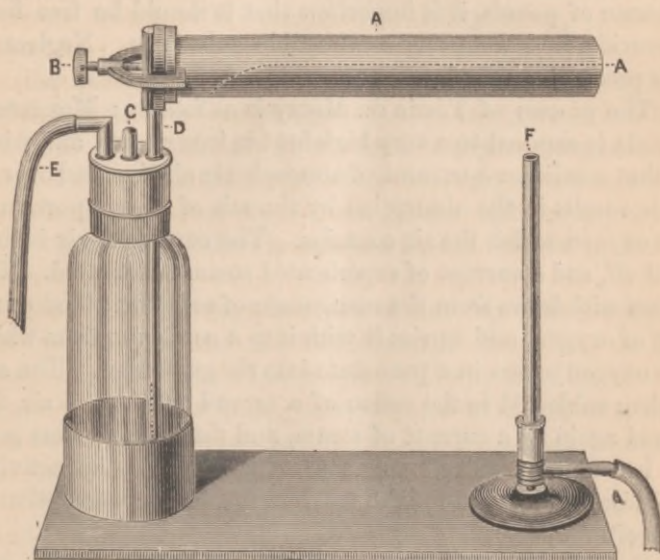
By mixing with the chlorate a little peroxide of manganese, the disengagement of the oxygen proceeds with greater rapidity and requires much less heat. It is usual to invoke the action of catalysis to explain this, but it seems to me to be owing simply to the facility with which the manganese conducts the heat and diffuses it through the whole mass. Chlorate of potash alone is an exceedingly bad conductor of heat, as is also chloride of potassium. Hence the action of slight degrees of heat is confined to that part only of the mass exposed which is in contact with the retort. But the manganese, being a heavy metallic substance, transmits the heat readily from particle to particle of the salt. Any other substance having an equal conducting power will do as well, provided it will not combine with oxygen. I have succeeded admirably with black oxide of copper. Sand may be used, but with less advantage, as it is comparatively a poor conductor. It is generally stated that this process yields perfectly pure oxygen gas. This, however, is not the case if the evolution is at all rapid, as the gas will then be slightly contaminated with chlorine. There is also another impurity, not noticed in any work on chemistry which I have seen. Pure oxygen, as is



well known, is invisible, yet the product from chlorate of potash has usually more or less of a smoky appearance when first evolved. If the gas be allowed to stand for half an hour or an hour, it will lose this appearance, while the glass vessel in which it is contained will be seen to have a deposit on its inner surface. Under the microscope this deposit is found to consist of minute crystalline particles. If enough of these be collected to respond to chemical tests, they will be found to be chlorate of potash. It would seem, then, that a small portion of the chlorate, instead of being decomposed by the heat, is sublimed unchanged, and such is its insolubility that it is not separated from the gas except by repeated washings. Not the least harm results, however, from inhaling it, as I have demonstrated repeatedly in my own person.

The quantity of gas procured by this process is very great, amounting in round numbers to five hundred cubic inches for each ounce of the chlorate of potash, or thirty-nine per cent. by weight. The quantity yielded renders this method peculiarly adapted for use in the sick-room, where portability of apparatus and material is much to be desired. Until recently I have employed a copper flask in which to heat the materials. But I found inconvenience to result from this form of container, inasmuch as the entire quantity of the chlorate was heated at once, resulting in a tumultuous and often unmanageable evolution of the gas. To obviate this difficulty, I have had constructed the apparatus figured in the annexed cut. It consists essentially of a brass retort in the form of a cylinder, nine inches long and one and a quarter inches in diameter, resembling in shape a very large test-tube. To the open extremity of this retort is fitted a cover of cast iron, held in place by a clamp which catches upon a projecting flange surrounding the mouth of the retort. This clamp is tightened by means of a screw. Passing through the cover is the tube carrying the gas into the wash-bottle, and which is arranged at a right angle to the retort. The latter is therefore in a horizontal position, and is supported by its connection with the wash-bottle, which in its turn is firmly fastened to a board forming the base of the whole apparatus. The tube before referred to passes to the bottom of the wash-bottle, and has near

its lower extremity a great number of very small holes through which the gas escapes in fine bubbles. This is important, as it insures a much more perfect washing of the gas. Another tube, merely passing through the cap of the wash-bottle, provides for the passage of the gas into the bag from which it is inhaled.



A, retort. The dotted line indicates the manner in which the chlorate of potash is to be disposed. B, clamp, holding the retort in position. C, safety-valve. D, tube leading into the wash-bottle. E, delivery-tube. F, Bunsen burner.

The retort is but half filled with the mixture of chlorate of potash and peroxide of manganese, and this quantity is distributed along its whole length to within an inch of the cover, thus leaving nearly one-half of the diameter of the retort free for the passage of the gas. The heat of a Bunsen burner or of a powerful spirit-lamp is employed, beginning first at the closed extremity of the retort and moving it along as the material becomes exhausted. The wash-bottle is half filled with a solution of caustic potash.

The advantage of this apparatus is, that only a small portion of the material is heated at a time, and the rapidity of evolution is under perfect control. By having two retorts, and

using them alternately, a continuous supply may be kept up, sufficient for any emergency. The whole apparatus, including the bag, may be easily packed in a box ten inches square and five inches deep, and a supply of gas may be generated in fifteen minutes, at the house of the patient.

In using black oxide of manganese in connection with chlorate of potash, it is important that it should be free from protoxide, and from any combustible substance. Neglect of this precaution may lead to an explosion.

The process of T<sup>é</sup>ssie du M<sup>ô</sup>tay is as follows: Manganate of soda is exposed to a very high heat in iron retorts, and while in that condition a current of atmospheric air is passed over it. This results in the absorption by the salt of a large portion of the oxygen which the air contains. The current of air is then shut off, and a current of superheated steam substituted. The steam withdraws from the manganate of soda the added quantity of oxygen, and carries it with it to a condenser from which the oxygen passes in a pure state into the gasometer. The salt is then subjected to the action of a second portion of air, followed again by a current of steam, and thus the process goes on indefinitely. The manganate of soda retains its activity, and loses nothing in weight, so that the only consumption is that of fuel.

For use in the sick-room, the gas may be compressed into cylinders of copper or iron, and thus rendered conveniently portable.

In localities sufficiently near to a factory, this is destined to supersede all other methods of supplying oxygen for medical purposes. The gas is perfectly pure, and the quantity which can be compressed into even a small cylinder is sufficient to meet the requirements of any case likely to occur.

The method of administration of oxygen is very simple. The gas, being in a bag or in a gasometer, is conveyed to the mouth or nostrils of the patient by means of a flexible tube, terminating in a mouth-piece of glass, hard rubber, or ivory. This being taken into the mouth, or held to one nostril, the patient breathes the oxygen mingled with a greater or less proportion of common air, one or both nostrils being free for the admission of the latter. The proportion of gas is regu-



lated by the size of the orifice through which it escapes. During *expiration* the rubber tube is compressed between the thumb and index-finger. When the patient is not able to do this for himself, it may be done by an attendant, who, by watching the movements of the chest, soon catches their rhythm. I prefer this plan to the use of an inhaler with a complicated system of valves, which always offers an impediment to respiration.

The quantity given will vary from one or two gallons daily, which is sufficient in some chronic cases, to eighty or one hundred gallons, which may be required in urgent dyspnoea. In chronic cases it should be given from a very small orifice, so that the inhalation of four or five gallons will occupy fifteen to thirty minutes. Feeble patients should take it in the recumbent position.

The inhalations may be repeated morning and evening, or less frequently, as the case may demand. Some very striking results have followed when the interval was as great as three days. On the other hand, when respiration is very much obstructed, it may be necessary to give the gas almost constantly and but little diluted.

Knowing the capacity of the bag employed, and bearing in mind that an adult usually respire from eight to ten pints of air per minute, it is easy to judge approximately of the quantity of oxygen which is being inhaled.

The plan of surcharging the atmosphere of a room with oxygen, and allowing the patient to remain in it for a certain period, has this disadvantage, that, to retain the oxygen, ventilation must be sacrificed. If the room be so large as to do away with this objection, the quantity of oxygen required will be greater than can generally be supplied. These considerations have led to the abandonment of this mode of administration.

Dr. Birch lays great stress upon the gas being given in what he calls a "*quasi-nascant*" condition, that is, he thinks it should be inhaled at once as rapidly as it is generated, or, if not, that it should be kept under pressure until wanted for use. It is enough to say that he brings forward no facts to sustain the alleged advantage of this plan, and that, moreover, others who have not followed it have obtained equally good results.

## CHAPTER III.

## PHYSIOLOGICAL ACTION OF OXYGEN.

IN regard to the physiological action of oxygen, the first question to be determined is, whether it is possible to cause the blood to take up more oxygen than it receives from the atmospheric air; whether the point of saturation is not attained in ordinary respiration. On this point there was formerly but one opinion. It was thought that there was practically no limit to the power of the blood to absorb oxygen. This idea was no doubt in part based upon the known energy of combustion in pure oxygen gas, and the supposed identity of that process with the retrograde metamorphosis of animal tissue. It was held that the inhalation of pure oxygen would induce rapid chemical action within the body, that a state of general inflammation would ensue, and that destructive metamorphosis would be so much more active than the process of reconstruction that the vital machinery would soon be spoiled, and rendered incapable of continuing its action.

But after a time it was observed that these extreme results did not actually take place, that an animal could remain for a number of hours in pure oxygen without sustaining any apparent injury. This led certain observers to the conclusion that the blood-corpuscle became saturated with oxygen when common air was breathed, and that it would take up no more, no matter how much was presented to it in the air-cells of the lungs. This view was defended by Regnault and Reiset, who endeavored to sustain it by the following experiment: They confined animals in oxygen, and after a time examined the gas, and found that it contained no more carbonic acid than would have been exhaled in the same time if the animals had respired atmospheric air. That these experiments were not conclusive, will become apparent as we proceed.

On the other hand, was cited the fact that animals die in a period varying from three to eighteen hours if confined in an atmosphere of oxygen, and that the tissues present an unusually florid aspect, approaching to a vermilion hue. These observations I believe to be no more conclusive than the others.



