PURE AIR,

AND ITS INFLUENCE UPON HEALTH.

My Lord, Ladies, and Gentlemen,—I am here to-night to deliver the first of a series of six "Health Lectures for the People" to be given this winter by the lecturers of the Manchester and Salford Sanitary Association. But before I pass to the immediate subject of my lecture it may, perhaps, be well to ask why it is that we have thus associated ourselves in the common object of saving life.

"For all flesh to die
Is Nature's due ; nor is there any one
Of mortals with assurance he shall last
The coming morrow."

Why, then, should we try to postpone the inevitable fate of mankind? The efforts made, especially by members of my own profession, to prevent disease and to postpone death must appear something extraordinary to those who regard our vocation merely as a mode of earning a living.

The attempt seems to be, and is, so directly contrary to our own interests that it could only be accounted for either by crediting us with a soldier-like desire to grapple with the foes that we have been trained to encounter—to a life-saving instinct—or else to some ignoble terror of death both for ourselves or for other people. But none of these would represent the true origin of the impulse to save life that actuates most medical men and the members of this association.

Death has for the medical man fewer terrors, probably, than for most men. He knows well how seldom it comes in any terrible form as the result of disease ; how frequently the end is peaceful or mercifully passed in unconsciousness ; how often it proves a welcome release from suffering, fatigue, or sorrow.

No! our fear of death—I say it with reverence—is also in one sense the fear of the Lord. We see in its premature form, and in preventible disease, simply some physical wrong-doing, Nature's penalties for sins committed against her laws; and I cannot but think that it would be well if the significance of disease, as it appears to medical men, could be fully grasped by the public mind—if the first thought in every case were given to the true source from which the disease has sprung, and if the first effort made were for the radical removal of the cause. Our true aim is to arouse men from the apathy with which they now regard this subject, and to bring home to them the truth, that much of the disease from which they suffer is simply due to their own wrong-doing, or to the neglect of those to whom they have intrusted their government.

I will now turn to the subject chosen for to-night's lecture. It is often made a reproach to sanitary science that it deals chiefly with very repulsive subjects; that when it is not entangling itself in a maze of figures, such as go under the name of vital statistics, it for the most part busies itself with foul smells, impurities, and nuisances of all kinds.

When our present Prime Minister announced his intention of devoting a large part of the attention of his Government to sanitary matters, his policy was supposed to be correctly designated as a "policy of sewage." Now these are not attractive subjects; and in casting about for something more likely to interest a general audience, it seemed possible that a discourse on "Pure Air" would, at the present time, be as acceptable as any. The title would, at any rate, carry us far enough away from all sources of impurity, and might lead us, in imagination, to the chief haunts of pure air—to the seaside, or to the breezy uplands—to forests of pine trees, or to the mountain top.

If we chose, we might concern ourselves with some of the mighty operations of nature—the processes by which the self-purification of the atmosphere is accomplished. We could watch its watery vapour, gathering in mists in the valleys or over the ocean, rising into clouds, swept along by the winds, and descending in purifying streams in the form of rain. We might try to learn something of the work that goes on in the vast laboratory of the sky—the destruction of organic matter by oxidation—and how this is assisted by the whirlwind and the storm, by the stirring up of the depths of the aerial sea by cyclones, and by the electrical discharges, of which we have such mighty evidence in the lightning and in the thunder.

And yet, from a sanitary point of view, what would all this be but an insight into a very perfect and very elaborate system of scavenging?

Air and water, the wind and the storm, are for us, as sanitarians, the great purifiers of the universe; and the phrase "air sewage" is a customary description of the results of their work. We find then that we cannot long remain in the pleasant regions to which we are tempted to turn in the first instance, and we have to come back to the unpleasant details from which we recoiled at the onset.

But there may be another objection to the subject of our discussion to-night. It may appear that we are all sufficiently fond of pure air, and that there need not be much said about its virtues at the present time. I only hope that it is so, and that what I have to say will fall upon ears already well prepared to accept my doctrine. But, in truth, the fact that air, pure in quality and large in quantity, is absolutely needful to keep people in good health is comparatively a very recent discovery, and it has really been forced upon our attention by a very grievous amount of suffering and loss of life in past times—nay, I may say that even now the lesson is very imperfectly taught, and that at the present time many thousands of lives are lost for want of fresh air.