On this point Demarquay says: "Science had already taught, what our experiments have confirmed, that animals can live without danger in an atmosphere of pure oxygen, and for a much longer time than in the same volume of air. But beyond a certain limit these animals at last succumb, and one may then satisfy himself that the medium in which they have respired is still capable of relighting an ignited body, a very evident proof that death has taken place from the oxygen itself and not from any alteration which it may have undergone from admixture with the carbonic acid exhaled."<sup>1</sup>

As the test referred to above, that of relighting an extinguished taper, the extremity of the wick being still red hot, is constantly relied upon to prove the respirability of the gas after such experiments, it is well to state at the outset that it is entirely worthless. This is shown by the following experiment:

EXPERIMENT I.—Two parts of pure oxygen were mixed with one part of carbonic acid, prepared by the action of sulphuric acid upon marble. A pint jar was filled with the mixture, which sufficed to relight a taper four times.

Demarquay himself states that ten per cent. of carbonic acid, mixed with oxygen, is sufficient to render the latter incapable of sustaining life; yet we find, by this experiment, that the test which he relies upon would indicate its respirability when containing thirty-three per cent.

The apparatus employed by Demarquay in his experiments, which are essentially similar to those of his predecessors, consisted of a large cylinder furnished with two openings, through one of which the animal was introduced, while to the other a tube was fitted connected with a reservoir of oxygen. The animal, having been placed in the cylinder, a large quantity of oxygen was introduced by the tube, the amount being sufficient to drive out the air in the apparatus, which escaped by the other opening. When it was judged that the cylinder was filled with pure or nearly pure oxygen, both apertures were closed. The animals experimented upon were common fowls, pigeons, and rabbits.

<sup>1</sup> Essai de Pneumatologie Médicale, p. 644.



The result of these experiments was that, when the animals were allowed to remain in the apparatus for the space of an hour and three-quarters, and were then killed, nearly all the tissues of the body were found reddened to a greater or less extent, but the venous blood retained its darker hue. Two rabbits were allowed to remain until death took place, which, in one instance, was at the end of fourteen hours, and in the other after seventeen hours. At the close of each experiment the gas was found to relight a taper.

These experiments coincide in their results with one of my own, in which the conditions were similar :

EXPERIMENT II.—*June 10, 1860.*—A rat was confined in a jar containing about a gallon of pure oxygen, and inverted over water. At the end of two and a half hours death took place. On opening the body all the internal organs were found to be of a bright-red color.

It will be observed that, in both these instances, no provision was made for removing the carbonic acid and other products of respiration, and that the gas must have become excessively impure. In the following experiments this omission was corrected :

EXPERIMENTS III., IV., and V.—*July 15, 1869.*—A pigeon and two mice were confined respectively three, four, and five hours in jars of oxygen, having a strong solution of caustic potash in the bottom, under a stage upon which the animal rested. The jar was so arranged at the same time that a small stream of oxygen from a rubber bag was constantly flowing into it, and escaping by an aperture of like size. The solution of potash absorbed the carbonic acid, while the gradual change of the atmosphere within the jar was sufficient to prevent a sensible accumulation of other impurities.

*These animals when killed did not present any appreciable change in the appearance of the tissues.*

EXPERIMENT VI.—*August 25, 1869.*—At 3 p. m. a pigeon was placed in a jar of oxygen, of the capacity of three hundred cubic inches, and the jar inverted over a solution of potash. The following morning the animal was found dead. Upward of one hundred and fifty cubic inches of oxygen had been converted into carbonic acid, and absorbed by the potash, the liquid rising in proportion in the jar. On opening the body *no unusual redness of the tissues was observable.* The feathers of the bird, and also the sides of the jar, were wet with the condensed moisture of the breath. The animal was also in a constrained and uncomfortable position, which, doubtless, hastened its death.

The conclusion which I draw from these experiments is, that the lively red color of the lungs, heart, liver, etc., which are described, and which I have myself seen, does not depend upon hyperoxygenation alone, but also upon a coincident retention of carbonic acid in the tissues. The color pervades the intervascular substance as perfectly as the natural coloring-matter pervades the muscular fibre. It cannot, therefore, be ascribed to simple increase of vascularity.

The following experiments show that, in Demarquay's observations, the oxygen is as little chargeable with the death of the animals as with the change in the color of their tissues :

EXPERIMENT VII.—*August 13, 1869.*—A mouse was confined in a jar of oxygen inverted over a solution of caustic potash. At the end of twenty-five and a half hours, during which he had had neither food nor drink, he was dull and stupid, but, when released, ate greedily, and was soon as lively as ever.

EXPERIMENT VIII.—*August 16, 1869.*—A tin box, seven by ten inches, and six inches deep, open at the bottom, and having the top of glass, was placed in a shallow vessel containing a solution of potash. A little above the surface of the solution was arranged a false bottom of wire-cloth, which formed the floor of the apparatus. A circular opening on one side of the box was fitted with a projecting rim soldered to its edge. To this rim or collar a cap was fitted, and the joint was made air-tight by an india-rubber band stretched around it. This opening was for the purpose of introducing the animal to be experimented upon. A small tube passing into the box was connected with a large reservoir of oxygen. By means of a stop-cock the amount of gas passing into the apparatus was so regulated that a bubble would escape every second or two from under the edge of the box. Within the box was placed an open vessel containing chloride of calcium to absorb the moisture from the breath, and another vessel with dilute nitric acid to take up the ammonia exhaled. Food, water, and a quantity of tow for a bed, having been provided, a mouse was introduced into the apparatus, and the aperture closed air-tight. Oxygen was then admitted freely for some time until all the air was expelled, when the stop-cock was closed to the point already indicated. The animal ate, drank, and arranged his bed, and acted in every particular as mice generally do, until the third day, when he buried himself in the tow, and seemed very quiet. By this time his excretions gave to the gas, which escaped from the apparatus, a very sickening smell.

At the end of four days the mouse was removed and transferred to a cage, where he recovered at once his accustomed liveliness, and appeared no worse for his unique experience.



This single experiment is sufficient to overthrow the theory of hyperoxygenation of the blood, as the term is generally understood, and to show that the fatal results heretofore observed, as well as the peculiar *post-mortem* appearances, were the result of the admixture of the products of respiration with the gas inhaled.

Are we, then, to accept the conclusion of Regnault and Reiset that inhaling pure oxygen makes no difference with respiration? Clinical observation and facts derived from experiments teach us clearly to the contrary.

The quantity of oxygen in the blood under normal conditions is extremely variable. This follows from the varying exigencies of the system. The transition from perfect repose to active exertion implies increased molecular action and increased consumption of oxygen. The blood-corpuscles are the carriers of oxygen, and, as their number remains the same, each one must assume a greater burden. To explain all the phenomena resulting from the inhalation of oxygen, it is not necessary to assume the absorption of more than corresponds with the extreme limit of this healthy respiratory demand. All the analogies of Nature lead us to suppose that this limit coincides with the point of complete saturation of the blood. To assume a margin beyond it is to suppose a provision against an emergency which can never arise. It is contrary to the economy of Nature that the blood should have the capacity for absorbing more oxygen than Nature can supply.

My view is, then, that if pure oxygen be taken into the lungs, only as much will be absorbed by the blood as would be taken up from the air under circumstances involving the greatest possible physiological demand for oxygen. I know that it has been asserted that blood agitated in a vessel with oxygen will assume a livelier red than when agitated with common air. This, however, is a mistake. The change will take place more promptly with oxygen, but the hue will be in the end the same. We may therefore assume that, if the blood and the air be brought into sufficiently intimate contact in the lungs, the corpuscles will become saturated with oxygen from the ordinary atmosphere.



EXPERIMENT IX.—August 20, 1869.—A quantity of defibrinated sheep's blood was divided into two portions. One portion was thoroughly agitated with oxygen, and quickly assumed a bright-red hue. The other was agitated in the same way with common air. The change took place more gradually, but eventually, when the two jars were placed side by side, no difference in the color could be distinguished.

The portion agitated with air was then placed in a vessel filled with oxygen, which was closed tightly, while its interior was made to communicate with a delicate manometer. After the lapse of an hour, during which the vessel was frequently agitated, no change had taken place in the height of the fluid in the instrument, thus indicating that no additional oxygen had been absorbed.

How, then, is this appearance of superoxygenation of the blood to be accounted for, since it never occurs when atmospheric air is respired? The conditions which obtain while breathing oxygen, without removing the products of respiration, are entirely *sui generis*. They differ from that observed when air is substituted, in that the proportion of carbonic acid may become much greater without destroying life. They differ, also, from the effect produced by confining an animal in a mixture of carbonic acid and oxygen, since in the latter case the change is abrupt, while in the former it is very gradual. The experiments of Count Morrozo, and of Bernard, show what an immense difference, in the effect upon the animal, results from this circumstance. I offer the suggestion, therefore, that the red stain of the tissues is the result of the prolonged action of carbonic acid retained in the blood—life, meanwhile, being kept up and the activity of retrograde metamorphosis sustained by a *maximum absorption of oxygen*.

When a considerable quantity of pure oxygen is inhaled, there is usually a sensation of freedom about the chest, as if respiration were easier. Some persons describe a feeling of warmth beneath the sternum, such as results from inhaling a slightly-stimulating vapor. Sometimes a slight degree of vertigo is produced. Generally there is a tendency of the blood to the surface, and the hands and feet, if previously cold, become warm. In some cases this change of the circulation is accompanied by a prickling sensation. The pulse is sometimes accelerated, but more frequently remains unchanged. In cases of debility it is often reduced in frequency. The temperature is but little changed, if at all. I have sometimes

observed a disposition to yawn constantly during the inhalation, and there is generally an inclination afterward to sleep. All these effects are more marked when the gas is inhaled fasting.

In reference to the effect of the inhalation of oxygen upon the amount of carbonic acid formed, and of urea excreted, there has been as yet but little research. The experiments of Regnault and Reiset, upon the first point, have been already referred to. The subject, however, is beset with difficulties, and much caution is required in accepting the results of experiments as to the amount of carbonic acid exhaled when breathing a greater or less proportion of oxygen. Different results will be obtained at different times when breathing the same medium under apparently the same conditions as to diet, stage of digestion, exercise, etc. The slightest bodily exertion, or even mental excitement, will vitiate the experiment. In experiments with animals, eructations of gas from the stomach will sometimes add largely to the percentage of carbonic acid obtained.