In early times, when the English were much thinner on the ground than they are now, they lived for the most part in ill-constructed, draughty houses, often, as we are told by Erasmus, mere shelters formed of wattles, plastered with clay. In those days the evils of organically impure air were probably much less felt than they became later on. In the large towns, doubtless, there was sufficient crowding together to do harm. Thus the desolating plagues of the middle ages would be intensified in their virulence by the mode in which the people lived. But very little notice appears to have been taken of the subject until the beginning of the last century.* The Houses of Parliament then began to bestir themselves in order to bring a sufficient supply of air into their chambers. About the same time one of the engineers, Désaguliers, who had been employed in the House of Commons, was also requested to advise respecting some transport vessels lying at Spithead. An expedition was then being organised against the Spaniards. Troops had even been embarked, but "numbers of them were obliged to be relanded and sent to hospital, for the ships stunk to

* "Public Health" Dr. Guy, p. 131.

such a degree that they infected one another." This engineer's advice was not then taken, but shortly afterwards a brewer named Samuel Sutton also took the matter up. In the discussions which then took place the subject was well ventilated, even if the said ships were not, and the result was, as Dr. Guy tells us, "that ventilators and schemes of ventilation came into fashion; and when the managers of public establishments found their buildings offensive, and deemed them dangerous, there was always some ingenious person to assist them in the work of improvement. Hence it happened that, in 1784, St. Thomas's Hospital was ventilated by a Mr. Whitehurst, of Derby; and that, the year following, a contrivance borrowed from a French frigate began to be used in English vessels of war." It was mainly owing to these and other sanitary measures that a great improvement at once took place in the health of the navy; Sir Gilbert Blane states that in 1779, out of 70,000 men voted for the service of the navy, 28,592 were sent sick to the hospital, and 1,658 died; but in 1813, out of just twice the number (140,000) only 13,000 were sent to hospital, and 977 died. In the former year, therefore, the sick were more than 2 in every 5, and the deaths 1 in every 42, whilst in 1813 the sick were about 2 in 21, and the deaths 1 in 143—the sickness reduced to one-fourth, the deaths to little more than a third.

Dr. Guy gives also the following numbers of the sick during years when the number of marines and seamen voted was the same, namely, 120,000. They form, as he shows, a descending series: 20,544, in 1797; 15,713, in 1798; 14,608, in 1799; 8,083, in 1805; 7,662, in 1806; or taking a similiar comparison where the number voted was in each year 100,000—the years 1782, 1795, and 1804—the figures for the sick are 22,909, 20,579, and 7,650.

"Is it possible," asks our author, "to imagine a more conclusive demonstration than these facts afford of the reality and importance of the science and art of hygiene?"

It was about the same period to which we have been referring that Dr. Joseph Clarke, in 1783, then master of the Rotunda Hospital in Dublin, turned his attention to the ventilation of that institution. For twenty-five years there had been a most frightful mortality amongst the infants born in the hospital. In this period, in round numbers, out of 18,000 children born, no fewer than 3,000, or one in every six, had died, mostly within the first fortnight after birth, of what was commonly called "nine-day fits."

This disease was a peculiar form of convulsion, affecting first the muscles of the lower jaw and then passing on to other parts of the body, until it destroyed life by a general spasm of the muscles of breathing.

After a thorough ventilation of the wards had been carried out the number of these cases diminished at once in a surprising manner, and in the next twenty-eight years, out of 15,072 children born, only 550, or 1 in every 104, died in the hospital. I am informed also by Dr. McClintock, of Dublin, that during his mastership, ending in 1861, further improvements in the ventilation took place, and since then the occurrence of this disease is almost unknown.

One might have supposed that these lessons would have been sufficient to teach the vast importance of pure air where people are massed together in ships or in buildings on land; but just as we have recently seen in the case of the last Arctic Expedition—which suffered so frightfully from scurvy, in consequence of the neglect of medical teaching—so it has been over and over again both in the naval and military forces of the country and in public institutions throughout the land.

I will give one or two instances of the truth of this statement, only premising that they might be multiplied many-fold if we had time to go fully into the history of the need of pure air.