My experiments on this point have brought out an (to me) unexpected result, viz., that the inhalation of a considerable quantity of oxygen is followed within a few moments by a temporary *decrease* in the amount of carbonic acid exhaled, as is shown in the following table. The experiments were made upon myself:

	Hour.	Cubic inches of oxygen inhaled.	CO <sub>2</sub> exhaled per minute. 21 c. in.
EXPERIMENT XI., July 29, 1869.	4.35 P. M.		
	4.45	600	
	5		19
EXPERIMENT XII., August 3d.	5.18		20
	3.25		22
	4	400	
EXPERIMENT XIII., August 5th.	4.10		16
	12.15		19
	12.25	700	
EXPERIMENT XIV., August 5th.	12.30		16½
	12.45		18
	2		19½
EXPERIMENT XV., August 5th.	2.50	400	
	2.55		19½
	2.55		19½
EXPERIMENT XVI., August 5th.	3.15	1200	
	3.35		17½
	6 A. M. (fasting)		18
EXPERIMENT XVII., August 12th.	6.15	500	
	6.40		17
	7		17½



EXPERIMENT XVII.—*August 4, 1869.*—A pigeon was placed in a jar containing three hundred cubic inches of oxygen, and the jar inverted over a solution of caustic potash. After twenty minutes the oxygen was removed and replaced by common air. In thirty minutes the volume of air had decreased thirteen cubic inches. The following day the same pigeon was confined again in the same quantity of air for the same period, not having previously inhaled oxygen. The decrease amounted to eighteen cubic inches. There was no evidence that the health of the animal had been injured by the previous experiment.

The manner in which oxygen produces this effect is not easily explained. It is possible that its immediate action may be like that of alcohol, which is known to cause a diminution of the carbonic acid exhaled from the lungs. This is the more probable from the similarity of its other effects, when well marked, to those which alcohol produces.

Notwithstanding this temporary decrease of carbonic acid, I am of the opinion that the ultimate effect of oxygen is to cause its increase. The increase is probably small, and it would doubtless be extremely difficult to demonstrate it conclusively, under normal conditions of activity. Still it seems to me that the result of the following experiments could hardly be attributed to mere accident :

EXPERIMENT XVIII.—*August 12 to 24, 1869.*—Three observations were taken daily of the amount of carbonic acid exhaled by myself. In all, twenty observations were made, in seven days, nearly every hour of the day being represented. The average of these observations gave 17.2 cubic inches per minute. During the four following days, eleven similar observations were made—the conditions remaining the same, except that from six to ten gallons of oxygen were inhaled each day in divided doses. The average of these gave 18.9 cubic inches, as the amount of carbonic acid exhaled per minute.

These results, while they coincide with the generally-received opinion as to increased activity in the retrograde metamorphosis as resulting from the use of oxygen, show nevertheless that the increase is confined within narrow limits, and thus confirm the view already expressed, that saturation of the blood-corpuseles with oxygen is quickly attained, is a *strictly physiological condition*, and in no way necessitates the setting up of any morbid action within the system.

To test the effect of oxygen upon the amount of *urea* excreted, I made the following experiment :



EXPERIMENT XIX.—*December 8 to 22, 1869.*—The urine for each twenty-four hours was carefully preserved, and the amount of urea estimated according to Haughton's second formula. The result is given in the following table :

DATE.	GALLONS OF OXYGEN INHALED.	UREA IN GRAINS.
December 8.....	..	641
“ 9.....	8	624
“ 10.....	8	561
“ 11.....	10	472
“ 12.....	6	472
“ 13.....	6	590
“ 14.....	12	550
“ 15.....	14	552
“ 16.....	18	510
“ 17.....	..	542
“ 18.....	..	601
“ 19.....	..	546
“ 20.....	..	556
“ 21.....	..	495

This table shows a rapid decrease in the amount of urea, during the first four days after beginning the inhalations of oxygen. It then increased again, but did not attain to the former figure. With the cessation of the oxygen there is again an increase. The average of the days without oxygen is 563 grains, of those with oxygen 541 grains.

So far as these experiments go, they indicate that oxygen causes a *decrease* in the amount of urea formed. This is surprising, if we are to consider urea as the result of *oxidation* of tissue, as is generally held. More extended observation is required before it would be warrantable to call in question the views so ably enunciated upon this point; but, should it be established that the continued use of oxygen really diminishes the excretion of urea, it would place the latter substance in analogy with the smoke resulting from combustion, a product, it is true, of the combustion, but at the same time a measure of the incompleteness of the process.

The quantity of uric acid in the urine is rapidly diminished by the daily use of oxygen. This fact, suspected by Dr. Golden (*Lancet*, March 10, 1866), has been fully established by Kollmann, of Munich.

In the course of the experiments described above, I observed a very striking diminution of the coloring matter of the urine. At the commencement of the experiment the urine was very high-colored, but within twenty-four hours it became very pale, and remained so for several days after the oxygen was discontinued. This paleness was not owing to an excess of water, as the specific gravity never fell below 1.022, and was usually above 1.025.

## CHAPTER IV.

### THE USE OF OXYGEN IN DISEASES INVOLVING DEFECTIVE RESPIRATION.

THE diseases to which the use of oxygen is applicable fall naturally into two classes: those in which respiration is more or less at fault, and which are for the most part acute; and those in which there is defective nutrition, or excretion, and which are chiefly chronic.

In general terms it may be asserted that any disease which gives rise to dyspnoea will be benefited, at least temporarily, by the use of oxygen, in so far as the dyspnoea is concerned.

The manner in which this is effected is sufficiently obvious. The essence of dyspnoea consisting in a disproportion between the quantity of venous blood brought to the lungs and the amount of oxygen which finds access to the air-cells, it is plain that, by causing the patient to breathe an atmosphere containing more than the usual proportion of oxygen, the dyspnoea may be *pro tanto* relieved.

This is well illustrated by the following experiment:

EXPERIMENT XX.—*January 15, 1860.*—Tracheotomy was performed on a rabbit, and a tube provided with a stop-cock was tied in the trachea in such a way that no air could enter the lungs except through the tube. The stop-cock was now turned until symptoms of suffocation were produced; the eyes protruded, the pupils dilated, and the whole body was convulsed. The free end of the tube was then brought into a stream of oxygen, when the symptoms were at once relieved, and, though the breathing was labored, there were no signs of actual distress.

*Asthma.*—Probably there is no other disease affecting the respiratory organs which so immediately suggests the use of oxygen as does asthma. The dyspnoea is often very severe,

and the indications of imperfect aëration of the blood very apparent. Every movement, every gesture of the patient, is a plea for more air. It is not remarkable, therefore, that this should have been one of the first diseases in which oxygen was applied. Beddoes employed it in twenty-two cases, ten of which were cured, nine relieved, and three did not receive benefit.

Demarquay describes two cases, one of which was definitively cured, the other greatly relieved. Birch reports a case of absolute cure.

Dr. Howard Pinkney, of New York, administered it recently in one case with the effect of relieving the paroxysms, and of reducing most decidedly their frequency.

Dr. Beigel, of London, reports three cases, two of them hereditary, in which oxygen was used conjointly with inhalations of liq. potas. arsen. The oxygen in each case relieved the paroxysms, and apparently contributed to remove the tendency. At all events, the paroxysms became less and less severe, and occurred at longer intervals, and finally ceased altogether.

The case of the late Secretary Stanton presents an instance in which oxygen was the means of averting a great deal of suffering. He was subject to severe paroxysms of asthma, which, during his last illness, constituted a serious aggravation of his condition. His medical attendant, Surgeon-General Barnes, of the United States Army, procured from New York a supply of compressed oxygen, of which from three to four cubic feet were inhaled daily. It controlled the paroxysms completely, and, so far as the asthma was concerned, met every indication. In a recent conversation with me, General Barnes expressed himself warmly in favor of the gas in similar cases, and stated that both he and his illustrious patient were entirely satisfied with its effects.

I have myself administered oxygen in two cases during the paroxysm, with the effect of causing almost instant relief; but, as it was not continued during the intervals, no permanent benefit was experienced.

It will be observed that three of the cases reported by Beddoes received no benefit whatever. I have, also, had a



similar experience. A clergyman, subject for many years to infrequent but prolonged attacks of asthma, which had completely baffled all previous treatment, was seen by me at the onset of a paroxysm. The respiratory movements were very rapid and extremely energetic, and the dyspnœa considerable. Still there was no evidence whatever of imperfect aëration of the blood. The countenance was flushed, but not in the slightest degree dusky. Oxygen was administered very freely, about four gallons every half hour, but with no appreciable relief to the dyspnœa.

*Pulmonary Emphysema.*—Dr. Beigel reports a case in which the shortness of breath was so great as to prevent the patient walking more than a few steps at a time. By inhalations of oxygen, one gallon every three hours, a prompt amelioration was brought about, and at the end of six weeks the distressing symptoms had nearly disappeared. During this time there was no other treatment than inhalations once or twice a day of solution of common salt, two gr. to the oz. for twelve days, after which "pulverized," pure water was substituted. Subsequent to this time a solution of tannin and morphia was used in connection with the oxygen, and in less than two months from the commencement of the treatment the patient was able to return to his business, though he could not dispense with the oxygen for more than a few days at a time without a return of dyspnœa.

Two months later the unnatural prominence of one side of the chest, which previously existed, had sensibly diminished, the area of tympanitic sounds was much decreased, and the amount of respiration had increased from 2.150 to 3.200 cubic centimetres.—*Beigel on Inhalations*, p. 143.

In this case it is evident that something more was accomplished than mere present relief of the dyspnœa. A radical improvement in the disease itself was effected. This was perhaps due to the diminished force of the respiratory movements, and the consequent lessening of the strain upon the delicate tissues of the air-cells, resulting from the relief to the dyspnœa.

A case is reported by Dr. A. H. Smith in the May number of *New York Medical Journal*, 1869, in which the

gas was given, but only for a short time. The dyspnœa was greatly relieved, the countenance lost its livid hue, the pulse fell from 122 to 100, and the respiration from 36 to 20.

The relief continued but a short time after the oxygen was discontinued, but was again experienced when its use was resumed.

*Croup.*—Dr. Beigel describes a severe case of croup, in which the usual modes of treatment had been exhausted without avail, the respiration being 40 per minute and noisy, the pulse too frequent to be counted, lips livid, and face pale and agitated by convulsive movements. The inhalation of one cubic foot of oxygen was followed by decided improvement, and in the course of two or three hours the child fell asleep, awakening convalescent, and making a prompt recovery.—*Beigel on Inhalations*, p. 105.

Dr. Miquel reports a case with symptoms identical with those above mentioned, which was immediately relieved by the use of oxygen, and ultimately recovered.—*Half-Yearly Compendium*, January, 1869.

I have been called in to give oxygen in several cases of croup, but always in the last stages, when the long-continued dyspnœa had led to mechanical engorgement of the lungs, and to poisoning of the nerve-centres by the circulation of un-aërated blood. Under these circumstances, although I have been able to relieve the dyspnœa in a measure, still death has been the result. The termination in such cases is the same when the trachea is opened, even if the respiration is thereby made easy.

It is my firm conviction that oxygen will do in croup all that can be done by tracheotomy, but neither the one nor the other is competent to undo the mischief wrought by severe and protracted dyspnœa. Hence the practical rule in the use of oxygen is the same as that in the use of the knife—*use it early*. There is nothing painful, nothing horrible, nothing dangerous about it. Why, then, should it be resorted to only at the last moment, as if it were a more desperate remedy even than tracheotomy?

*Diphtheria.*—Dr. Beigel gives the history of two cases in which oxygen was used in connection with inhalations of va-



rious atomized solutions. In the first case, that of a child six years old, a single administration of the gas roused the patient from a state of coma; the eyes, before dull, became brighter, and the pulse rose from 60 to 75. After five inhalations the tendency to coma disappeared entirely, the countenance assumed a ruddy color, and the appetite returned. The quantity used at each inhalation was one gallon.

In the second case the benefit was also immediate and decided.—*Beigel on Inhalations*, p. 114.

I have given oxygen in but one case of diphtheria, to which I was called, in accordance with my usual experience, only when the child was in *articulo mortis*. For four hours life was sustained by the gas, which could not be withheld for more than a few minutes at a time without producing suffocation. At the end of that time the parents were informed that the case was hopeless, and it was left for them to continue the gas as long as they saw fit, a supply being prepared beforehand. The inhalation was continued an hour longer, and then abandoned. Death took place within five minutes after the gas was withheld.

In this disease, in addition to the impediment to respiration, we have to contend with a septic condition of the blood, tending greatly to depress the powers of life. I believe, with Dr. Beigel, that this latter condition may be prevented or remedied more surely by inhalations of oxygen than by any other resource we possess, while, at the same time, the danger of death by apnœa is obviated.

For the removal of the local affection the usual remedies may be simultaneously applied.

*Pneumonia*.—Dr. Golden reports in the *Lancet*, for March 10, 1866, a case of double pneumonia accompanied by great dyspnœa, which resolved in four days under the use of oxygen.

I have seen a case in which a circumscribed pleuro-pneumonia, occurring in the course of chronic pyæmia, was apparently aborted within thirty-six hours by the use of the gas.

Although the existence of acute inflammation, as a rule, precludes the use of oxygen, yet, when respiration is seriously interfered with, the danger from this source outweighs all risk



from any possible increase of the inflammation which the use of oxygen may occasion. In a case of double pneumonia, therefore, I should not hesitate to employ it, nor should I allow any case of this disease, which appeared to be tending toward a fatal termination, to proceed without a trial of its effect. The fear formerly entertained, that oxygen would excite pneumonitis by its local action, is refuted by its entire history as a remedy. Especially in the typhoid form of pneumonia, I should expect great benefit from the gas.

Dr. Butler, of New York, reports, in the November number of the *New York Medical Journal*, a very interesting case of chronic pneumonia, in which the deposit was rapidly absorbed under the use of oxygen.

*Capillary Bronchitis.*—In this affection oxygen is of great value, not only in relieving the dyspnoea, but also in diminishing the formation of mucus in the lungs, which latter is in a great measure the mechanical result of excessive inspiratory effort. For, whenever the inspiratory effort is in excess of the capacity of the air-passages to supply the necessary air, the atmospheric pressure within the chest is necessarily diminished, and turgescence of the blood-vessels of the lungs follows, as certainly as hyperæmia of the skin follows the application of a cupping-glass. Inhalations of oxygen, by satisfying the *besoin de respirer*, remove the necessity for the employment of excessive inspiratory force, and in this way lessen the congestion of the mucous membrane, and diminish the tendency to effusion. Hence it is not only palliative but curative.

This is admirably illustrated in a case reported by Dr. A. H. Smith, in the *Medical Record* for June 15, 1869.

The patient, a child, two and half years old, was at the point of death from bronchitis, intercurrent with measles. The respiration was 80, and accompanied by mucous râles audible at some distance from the bed, pulse too frequent to be counted; face pale and dusky, extremities cool. Within one hour after the continuous administration of the gas was resorted to, the pulse had fallen to about 160, and the respiration to 40. Within another hour the face had regained its color, and the râles were no longer audible, unless the ear were applied to the chest. The inhalation was continued without

interruption for three hours, and irregularly for five hours longer, when it was wholly discontinued. The following day convalescence was fully established.

*Dyspnœa from Cardiac Disease.*—I have administered oxygen in two cases of dyspnœa from valvular disease. In the first case the patient was speechless, could scarcely be aroused; face livid, no pulse at the wrist, whole surface cold, respiration 40, and extremely labored, pupils widely dilated and fixed. Within fifteen minutes after the administration of the gas was begun, the pulse became perceptible at the wrist, the breathing was easier, intelligence began to return, and waking from his lethargy he complained of cold, and requested more covering. At the end of an hour, the surface was warm and slightly moist, face almost natural in color, lips still blue, pupils almost normal in size and reacting to light. He answered questions intelligently, and swallowed without difficulty. Respiration 25, quite easy. Pulse 120, and of moderate strength, though small. Patient remained quite comfortable for about ten hours, when a sudden paroxysm of dyspnœa proved almost immediately fatal. Attempts were made to give the oxygen, but the extreme jactitation rendered it impossible to do so efficiently.

In the second case the dyspnœa was less severe, but the paroxysms were very much relieved, and often entirely averted, by the use of the gas.

Dr. Const. Paul reports (*Bul. Gén. de Thérap.*, tome lxxv.) a case of dyspnœa (cause not stated), which was relieved by inhalation of oxygen, after the radial pulse had ceased.

*Poisoning with Opium.*—The effect of opium in reducing the frequency of respiration indicates that the sensibility is so blunted that the blood requires to become unnaturally charged with carbon before the *besoin de respirer* will excite to the act of respiration. Hence the blueness of the face, and the generally asphyxiated appearance. We should suppose *a priori* that oxygen would be useful in such cases, and such has been found to be the fact. M. C. Paul mentions a case in which the gas was used successfully after atropia had failed, and when the patient appeared to be dying. The respiration had fallen to 7, the pulse was very rapid and hardly perceptible,



and there was mucous rattling in the throat.—*Bul. Gén. de Thérap.*, tome lxxv.

*Poisoning with Charcoal Gas.*—M. Paul has been successful in a case in which the face was livid, the surface cold, the pulse very small, and the dyspnœa decided. In such a case the action of the gas is probably due chiefly to its superior displacing power for carbonic acid, in comparison with common air.

*Poisoning with Chloroform.*—Duroy and Ozanam show, by a number of experiments, that the effect of oxygen is antagonistic to that of chloroform, and they propose that it be used as an antidote.

Birch, on the other hand, asserts that it renders the anæsthesia deeper.

*Cholera.*—In view of the lividity of the skin, indicating imperfect aëration of the blood during the stage of collapse in cholera, and of the depression of temperature, showing decrease of molecular action, it was natural to hope that inhalations of oxygen would be beneficial, and several physicians have made trial of its use. There is a wide difference of opinion among observers as to the value of the remedy. M. De Smyttere (*Comptes Rendus*, October, 1848) speaks of it in the highest terms. He employed it in the epidemic of 1832, in the algid stage with "full success." He says: "A new animation and a salutary reaction follow promptly the employment of this means, which is entirely rational, and of which no one, so far as I know, has yet thought. I regard the inhalation of oxygen gas during the period of cold and prostration so dangerous in the choleraic attack, and when the intestinal and cutaneous functions are profoundly perverted, as the remedy the most prompt and the most efficacious of those employed up to the present time."

Macrae, in India (1850), and Harvey, in London (1853), also report favorable cases.

On the other hand, in the debate in the Academy, upon the paper of De Smyttere, cited above. M. Hutin stated that he had employed oxygen in numerous cases in 1835, in Africa, without a single case of success.

M. Foy also stated that he had used it in Poland, in 1831, without any especial benefit.



M. St. Ange had had a similar experience, but thought that the difference in the results obtained might be referable to difference in the period in the epidemic, in which the observations had been made.

## CHAPTER V.

### THE USE OF OXYGEN IN DISEASES INVOLVING DEFECTIVE NUTRITION.

THE benefit derived from the use of oxygen, in cases not primarily involving respiration, is to be explained on the principle that it aids defective nutrition. The replacement of old and effete matter by that which is new and active, is fully as much the work of respiration as of digestion. Without the oxygen derived from respiration, *tissue change* would be immediately checked. If the blood does not convey to the tissues the requisite supply of oxygen, the gastro-intestinal system may do its part, and the food may be absorbed, but there the process will be arrested. The material will be on the spot, but the structure will not be repaired. Nor is it enough to present the usual supply of oxygen to the blood in the lungs. The blood itself must be in a proper condition to receive it, or it cannot reach the tissues. The quality of the blood by which it takes up oxygen depends upon the exactness of its chemical constitution. A slight variation in this will affect its absorbing power. But a condition of the blood which prevents the absorption of sufficient oxygen from the diluted medium usually respired, may allow its absorption from a medium in which a greater proportion of oxygen is contained. A deficient absorbing power may be supplemented by an increased supply of the material to be absorbed.

It is on this principle that even a very small quantity of artificial oxygen inhaled each day is capable of producing such decided results in cases appropriate for its use. The deficiency of oxygen in the blood and in the tissues has been very gradually produced, and, once restored, considerable time will be required before the previous condition will again be reached, even if the cause by which it was produced continues operative. Thus, by daily inhalations, the normal condition may be, in a

measure, restored and maintained until Nature is enabled to resume her sway.