1. In the *Navy*, as late as 1861, a fearful lung disease broke out in some of the ships of the Mediterranean Squadron, and the cause was found to be the crowding of the men on the lower deck. "In one ship, the St. Jean d'Acre," says Dr. Bryson, "only fourteen inches space were allowed to each hammock; and so thoroughly was fresh air excluded that the temperature of the air above the hammocks was 8° or 10° hotter than the air below, and nausea was caused in anyone going between-decks from the open air."

2. In the *Army* similar histories are to be found. Thus, in the West Indies, about fifty years ago, Sir A. Tulloch tells us that the men slept in hammocks which touched each other, in barracks without ventilation, and every year, in consequence, in that most equable of climates, a large number of deaths took place from consumption.

The records of deaths from this disease in the army afford a remarkable proof of the waste of valuable life from the want of pure air, and of the immediate good effects of its plentiful supply. In the report of the Commission on the Sanitary State of the Army, published in 1858, numerous instances of this kind are given, taken from almost every branch of the service. Perhaps the most striking is that of Her Majesty's Foot Guards. It must be remembered that the Guards are physically the very select out of the population. Any impediment or disease is enough to prevent a man being taken for military service, and none but the strongest and best-looking recruits are accepted by the Guards. The young Guardsman's is in every sense a picked life and would be considered as a first-class life by any insurance office As soon as the recruit enters the service he is placed under the entire control of educated officers. His diet, cleanliness, and personal habits are strictly attended to. He is lodged in barracks that have cost the country far more than was the relative cost of the house in which he was brought up. He never leaves the country in time of peace, but passes from his town quarters in London to his country quarters at Windsor or at Chichester; and whenever he suffers from the slightest ailment his medical adviser is instantly beside him—he has hospital accommodation, medicine, attendance, and every necessary comfort immediately. One would say that of all men a soldier in Her Majesty's Guards was the most likely to enjoy perfect health and long life. And yet look at the result! At every age the mortality of the Guards is twice that of the ordinary civil population of England, although the latter is exposed to all the hazards of life arising from poverty, hunger, and dirt, from imperfect shelter from the elements, and from neglect of all kinds, and the chief cause of this excessive mortality was consumption. How was this strange circumstance to be explained? Mainly by the want of fresh air—defective ventilation of the barracks. As Dr. Farr says, in his evidence, "If our army consisted of 100,000 Guards we should save 1,500 of them every year by proper sanitary arrangements, who, from all experience, are as certainly killed by neglect as if they were drawn out and shot."

In the treatment of the sick and wounded, also, it is quite a recent discovery that pure air is the medicament more urgently and more largely needed than any other. In the Hospital of Lariboisière, in Paris—the most perfect of its kind when built thirty years ago—there was a very elaborate system of ventilation by means of fans in one pavilion, and by extraction in another; but the total quantity of pure air that was supplied per head per hour was only 700 cubic feet—not one quarter of the amount that is now thought necessary, for an ordinary dwelling-house inhabited by healthy people.

It is the recognition of the paramount necessity of keeping the air of hospital wards almost absolutely pure that has caused many surgeons to prefer to treat the wounded in tents or in well-ventilated wooden sheds, that can with trifling expense be taken down, burnt, and rebuilt with fresh uncontaminated material.

In the American Civil War, between the Northern and Southern States, it was found that nothing was better for the sick and wounded, winter and summer, than a tent or a ridge ventilated hut. Erysipelas and hospital gangrene were almost unknown; wounds healed more rapidly; and even in fractures the beneficial effects of the fresh air were to be remarked.

The same fact comes out strongly in the records of the Austrian army. In 1854, at some of the stations of the Austrian army in Hungary, the plan was commenced of treating a portion of the patients in tents instead of in the permanent hospitals. The results were very satisfactory. "The most severe maladies ran their course" much more mildly in the free air, and the patients recovered more quickly and more perfectly than in the confined spaces of hospitals. Typhoid fever, smallpox, wounds, and other inflammations, did much better in the tents; and in no single case could it be made out that gangrene originated in a tent.

One of the largest of the Continental hospitals, that of Leipsic, is now being constructed chiefly of wooden wards; and I believe that the further stipulation is made that all the corners of the wards shall be rounded off so as to leave no lurking places in which any enemy of a pure atmosphere can by any possibility remain.

I have brought forward these instances of the extreme need of fresh air, not only because I think they are interesting in themselves, and because they are lessons of Nature's teaching that should never be lost sight of, but also to impress the truth more forcibly upon your minds; for the same processes are constantly going on around us at the present day. We are apt to be startled when we read in the newspapers of the poisoning of a whole family, or the slow starvation of some person, either by design or neglect; but we do not realise the fact that at the present time there are many thousands dying every year from slow poisoning of the air, or from deprivation of that fluid food which nature has everywhere provided so bountifully for us. To prove that this is no mere figure of speech, it is sufficient to look at the enormous death-rate from diseases of the respiratory organs in England and Wales, and then to note the variations in the percentage of those complaints in different parts of the country. Yet these deaths are only a small portion of those traceable to impure air. I have elsewhere* given some strong evidence, proving that the large class

* Lecture on "Foul Air and Lung Disease.

of diseases called strumous or scrofulous, which carry off so many young children, are mainly caused by the impure atmosphere in which so many of them are obliged to live. The variations of these diseases also shows the local character of the causes by which they have been produced.

I trust, then, that with these proofs of recent misdoing in relation to the supply of air you will not think that I am insisting too much upon its importance.

But we have next to inquire what is meant by pure air. Atmospheric air, as most of you will probably be aware, is a mixture of certain gases or vapours. It is usually said to be made up of three gases—nitrogen, oxygen, carbonic acid, and of aqueous vapour. About 21 per cent consists of the fire-making gas, oxygen, with 79 per cent of a neutral gas, nitrogen—1 part of oxygen to 4 parts of nitrogen. The latter gas, when uncombined, chiefly rejoices in negative properties. It will not burn, will not support combustion, nor yet life; it is colourless, odourless, insoluble in water, and without taste; and yet, in combination, it forms some of the most powerful, most explosive, most poisonous substances in nature.

Oxygen, on the other hand, is the great supporter of combustion, and this fact is easily shown by some often-repeated, but always beautiful, experiments. Oxygen is also usually present in pure air, in minute quantities, in the form of ozone, which is a kind of combination of oxygen with itself—an oxide of oxygen, O_2O—"three single gentlemen rolled into one." This substance is formed in the great laboratory of nature by the operation of various electrical and physical agencies. It is produced during thunderstorms by the dashing of the waves on the sea-shore, or in the downward rush of the waterfall. It is the most determined foe of all organic matter, seizing upon it and destroying it wherever it meets with it. Unfortunately, its own existence is sacrificed in the process; and hence we never meet with this substance where people are crowded together in towns, or in rooms where they live. It is entirely absent in the air of towns, and even in the best ventilated bedrooms.

The other substances always present in atmospheric air are carbonic anhydride (CO_2), or carbonic acid gas, as it is called, in the proportion of about 4 parts in 10,000, and aqueous vapour in varying proportions—according to the temperature and other meteorological conditions of the atmosphere. The CO_2 is the fearful choke-damp gas of the coal-mines, often suffocating those whom the fire-damp has spared. It oozes out of the ground in the notorious Grotto del Cane, which has received its evil name from the number of dogs that have been cruelly cast into it to show its poisonous effects. Its presence and properties are also easily shown by experiments, such as extinguishing a lighted taper immersed in a jar of the gas, and forming a precipitate with lime water or baryta water. The presence of watery vapour in the air of Manchester is usually sufficiently evident, especially at this time of the year, in the form of fogs, &c. Its presence in a room may also easily be shown by placing a mixture of ice and common salt in a flask in any room. Vapour soon condenses outside the glass, and may be scraped off in large quantities. But these are far from being all the things that are found even in pure air. The atmosphere is the natural receptacle for myriads of emanations that are continually arising from the face of the earth, from plants and animals, and from results of their various operations. "As the earth receives all things falling down upon it from the air, so, in return, does the universal air receive many things back from the earth." (Boerhaave.) There is thus in the air an infinite variety of composition. There are also in it many kinds of floating bodies.