But there is one form of disease which at the same time depraves the blood and interferes with the function of the lungs, thus striking a double blow at the function of hæmatisis. It may therefore be appropriately considered first, as intermediate between those cases in which respiration is principally involved and those in which nutrition is chiefly at fault.

*Phthisis.*—Among chronic diseases, pulmonary phthisis was the one which offered from the first the most tempting field for the use of oxygen. It was natural to expect that the profound dyscrasia which lay at the root of the disease might be favorably modified by an agent bearing such intimate physiological relations to the normal blood. At the same time there was room to look for a double local action within the lungs. What might be the result of bringing an excess of free oxygen into direct relation with the tubercular matter in the pulmonary tissue, was a question not less interesting than what might result from the local action of the gas upon the ulcerated surfaces with which it would come into contact.

After the lapse of eighty years these problems still remain but partially solved. With regard to the effect of oxygen upon the system generally in phthisis, we have abundant evidence to show that, *as a rule*, in this disease, as in others in which nutrition is defective, the use of the gas *favors assimilation and results in a gain in weight*. But whether it exerts an influence upon the morbid principle which constitutes the essence of the disease, is a point which facts alone can determine, and up to the present time sufficient facts have not been gathered to warrant a decided answer.

The observations of Hill, Thornton, and others, in the latter part of the past and the early portion of the present century, were made before the days of physical exploration of the chest, and their results are therefore of little real value. They report a number of cases very decidedly benefited, but we cannot be sure that they were instances of genuine phthisis. Since the time of Laennec, we have only isolated cases here and there, in which the gas was given for a few weeks, or at most two or three months, and generally without a very close study of the



physical signs. Still, among these cases there is considerable reliable evidence to show that oxygen may sometimes arrest the progress of this disease for a considerable period, and possibly eradicate it altogether. What is required, however, is that a large number of patients in some public hospital should be under careful observation for some time in order to ascertain their real condition and the progress the disease is making, and that the oxygen should then be administered several times a day, and the physical signs watched by a competent observer. Until this is done, neither the general effect upon the dyscrasia nor the local effect upon the lung can be satisfactorily appreciated. Theoretically there is much to encourage to such a trial. First, we have the fact that in phthisis the nutrition is faulty to a degree that has given the disease its name, and the correlative fact that oxygen promotes nutrition in a remarkable manner. Secondly, we know that an impure atmosphere promotes phthisis, and that persons whose occupation keeps them constantly in the open air rarely become phthisical. Thirdly, modern chemistry teaches us that oxidation is the first step in the metamorphosis of tissue which precedes its resorption, as it is the first step in the decay and disintegration of dead organic matter. It is reasonable, therefore, to suppose that the presence of free oxygen in contact with tubercle would initiate a process of disintegration which would favor its absorption. How far the few clinical facts on record bear out this reasoning will be seen hereafter.

Lastly, numerous experiments show that oxygen in contact with a wound or ulcer acts as a stimulant, promoting the formation of granulations, and, if carried too far, setting up active inflammation. We have in this fact at once a therapeutic indication, and also a possible solution of the want of success which has so often attended the use of oxygen in phthisis, especially in the advanced stages. As a solution of nitrate of silver of appropriate strength, applied with discrimination, facilitates the healing of an external ulcer, so oxygen, properly diluted and carefully employed, may have a healing effect upon ulcers of the lung. But as a strong caustic applied indiscriminately to external ulcers would often induce excessive action, so oxygen in excessive proportion may excite inflammatory



action in ulcers of the pulmonary tissue, which, reacting upon the general system, would produce fever and other symptoms apparently indicating an aggravation of the general disease. These considerations show how far we are from a knowledge of the possible usefulness of oxygen in this dread disease. The effects heretofore obtained have resulted from a hap-hazard use, such as in the case of any other remedy would have insured its total failure. Only when we learn to use it with the same discrimination and care that we exercise in the use of opium or strychnia, shall we know the limit of its power for good. The quantity and the mode of administration should be regulated by the actual condition of the lung. In the first stage when we may assume that the mucous surface is entire, the gas may be given with impunity diluted with two or three times its bulk of air, but even then the symptoms should be carefully watched, and especially the temperature, and any thing indicating the occurrence of local inflammation should be the signal for further dilution of the gas. There is no necessity for adding to the inspired air more than three or four per cent. of oxygen in order to produce a decided effect upon nutrition by one or two inhalations daily of half an hour's duration each. An atmosphere of this kind could have no appreciable local effect even upon an ulcerated surface.

When there is profuse purulent expectoration, or when the signs indicate the existence of cavities, the local effect of oxygen but little diluted might be cautiously tried. In such cases the expectoration will sometimes rapidly diminish. This is notably the case in chronic bronchitis, and it is probable that some of the favorable cases reported by early observers were instances of this disease rather than of phthisis. But there are cases on record in which oxygen has been for a time beneficial, but after a few weeks has produced the symptoms of local inflammation. It is probable that the action in these cases was the same as that observed when ulcers on the surface have been exposed to the direct contact of oxygen. For a time the ulcer improves, the indolent character is lost, granulations spring up, and cicatrization commences. But soon the action becomes excessive, and inflammation results. By diminishing the action in time, this effect would be avoided and the benefit al-

ready procured would be retained. A like management in the cases of phthisis referred to would probably have obviated the difficulty experienced.

The use of oxygen in phthisis need not exclude any of the usual remedies employed. On the contrary, such of them as undergo a process of digestion and assimilation, as, for example, cod-liver oil, would doubtless be more efficacious for being associated with the gas.

I have been able to collect the histories of a considerable number of cases of phthisis in which the use of oxygen was beneficial. I will mention the leading points of some of these, referring the reader to the original source for details, which would occupy too much space in this essay :

CASE I.—Reported by Demarquay (p. 733). X —, aged thirty-two. Tubercles in both lungs; cavity in left of the size of an egg. Greatly emaciated, pale, anæmic, profuse expectoration, intense fever in the afternoon, diarrhœa. Tubercular epididymitis. *March 1st.*—To take four litres of oxygen in ten of air, daily. *March 3d.*—The cough is less frequent, expectoration less abundant; slept well. Increased the dose to twelve litres. *4th.*—A little appetite, but little cough, no expectoration. *6th.*—Great appetite, sleeps well, physiognomy better. *8th.*—Increased to fifteen litres. *10th.*—Patient has been up and about for the last two days. Appetite so great that, after eating the dinner provided by the institution, he goes out and dines again in the city. Face has more color, cheeks filling out. Respiration easier. *16th.*—Cavity still remains, but the surrounding tissue which was hepatized now performs its function. *19th.*—Able to take a long walk. *26th.*—Cough and expectoration have entirely disappeared. No gurgling as formerly, respiration still amphoric.

*April 30th.*—Discharged in a very satisfactory condition.

CASE II.—Demarquay (p. 736). Madame De B., aged twenty-seven. Tubercles in both lungs. Emaciation, frequent cough, profuse expectoration, almost no appetite, abundant night-sweats. The appetite improved and the strength increased, and, on the twenty-seventh day of the treatment by oxygen, patient was able to give a dinner-party and preside for two hours at the table. The menses, which had been absent for five months, returned. The cough and expectoration, though less, persisted during the summer and toward autumn; the use of the gas having been for some time suspended, a relapse took place, and death followed the ensuing February.

It is to be remarked that in this case all other treatment was suspended from the moment the use of the oxygen began.

CASE III.—Reported by M. Monod (quoted by Demarquay, p. 739). M. C. B., aged twenty-six. For some years has had very abundant hæmor-



rhages. Signs indicate a number of cavities and an abundant deposit of tubercle, especially in right lung. At the commencement of treatment was so feeble that he could only be moved from the bed to the sofa. Abundant muco-purulent expectoration, complete anorexia. Twelve litres of oxygen were given twice a day, and within a brief period he had so far improved that he was able to walk in the garden, and even to attend occasionally to business. For sixteen months the treatment has been continued, during which time there has been no return of hæmorrhage, the expectoration is now insignificant, and the cough infrequent. The appetite is habitually good. Still the disease is making progress, the pulse is frequent, and the strength less than last year. But the oxygen has restrained the march of the disease, which last spring seemed to have arrived at its last stage. The improvement followed so immediately upon the administration of the gas that it could not be attributed to any other cause.

Demarquay quotes, from notes furnished by M. Hervé de Lavour, an account of that gentleman's experience with oxygen in phthisis which is particularly valuable, as he gives the unfavorable as well as the favorable results. He says: "I have had only nine patients who have been submitted to a somewhat regular course of inhalations of oxygen. Among this number I have obtained three remarkable successes. The first was a phthisical case of old date, having enormous caverns at the summit of one lung, and who, at the time I prescribed the inhalations, had an abundant expectoration, fever in the afternoon, a frequent cough, and such a degree of dyspnœa as rendered the least movement fatiguing. Anorexia was complete. The inhalations of oxygen were prescribed at the dose of fifteen litres" (four gallons) "daily in two portions, mixed with about one-third of common air. Gradually the quantity of gas was raised to forty-five litres daily, taken pure in two doses. Under this influence the expectoration ceased, the appetite returned, and the patient began to convalesce. The gas was continued two months, when the dose was diminished gradually and finally discontinued. For the last five months the patient has gained flesh, follows his usual occupations, and goes on as well as possible."

CASE IV.—In the case of the second patient there were crepitant *râles* in almost the entire extent of both lungs, with crackling at both apices, a frequent cough, an abundant expectoration, and a horrible dyspnœa, which compelled her to pass the greater part of her nights in her chair.

"There was a consultation, and two of our most eminent practitioners



gave the most unfavorable prognosis. The patient went on from bad to worse, and at last the appetite failed altogether. I prescribed inhalations of oxygen . . . and they were regularly employed for about a month. The dose of the gas was at first about fifteen litres mingled with air, then twenty, and at last forty-five litres were given without any mixture. Under this influence the amelioration was rapid, the dyspnœa disappeared, the appetite returned, and the patient is now as well as possible, attending to all his affairs, and saying that he has never been better."