Since, then, we may find even in the purest atmosphere traces of numberless ingredients that must be considered natural to it, it follows that, in estimating the purity of the atmosphere, we have to regard the quantity in which its several ingredients occur rather than their quality, and the proportion in which each exists rather than their actual presence. We have seen that the quantity of oxygen varies very slightly; but very small variations in the proportion, even of this ingredient, may be of vast importance to the animal economy. The probability of this being so will be readily seen when we consider the large quantities of air that we take into our bodies in the course of a day or of a week. Every day, as Dr. Angus Smith tells us, we imbibe one or two thousand gallons of air; and if we follow this air in its course through the body we shall cease to be astonished at the effects of any small proportion of impurity that it may contain.

There are indeed many lessons that may be thus learnt, and they will afford a striking commentary upon the phrase of the Psalmist that we are "fearfully and wonderfully made." The problem that has to be solved is that air must be brought into the body at all temperatures, from the 50° below zero of the arctic regions to the 200° to 300° of heat of the glass-blowing or iron-smelting works—and this air must not only enter the lungs but, at least a portion of it, must penetrate into the vital fluid, the blood, whose temperature, if health is to be maintained, must never vary more than a very few degrees—5° or 6° perhaps, at the most. This would seem to be a sufficiently difficult task, but it is accomplished by a series of very wonderful provisions. First, the air is received either into a warm chamber, the mouth, partly filled with warm air, or it passes through the nostrils, in which is a kind of warm water apparatus—convoluted passages, in which a certain degree of warming of the air necessarily takes place. Thence it is carried along the air passages; and these are always partially filled with already warm air. Even by the deepest effort at expiration they are never emptied, but are kept from collapsing by hard rings of elastic gristle. These tubes are also furnished with a self-acting regulating apparatus in the shape of muscles which, to a certain extent, control the passage of the air along them. In ordinary breathing only about twenty cubic inches (about two-thirds of a pint) of air enter the lungs at once, and as this is gradually mixed with about 300 cubic inches, or above two quarts, of already warmed air, no great amount of cooling of the whole takes place. Again, another safeguard against cooling the blood is found in the rapid rate at which it courses through the little capillaries. It is only exposed for a moment to the air and then dives down again into the well-warmed recesses of the frame. The final result of all these provisions is that the blood in the lungs is seldom cooled down more than two or three degrees in temperature.

That there is real danger, however, from this source is sufficiently shown in the great increase of deaths from bronchitis and other lung diseases in the winter months—a mortality that takes place chiefly amongst the very young and the very old—in persons, in fact, whose circulation is feeble, and whose vital heat is small.

But a very large number of the diseases of the respiratory organs are due far more to imperfect protection of the general surface of the body, and to impurities in the air breathed, rather than to the direct influence of cold air in the air passages of the lungs. What are commonly called "colds" are often caught from inhaling the vitiated atmosphere of crowded rooms, or are the result of some derangement of the circulation of the blood, either from feebleness of its current in some part of the body, or from cold being unequally applied to the surface. When people are well clothed, and when, by active exercise, the blood is sent vigorously through the frame, and the air breathed is the pure air of the open country, it is very seldom indeed that any harm results from breathing it.

But, again, the question may be asked, with some not unreasonable fear, how can the blood be exposed to the air and yet not pour out of the blood-vessels? The first glance at the structure of the lungs does not tend to remove this fear. The branching tubes along which the air is conveyed end at last in minute twigs, on which are placed, like leaflets, a number of little soft flexible bags called air cells, formed of a membrane $\frac{1}{3000}$ of an inch in thickness—not much thicker than the film of a soap-bubble. It has been calculated that "the lungs of a full-grown man contain 600,000,000 of them; and if the membranes of which they are composed were spread out flat they would cover 21,000 square inches of surface—a space thirty times larger than the external skin." Lavishly spread over the surfaces of this membrane are fine hair-like blood-vessels, twisted and coiled about so as to offer as much surface as possible, and at the same time permit the distension of the air cells without stretching or breaking any one of them.

Some people take pleasure in looking at other persons risking their lives in feats of dangerous hardihood—trapeze jumping, tight-rope dancing, &c.; but these very people are, of all others, the least likely to take pleasure in their own danger; and yet they and we, every one of us, are only separated from death by a thin film of membrane $\frac{1}{3000}$ of an inch in thickness. This is truly a sufficiently fearful thought. But how wonderfully is the danger provided against; how seldom does fatal coughing up of blood occur, except in cases of disease. How, then, is it prevented? I cannot stay now to dwell on all the precautions that are taken, but in the first place the texture of the lungs themselves guards against it; it is tough and elastic in the highest degree. Next, the lungs are hung in such a way as to obviate all jar, all undue strain on any part. They are f stened to no bone, but hang from the soft parts, and from elastic bands of gristle, and the air tubes in their downward branching break all shock. Lastly, the air is drawn into the lungs by the intervention of atmospheric pressure. If the bony walls of the chest were fastened to the tender lungs, when they were drawn upon, as they would be when a deep breath was taken, they would soon be torn in pieces by the strain; therefore there is in health no direct connection between them. The lungs are left loose in the cavity of the chest, and are kept closely applied to its walls by means of a closed sac, called the pleura, which only contains a soft lubricating fluid, and which transmits to the lung, in the gentlest possible manner, the expanding force of the ribs when acted upon by the inspiratory muscles. Making its way past all these possible dangers, then, let us suppose that the air at length reaches the blood-vessels in safety.

We have already seen that one or two thousand gallons of air are thus brought daily in contact with the blood; and on the other hand I may tell you that the whole of the blood in the body is thus presented to the air in the course of less than a minute of time—about a thousand times every day.

This abundant exposure of the blood to the air may be some proof of the urgent need for air that is felt by the animal economy; and at the same time it shows the immense importance of purity in the air so exposed to that which is the very life of the body.

This truth will become still more clear if we follow the air a little further on its course through the frame, and if we briefly note the work it has to do. When it enters the blood the oxygen is at once embarked in a number of little vessels—the blood cells or red corpuscles as they are called. These little bodies, $\frac{1}{3000}$ of an inch in diameter, are found in myriads in the blood (about three millions of them in a single drop), and they are now known to be the chief carriers of oxygen through the body. The hæmoglovir that they contain—a substance of a purple colour—takes up the oxygen, and changes at once to the bright scarlet colour of arterial blood; but it holds the oxygen by so loose a grasp that, directly it reaches the tissues that require it, it gives it up at once.

We hardly know even yet what takes place in each of the myriad workshops, the tissue-cells, of which the body is composed. In only a few cases has the action of the oxygen thus conveyed been ascertained; but in nearly all the operations of the animal body the intervention of this powerful agent seems to be indispensable. It is in fact the means by which the force stored up in the tissues is set free. Owing to its intensely active affinities it becomes the liberator of the energy contained in the food that has been eaten, and hence it is for animals the paramount necessity. No muscle or nerve can work, and all vital action is arrested, in its absence.

But we have not yet done with the work accomplished by the air in the lungs. It is true that life has been quickened by its presence; but what is the result of the activity thus excited? The result is ultimately, and in a very short period, the death of the parts that have been thus visited.

In a physical as well as in a far higher sense, sacrifice is necessary to life. In order that the body, as a whole, may live, myriads of its parts die every hour. As Jeremy Taylor said ("Holy Living and Dying," p. 361), with a depth of meaning that even he could scarcely fathom, "Every day's necessity calls for a reparation of that portion which Death fed on all night, when we lay in his lap and slept in his outer chambers. The very spirits of a man prey upon the daily portion of bread and flesh; and every meal is a rescue from one death, and lays up for another. And while we think a thought we die—and the clock strikes, and reckons on our portion of eternity. We form our words with the breath of our nostrils—we have the less to live upon for every word we speak."

The truth of this statement will appear clearer in the light of the following facts: Carbonic acid gas is one of the final products of the destruction of organic matter by oxygen. When the animal body is placed after death in a cremation furnace, it is resolved in the course of an hour or two into carbonic acid, aqueous vapours, and some nitrogenous, sulphuretted, and phosphuretted vapours' which pass into the air, leaving, as you know, only a handful of ashes behind. But precisely the same process is continually going on during life. A species of cremation is being performed every moment in every part of our bodies, and the results of this destruction are deposited in the blood—in the impure blood of the veins—to be by it passed on to the various organs by which the refuse matter is at length expelled from the body. The nitrogenous parts of this refuse and the ashes of the furnace are chiefly excreted by the kidneys and the skin—certain heavy carbon compounds by the liver; but the great final result of the combustion of carbon (CO_2) has to be got rid of in the lungs.