CASE V.—The third case is a patient having tubercles at the summits of both lungs, and having besides hypertrophy of the heart, with violent palpitations, and a dyspnœa which would not allow the least exercise. He was submitted for a month to inhalations of oxygen, the cough diminished, the appetite, which was nil, returned, as did also the strength. At the end of three months the patient was able to take long walks without experiencing either dyspnœa or fatigue.

"In the case of the other patients the results were much less satisfactory. Three among them, having cavities, experienced a slight benefit; three others perceived no favorable effect whatever, without my being able to discover in the condition of the patients the difference in the results obtained."

I have quoted these cases in full, on account of the clearness with which they are described and the candor with which the writer relates his want of success in the larger number of his cases.

Birch relates two cases, in one of which "auscultation, percussion, and microscopical examination of the expectoration, confirmed the diagnosis as regards tubercular consolidation and central cavity. . . . From the very first dose of oxygen a diminution in the sensations of irritation and weakness of the chest could be felt by the patient; within a month marked improvement evidenced itself both in the lung and general health, and at the termination of four or five months' steady treatment . . . the flattening" (of the chest) "had given way to almost perfect symmetry. . . . The following winter there was still some pain and sensitiveness to the impression of damp and cold air, but otherwise, with a little extra prudence, she enjoyed herself like others. Two years after the commencement of the oxygen she was quite well, married, and has ever since enjoyed good health." (Written eight years after.)—*Birch on Oxygen*, p. 121.

In the second case the upper third of the right lung was full of small cavities, and soon broke up into a large cavity,

which, under the influence of oxygen, afterward contracted, causing considerable depression of the wall of the chest. Treatment was continued intermittingly for a year. Patient quite well six years after (p. 123).

During February and March, 1869, a series of experiments were tried at the New York Hospital, on the effect of oxygen in phthisis. Ten men, having phthisis in various stages, were placed in a ward together, and inhaled each about three gallons of oxygen morning and evening. This was continued for about four weeks, when it was found that six had gained in the aggregate forty-nine and a half pounds, while the remaining four had lost seven pounds.

In several of the cases there was a rise in the temperature after the first three or four days, and the gas was discontinued for a short time and again resumed, after which the temperature remained as before the administration. A transcript from the hospital records will be found in the the *New York Medical Journal* for September, 1869, and is worthy of attentive perusal. While the most prominent fact is the increase in weight, yet in several of the cases there was a very marked improvement in other respects, and that, too, when the patient had been growing worse up to the moment of beginning the inhalations.

In those cases in which the gas seemed to disagree with the patient it is probable that the result would have been different if it had been given more diluted.

The figures in Case V. are very remarkable. "February 15th, weight 127 lbs.; March 5th, 124½ lbs.; March 10th, inhalation resumed, weight 123 lbs.; March 16th, 126 lbs." This is one of the cases in which oxygen at first disagreed.

The *Practitioner* for May, 1869, contains an article on the Inhalation of Oxygen, by Edward Mackey, Professor of Materia Medica and Therapeutics, Queen's College, Birmingham. Among other cases are mentioned three of phthisis, all benefited by the use of the gas. All gained in weight, one of them two stone. In two of these cases the disease remained arrested, the third died of pleuritis.

The following cases are from my own notes: Mrs. S., aged twenty-eight, was sent to me by a physician in this city, with



the request that I would try the effect of inhalations of oxygen. She had had a distressing cough for three months, expectoration profuse, slight dulness, and tubular breathing at the summit of both lungs, extremely pale and anæmic, utter disgust for food, menstruation had been growing more and more scanty for some months past, and the last two periods had failed entirely. Three weeks before began the use of iron, but was obliged to abandon it as it disagreed with the stomach and caused headache. Six hundred cubic inches of oxygen were inhaled every morning mixed with about four times its bulk of air. For the first week little if any benefit was experienced, after that the appetite began to improve. On the tenth day of the treatment the menses returned and were more abundant and of a better color than for many months previous. The appetite now became very great, the patient declaring that, when returning from the office, she could scarcely wait to reach home, so great was the desire for food. Iron was now borne without difficulty, but after two or three weeks she found that she could not take iron and the oxygen the same day without headache, but could bear either separately. At this time the cough improved rapidly. A simple expectorant mixture had been ordered, but was taken very irregularly. In six weeks from the beginning of the treatment the cough had ceased entirely, the patient had gained flesh and strength and considered herself quite well. The treatment was then discontinued. Five months later she called at my office and reported that since I last saw her she had gained seven pounds, the menstruation had continued regular, and that, in short, she had never been better in her life. Respiration normal at the summit of both lungs.

Mrs. W., aged forty. Had been phthisical for eight years, having frequent hæmorrhages, and being very much reduced in flesh and strength. The summer of 1858 was spent out of town, she being unable to bear the air of the city. While in the country she had a succession of hæmorrhages which left little prospect of even a temporary rally. She improved somewhat, however, and returned to the city, where she passed the winter in a state of extreme feebleness. With the approach of warm weather she prepared to go again into the country,



but before doing so decided to try the effect of oxygen, hoping it would take the place of a removal out of town. Accordingly, she inhaled twice a day about four gallons of the gas, and found her strength and appetite so much improved that the change to the country was abandoned. During the summer two very slight hæmorrhages occurred, but her health in the main was infinitely better than the preceding year, notwithstanding the disadvantage of remaining in the city. She has continued the use of the gas, with occasional intermissions, up to the present time. She cannot omit it for more than a week without being sensible of a retrogression. Unfortunately, the physical signs were not noted at the beginning of the treatment, so that we can have no definite measure of her improvement. But the fact remains that the summer, which has always been the most trying season for her, has been passed with great comfort. That this was due to oxygen is shown by the effect of occasionally omitting its use.

On the 7th of December, 1869, I administered oxygen to Miss H., a patient of Dr. Frauenstein, of New York, aged about twenty-five. She was then extremely emaciated, had a distressing cough, and presented, as the doctor informed me, all the signs of pulmonary phthisis. After the first visit she continued the use of the gas under the direction of Dr. F. The 3d of January I received a note from the doctor, stating that the area of dulness in the lung was becoming less, and that although the cough continued she was gaining flesh. He wrote: *She coughs and grows fat.* Three days later she called at my office. The change in her appearance was marvellous. Her previously hollow cheeks had become round and full, and her whole person seemed to have expanded. It was like the change that one sees after recovery from a continued fever. Certainly up to this time nothing could be more gratifying than the progress of this case.

In several other instances I have administered the gas to phthisical patients with considerable benefit, the cough being lessened and the sleep improved, but circumstances have prevented continuing long enough to give decided results.

In other cases, there being no immediate benefit, the pa-

tients have become discouraged, and abandoned the treatment without giving it a sufficient trial.

It appears to me that, in the cases which have been mentioned, and which are far from embracing all which have been more or less successful, there is much to encourage the systematic use of oxygen in phthisis. Indeed, considering the extremely limited number of cases in which it has been thoroughly tried, and our ignorance as yet of its proper management, the results may well challenge comparison with those from any other mode of treatment. While not prepared to indorse the opinion of Birch that with the use of oxygen the cure of consumption in its earlier stages should be the rule rather than the exception, I have no hesitation in saying that I have more confidence in it than in any and all other remedies.

Even when it can do no more, it may procure a priceless boon—euthanasia. Often, even after the presence of the shadowy visitor is felt in the sick-chamber, reluctant life maintains a desperate struggle with its adversary, and the gasping sufferer lies for hours pleading for his release, the livid lips, the dilated pupil, and the convulsive breathing, bearing witness to his agony. In such a case the relief afforded by oxygen is beyond all price, as by it the horrible death by suffocation is exchanged for the peaceful falling asleep of exhausted Nature. (See *New York Medical Journal*, May, 1869, p. 149.)

*Anæmia.*—From what has been already said, it will be seen that oxygen is admirably adapted to this affection. I might select numerous examples to illustrate its effect, but will confine myself to two from my own notes.

Mr. S., aged seventeen, upward of six feet high, has grown very rapidly in the last two years. Eighteen months ago he was attacked with malignant pustule affecting the cheek. He convalesced from this very slowly, and was still feeble when he was seized with articular rheumatism, from which he suffered nearly the whole of last winter. After all inflammatory symptoms had passed, the least effort would bring on excessive pain in the joints, so that he lay for weeks in an almost helpless condition. At last he became able to walk a short distance with the aid of a cane, but still suffered greatly from pain and stiffness in the right hip.



In this condition he first came under my care. He was pale and anæmic, pulse 108, and so feeble that it would be lost every few seconds, and the counting have to be begun anew.

His appetite was good and had been so during his whole sickness. Tongue clean, bowels regular. Had been taking iron and other tonics for a long time with no benefit. He began on the 27th of September to inhale four gallons of oxygen each morning. For the first two weeks the pulse fluctuated between 104 and 120, but by the third or fourth day it had gained decidedly in strength, and could be counted without trouble. His strength improved rapidly; he laid aside his stick, and was able to walk a number of blocks without fatigue. By the 25th of October his pulse had fallen to 84, and was of good volume and strength. The gas was then discontinued. He has now resumed his business of insurance broker, which he conducts with a great deal of energy.

Wilhelm N., aged twenty-eight, had been becoming more and more feeble and bloodless for four months, probably owing to the effects of syphilis, from which he had suffered severely, although there was no longer any external manifestation of the disease. Had been under the care of a physician who gave him quinine and iron, which had benefited him slightly, but, as he was not progressing satisfactorily, he brought him to me for a course of oxygen. I first saw him on the 23d of November. He was then very anæmic, conjunctivæ and nails white, hands cold, pulse 96 and very feeble, no cardiac souffle. Has an absolute disgust for food, and is very restless in his sleep.

Gave him at once four gallons of oxygen, the inhaling of which occupied about ten minutes. To continue the use of tinct. ferri chlor. The following day the pulse had fallen four beats, and there was a little appetite. 25th.—A further decline of four beats in the pulse, appetite improving. 26th.—Pulse 84; appetite quite good; complains of constipation and headache; ordered ext. senna fl. 27th.—Pulse 96; bowels moved freely, but headache still continues. 28th.—Pulse 80; headache no better. To omit the iron. 29th.—Pulse 76; head still painful; ordered potas. bromide gr. x ter die. 30th.—Head somewhat better; pulse 84; appetite very good; nails

pink; conjunctivæ still pale, but not so much so as at first. *December 1st.*—Head much better; strength greatly improved. *2d.*—No more headache; has an excellent appetite. From this time he steadily improved.

*Dyspepsia.*—In this disease oxygen has succeeded when all other means failed. Its most unqualified commendation is by Trousseau, whose knowledge of the resources of therapeutics has rarely, if ever, been surpassed. He speaks of having by its means, in several instances, "*recalled to life* women regarded as lost," from great depression of the digestive powers consequent upon puerperal hæmorrhage or excessive lactation. He cites, as an example, the case of a girl twenty-two years of age recently delivered and exhausted with nursing. Her features were "absolutely those of a *cadaver*." She was admitted into the hospital April 1, 1864. The treatment began by weaning the child, but for fourteen days there was no improvement. She had continuous fever, pulse 120 to 130, skin hot and dry, and constantly-increasing debility. The debility became so great that she could not sit up in bed without fainting, and auscultation was rendered almost impossible. It was ascertained, however, that there were no tubercles. Tonics and iron were tried, but failed completely; the anorexia remained absolute. On the 14th of April, she began inhaling oxygen; very little was given her the first three days; the first attempt to inhale caused syncope. Still by the 19th she was able to sit up in bed with ease and to eat a little. Pulse 104. The 19th, she sat up for an hour, and asked for food. Pulse 92, skin cool. The 24th, the pulse fell to 80; the patient went down into the garden, described her appetite as *voracious*. April 30th, the pulse was 72 to 80, and had been so for the last four days. The patient desired to leave the hospital. But she was still pale, "the living fibre having regained its tonicity sooner than the blood its normal constitution."—*Clinique Médicale de l'Hôtel Dieu*, tome iii., p. 64.

Demarquay also relates similar cases in which the oxygen gave very prompt and decided relief.

Birch insists strongly on the power of oxygen to remove congestions of the liver, and to relieve the dyspeptic symptoms



consequent upon them. He cites a number of cases which sustain his views.

With regard to the possible effect of oxygen upon chronic disease of the liver, an observation of Hanfield Jones is very significant. In an article on the "Function and Diseases of the Liver," he says: "The oily contents of the hepatic cells are subject to great variation, both in individuals and in different classes of animals; the less perfect the type of the respiratory process, the greater the quantity of oily matter in the hepatic cells."<sup>1</sup> This statement suggests the inquiry how far fatty liver may be owing to defective hæmatisation. May it not be that the confinement which produces the *foie gras* so delicious to the epicure acts by preventing the reception of a due proportion of oxygen into the blood. Surely the "type of the respiratory process" under such conditions must be any thing but perfect. In the human subject, sedentary habits or improper alimentation may act to diminish the capacity of the blood to carry oxygen, and thus a condition of the respiratory process be produced approximating to the type of those classes of animals in which the hepatic cells are normally loaded with fat. Accepting this hypothesis, the systematic use of oxygen ought to be beneficial in such cases.

*Diabetes.*—Several cases are recorded in which inhalations of oxygen have caused a temporary disappearance of the sugar in the urine of diabetes, and with it relief from the general symptoms of the disease. Dr. Pinkney, of New York, informs me that he has met with two such cases. Peroxide of hydrogen has been given with the expectation that the second atom of oxygen would be liberated in the system, and result in the more perfect combustion of the sugar. Dr. Richardson has recently employed it in eleven cases, and gives it as his opinion that it is of no value.—*Medical Times and Gazette*, December 12, 1868.

Mr. Byfield, on the contrary, reports (*British Medical Journal*, October 17, 1868) a case *cured* (?) in ten weeks.

Demarquay, referring to the effect upon diabetes of a residence in the dense atmosphere of the sea-shore, attributes it to the greater quantity of oxygen inhaled, and adds:

<sup>1</sup> Braith., January, 1853.

“In support of these facts I may cite the results which I have obtained with inhalations of oxygen in the case of several diabetics, without changing their regimen in the least. I have seen the quantity of sugar in the urine diminish in a notable manner. The figure may descend in a few days to one-half of that usually observed, at the same time that the strength is seen to revive. M. Bérenger-Férand, a very distinguished young naval surgeon, as also Dr. Yvan, who have both applied, at my instance, inhalations of oxygen to the treatment of diabetes, have modified advantageously the condition of their patients. Without doubt, we have only acted upon the symptoms of the disease; but, in the present state of science, what other treatment can we apply to diabetes, since science has not determined either the nature or the real cause of the disease?”<sup>1</sup>

*Albuminuria.*—In some cases of this disease the albumen in the urine may greatly diminish, or, for a time, disappear entirely under the use of oxygen. I have seen two cases of this kind. The amendment, however, was but temporary. M. Const. Paul reports a similar case.—*Half-Yearly Compendium*, January, 1869.

The frequent occurrence of albuminuria, in pneumonia and other diseases or conditions involving the respiratory function, is a suggestive circumstance in this connection.

*Rheumatism and Gout.*—But little is known as yet of the effect of oxygen in these diseases. Dr. Golden (*Lancet*, March 10, 1866), observing that the lithic-acid diathesis appeared more decided in cases in which respiration was imperfectly performed, was led to try the effect of oxygen in gout. The result was very satisfactory. Since then Kollmann, an apothecary of Munich, has experimented as to the effect of the inhalation of oxygen upon the quantity of uric acid excreted. He found that it produced an immediate diminution, and that, after continuing it a few days, the uric acid entirely disappeared from the urine. The treatment certainly deserves a trial in these diseases.

*Uræmia.*—I have not been able to find an instance recorded in which oxygen has been employed in this disease, but it

<sup>1</sup> Essai de Pneumatologie Médicale, p. 709.



appears to me to offer a chance of benefit. If, as I suspect from experiments already detailed, oxygen has the effect of diminishing the quantity of urea formed, it certainly should be useful in this affection.<sup>1</sup>

*Headache.*—La Passe (*Essai sur la Conservation de la Vie*) states that he cured himself of “*atroces migraines*” by frequent inhalations of oxygen.

HILL cites one case, neuralgic pain in face, which had resisted every form of treatment, and which yielded promptly to oxygen.

DEMARQUAY.—Case of “*migraine*,” complicated with neuralgic pains recurring in daily paroxysms, entirely cured by oxygen.

BIRCH.—Case of “*nervo-congestive headache*,” of long standing, perfectly cured; another case in a lawyer, from overwork of the brain, relieved while taking the first inhalation. A third, connected with uterine derangement, and occurring periodically, entirely cured.

DR. MACKAY, Professor of Materia Medica and Therapeutics, Queen's College, Birmingham.—Three cases of headache, one from chlorosis, one from bilious attacks, and one from depression from over-use of brain and from mental anxiety—all permanently relieved, the headache ceasing each time *during the inhalation* of the gas.—(*Practitioner*, May, 1869.) These are three out of ten cases of various diseases relieved by oxygen. He considers that these ten cases had this in common, that there was venous congestion in some organ or other. Speaking of neuralgia in general, Demarquay says: “The blood is the regulator of the nervous system. According to this idea, it would be right to endeavor to allay certain troubles of the nervous system by introducing into the blood a

<sup>1</sup> Since the above was written, Dr. Howard Pinkney has kindly furnished me the notes of a case of uræmia following scarlatina, in a child nine years of age, which was successfully treated with oxygen. There was paralysis on one side of the body coincident with convulsions on the other. The attack had lasted three hours, and the face was dusky and the lips blue. After the inhalation of five gallons of oxygen the color improved, and by the time eight gallons had been taken the lips had a natural vermilion hue, and the paralysis and convulsions had ceased. There was no return, and the patient made a good recovery.

greater quantity of oxygen. In fact, modifying the conditions of the blood ought naturally to induce a change in the essential character (*manière d'être*) of the nervous system, central or peripheric."

*Paralysis.*—Beddoes cites two cases cured, one relieved, and one not benefited.

Birch describes a case of complete paraplegia, of "several" years' standing, entirely cured by two years' persistent use of oxygen.

In relation to paralysis, Demarquay observes: "We have seen, in the study of the physiological action of oxygen, that the muscles fix in some sort more especially this agent . . . It is certain that the inhalation of oxygen excites in some persons a necessity for muscular activity. This indication on the one hand, and the anatomical fact which we have cited on the other, prove the powerful effect of oxygen upon muscular action. The fact of paralysis cured under the influence of oxygen comes also to the support of this view."

*Epilepsy.*—Beddoes claims to have cured one case, while in five other cases he was entirely unsuccessful.

Birch adds to his almost miraculous cures two of epilepsy, one case being of thirty years' standing.

Dr. Ramskill (*Medical Times and Gazette*, July, 1863), reports a case of epilepsy in a young man, aged twenty-three, resulting from syphilis. The attacks occurred every fourteen or sixteen days. He inhaled oxygen twice or three times a day, stopping the inhalation only when a feeling of dizziness came on. At the end of three months he had had only one attack, which was slight. The cachectic aspect which he previously had had disappeared. Two years after he saw him in perfect health. He had had no attack for sixteen months.

*Fatty Placenta.*—Assuming the correctness of the views upon which Prof. Simpson bases the treatment of such cases with chlorate of potash, we should have in oxygen a more direct and more powerful remedy than any heretofore employed. Once prove that the foetus perishes from a deficient supply of oxygen through the maternal blood, consequent upon a diseased placenta, and the indication is as plain as in croup or asthma.



*Irregularities of Menstruation.*—Beddoes and Birch both cite cases in which irregularities of the menstrual function were corrected by the use of oxygen. The first case described by Birch is one in which the return of each menstrual period was attended by a most excruciating headache, beginning two days before the period, and continuing two days after its cessation. During all this time the patient was obliged to remain in bed, in a darkened room. This state of things had continued for a number of years, and had resisted every possible form of treatment. The use of oxygen for a short time produced a perfect cure.

In another case, along with various uterine symptoms, there were fulness and weight about the neck and about the base of the brain, and impairment of nearly all the special senses, and also partial paralysis of one side of the tongue. The patient was at the menopause. A few inhalations of oxygen produced a great improvement in the sight and hearing, and a course of six weeks completed the cure.

## CHAPTER VI.

### APPLICATIONS OF OXYGEN IN SURGERY.

THE effect of oxygen upon open wounds or ulcers is very remarkable, whether the gas be inhaled into the lungs, or applied directly to the part.

The following experiments by Demarquay are of the greatest interest. An incision was made through the skin and cellular tissue, and into the muscles near the axilla, of a dog, and the wound maintained open for three days. At the end of that time the wound was of a grayish color at the edges, and slightly red in the centre. The animal was then placed with its head in a receptacle of oxygen, the opening being made to fit tightly to the neck by means of a band of india-rubber. In two minutes the wound had changed to a lively rose-color. The surface presented small ecchymotic spots, which furnished a slight hæmorrhage. At the same time an abundant serous discharge flowed from the surface of the wound. When the inhalation of the gas was suspended, the wound immediately changed its appearance. The rose-color

was succeeded by a grayish hue, and the surface, which had been shining, became dry and dull-looking, resembling a mirror which had just been breathed upon. This experiment was repeated upon several different animals, with similar results.

In the use of oxygen subsequently in cases of great depression of the vital powers after capital operations, M. Demarquay observed, in several instances, the same effect upon the wound.

These observations are of extreme importance. They show the rapidity with which oxygen is taken into the blood, and the effect which it produces upon the reparative processes. They explain also the wonderful power which oxygen possesses, of inducing cicatrization in old and obstinate ulcers, and of which some remarkable instances will be cited hereafter.

Their bearing upon the treatment of the later stages of pulmonary phthisis by oxygen is also very important. That the introduction of pure or nearly pure oxygen into the lungs in such cases should be followed by a certain amount of hæmorrhage from the walls of cavities or the surface of tuberculous ulcers is what they should lead us to expect. They show also that the occurrence of such hæmorrhage should not of itself be considered as contraindicating the use of the gas. On the contrary, it may coincide with the commencement of a reparative process.

Solutions of continuity in the lungs, however, have this peculiarity, that while they partake of the effect of the gas acting through the circulation, they are also exposed to the influence of direct contact. This is of itself capable of producing decided effects, as has been already stated in another connection, and will be hereafter illustrated.

Beddoes, even in the infancy of the use of oxygen, observed its effects upon obstinate and ill-conditioned ulcers. Among others, he quotes a case of scrofulous ulcers of the arms and of one leg, healed in a few weeks under the influence of "vital air."

Another case of ulcer of the leg, which had continued for eighteen years, and had been treated in vain for four years by



Pott, and for seventeen months by Sharp, healed at the end of four weeks under the influence of oxygen. Six months after, there had been no return of the ulcer.

A third case is related of an old scrofulous ulcer on the arm of a debilitated patient. The inhalation of oxygen, in gradually increasing doses, caused an astonishing effect upon the general health, but no tendency to cicatrization of the ulcer. On the contrary, after a time, an inflammatory action was set up. To counteract this, a certain amount of carbonic acid was added, and the inflammation was promptly subdued, and cicatrization took place.

Finally, in a fourth case, there was an ulcer on the leg four inches long and three inches broad, ill-conditioned, and of such a depth as to involve the muscles. After a year of treatment with a vast number of topical applications, together with tonics given internally, there was no improvement whatever. Oxygen was then resorted to, and a very rapid change took place. The general health, which was very much depressed, improved, the strength returned, the ulcer assumed a more favorable aspect, healthy pus was formed, and in fifteen days the sore had closed over three-fourths of its extent. In six weeks from the commencement of the inhalations cicatrization was complete.—(*Considerations on Factitious Airs*, p. 65.) Demarquay describes (p. 792) three cases of phagedenic syphilitic ulcers of alarming extent, which yielded readily to treatment with oxygen. One had existed eighteen months, and had invaded the perinæum, the pubes, and the thighs.

Dr. Golden (*Lancet*, March 10, 1866) reports two cases of fetid phagedenic ulcers, probably of syphilitic origin, which healed very rapidly under treatment with oxygen.

Birch describes a very remarkable cure of a rapidly-spreading syphilitic ulcer of the leg (p. 78). He adds that no other remedy will compare with oxygen as, in common parlance, "a purifier of the blood."

The increase of the recuperative power which oxygen confers has been taken advantage of by Demarquay to enable patients to withstand the shock of severe surgical operations, or the subsequent drain upon the strength which they entail. In debilitated subjects he employs it *before* the operation to

prepare them for it, and *subsequently* to enable them to bear up against the after-effects. He is confident that the mortality after operations can in this way be immensely diminished.

In other surgical affections, such as otitis, caries, etc., especially when associated with anæmia, loss of appetite, and defective assimilation, oxygen is of great value. Demarquay cites a number of cases in point.

*Chronic Pyæmia.*—My notes present a case of this disease in which oxygen was apparently the means of rescuing the patient from otherwise inevitable death. W., aged fifty years, had been operated upon four weeks previously for stricture of the urethra, by external division. A few days after the operation chills set in, and soon an abscess formed under the pectoral muscles of the right side. Another abscess soon followed on the left arm, and a third over the sacrum. By this time his strength was reduced to the lowest ebb; he was unable to raise his head from the pillow, his pulse was 112, soft and gaseous, countenance Hippocratic; vomited every thing taken into the stomach. Tongue broad, dry, leathery, deeply fissured, of a light-brown color. When I first saw him his friends had already given the necessary directions for forwarding his remains into the country, and a clergyman had administered the last consolations of religion. Within the preceding twenty-four hours a circumscribed pleuro-pneumonia had developed in the right lung. His case, sufficiently desperate before, seemed now perfectly hopeless. Nevertheless, with the consent of the attending physician, I determined to see what could be done by oxygen. About four gallons were administered every two hours, beginning at 11 A. M. Each time the gas was given the color returned to the cheeks and lips, and the patient expressed himself as feeling "brighter." The pulse remained about as frequent, but seemed to gain a little strength. Before night the tongue had become moist at the tip and edges, there was less irritability of the stomach, and the pain in the chest had greatly abated. The gas was given every three hours during the night and the following day. The close of this day found the patient with a tongue moist throughout, pulse 108, no vomiting, no pain, to speak of, in the chest; was able to take



freely of stimulants and beef-essence. From this time he gradually but steadily improved. The pleuro-pneumonia disappeared, without running through the usual stages. The appetite returned to a moderate degree. Two more chills occurred, but no further abscesses. The gas was continued about three weeks, the doses being less frequent as the patient improved. At the end of that time convalescence appeared to be established, and the oxygen was discontinued.

Whether in this case the gas exerted any influence upon the septic material in the blood, or whether its effect was merely stimulant and tonic, it is difficult to determine. It is certain, however, that a very remarkable improvement took place simultaneously with the administration of the gas, and which could be attributed to no other agency.

The prolonged contact of oxygen with a denuded surface produces a stimulating effect which varies in degree with the condition of the surface. In the case of recent wounds there is merely a sensation of warmth. In suppurating surfaces the first effect is to render the granulations less florid and softer, and to increase the discharge. If the contact be too prolonged, however, or too frequently repeated, there will be a subsequent reaction so decided as to compel a suspension of the treatment. An analysis of the gas after prolonged contact with a denuded surface shows the presence of an abundance of carbonic acid and a considerable loss of oxygen.—(*Demarquay*.)

It does not appear that the local application of the gas possesses sufficient advantage over its use by inhalation to compensate for the difficulties attending it. Introduced into the blood the action is more uniform and satisfactory, and less liable to become excessive. A transient contact, however, may be of use in cases in which the cutaneous capillaries have lost their tone, and passive hyperæmia is the result. The effect will then be to cause contraction of the vessels, and paleness will take the place of the previous congested hue. *Demarquay* has illustrated this admirably in a case of *eczema rubrum*.

## CHAPTER VII.

## CONCLUDING OBSERVATIONS.

THE foregoing sketch is far from presenting a complete view of the therapeutical results which have been attained by the use of oxygen. Only those points have been brought forward which seem to be sustained by sufficient testimony to entitle them to serious consideration. Numerous isolated cases could be collected in which curative effects have been obtained in a wide range of affections. But enough has been adduced to show that in oxygen we have a remedy capable of aiding us more or less, under circumstances in which the usual resources of therapeutics are inadequate.

Occupying such a peculiar physiological relation to the system, it would be difficult to assign oxygen to any one class in a systematic nomenclature of the *materia medica*. Of its remote effects the tonic and alterative are the most prominent, while a new word must be coined to express its primary action in dyspnœa. Its local action is stimulant, but is appreciable only in diseased conditions of the surface to which it is applied.

A vast and inviting field for experiment is afforded by the possible effect of oxygen in the whole family of diseases supposed to depend upon a toxic material in the blood. In some of these diseases good has already been accomplished by it. But its action in contagious affections, with the exception of cholera, has not yet been studied, and presents a tempting array of possibilities to stimulate investigation. Especially in New York City, where oxygen will soon be placed within the reach of every practitioner, and in a form entirely free from every thing objectionable or troublesome, it is to be hoped that ere long its relations to disease will be as thoroughly studied as have been already its relations to the economy in health.

There is but one condition which may be considered as contraindicating the use of oxygen, and that is the presence of acute inflammation. But even to this, as we have already seen, there are exceptions. Indeed, it is, after all, a question whether we have any clinical proof whatever of this supposed



incompatibility. We do not find in practice that good, pure air aggravates inflammation, nor that the severer forms of the affection select by preference those in whom hæmatisis is most perfect. It may well be, therefore, that this supposed contra-indication will prove to be merely a fragment of the exploded idea formerly entertained as to the physiological action of the gas.

It is undeniable, however, that care should be exercised in the use of oxygen in cases in which there are solutions of continuity in the pulmonary mucous membrane. In such cases the local effect of the gas may be developed, and should be vigilantly watched for. The pulse and temperature will furnish the most reliable guides. But, by using the gas very largely diluted, allowing, for example, twenty or thirty minutes for the inhalation of three gallons, any local action will generally be avoided.

In practice, a great difference will be found in different persons in the readiness with which the gas appears to be absorbed, and in the quantity required to produce a given effect. It is possible that this may be owing, at least in part, to the fact observed by Chevreul, that oxygen is more rapidly absorbed when the blood is more than usually alkaline. This suggests the propriety of using alkalies moderately in cases in which the oxygen does not seem to be easily absorbed, provided their use is not contraindicated. It is possible that by their aid oxygen might be used successfully when it would otherwise fail to produce the desired effect.