It is not difficult to prove that this removal of carbonic acid gas is effected by the lungs. By breathing for a short time into a vessel originally containing pure air it is soon largely impregnated with carbonic acid, and its oxygen is diminished in proportion. The product extinguishes a light, as we have seen the former gas do, and gives the same reaction with either lime or baryta water.

The air, on entering the chest, contains, as we have seen, 21 per cent of oxygen and 4 parts in 10,000 of carbonic acid gas; expired air, on the other hand, contains only 13 per cent of oxygen and 500 parts in 10,000 of carbonic acid gas.

And now we are at once introduced to a new branch of our subject—the sources of variation in the ingredients of the air we breathe—and must face the inquiry as to the point at which it ceases to be pure health-giving air. This is far too wide a subject to be dealt with now in its entirety; but with regard to one ingredient—the carbonic acid—you have already seen the two chief sources of its variation—first, in the oxidation of carbon, such as goes on in ordinary combustion of fuel; and, secondly, in the respiration of animals and plants. An enormous amount of CO_2 is thus poured into the air every day. It has been calculated by Dr .Angus Smith that 15,000 tons of this gas every day pass into the air from the combustion of coal in Manchester alone, and the respiration of its inhabitants would also produce many hundreds of tons of the same fluid. It is not surprising, therefore, to find from the following table that Dr. Angus Smith obtained more carbonic acid in Manchester than on the sea-shore, and that it was especially abundant in days of fog and mist. The marvel rather is that the proportion of CO_2 is not larger—that our large towns, in fact, are not like so many Grottoes del Cane, or brewers' vats, suffocating the inhabitants in their own fumes :—

AIR.

	Oxygen. (Volume per cent.)	Carbonic Acid.
Sea-shore, Hills, &c.	20·999	·0332
Manchester Suburbs (in rain)	20·980	—
" " (fine)	20·947	·0403
" " (fog)	20·910	·0679
Close Sitting-room	20·890	·0970
" " (with lamp)	20·840	·1177
Pit of Theatre	20·740	·3200
Backs of Houses	20·700	·0774
In a Mine	20·140	·7850
" (badly ventilated)	18·270	2·5000
When Candles go out	18·500	—

The reason for our immunity is to be found in the self-purifying power of the atmosphere, and in the action of plants. The vegetable kingdom finds its nourishment in that very substance that is the bane of animals. Thanks to the power conferred upon them by the light of the sun, they are able to decompose the CO_2, to divorce the carbon from its mate, to build up the former into their tissues, and to set free the oxygen to be again the succourer of the animal creation. Thus the balance between animal and vegetable life is kept even, and we may to-night take the practical lesson from it, that in our crowded towns and cities where so much of this noxious gas is produced, it is well to have as many open spaces and as much green vegetation as possible. The Metropolis sets us a good example in its numerous parks and squares and other green oases interspersed throughout its crowded streets, and it probably owes its proud position as the healthiest city in the world not a little to the morsels of country greenery that are thus brought into the town.

But the beneficent action of plants would have been almost unavailing to purify the air unless a further power had existed to aid it. This is the power possessed by the air of at once drawing into its depths the gaseous poison as soon as it is formed. This work is accomplished by means of a property of gases, discovered by our great townsman John Dalton—the power of diffusion of gases—a power by which the carbonic acid particles pass into the interstices between the particles of common air as if they were being sucked away with all the force of a powerful air-pump. This power of diffusion is of vast importance in preventing the accumulation of poisonous gas, but I need hardly say that it will not do to overweight it. If you glance again at the table you will see that in spite of its operations, considerable variations in the quantity of carbonic acid do occur in the air of rooms or crowded courts, and still more in badly ventilated mines. Remember then the sources from which the vapour may arise; and in these days of gas-stoves be especially on your guard against the products of combustion of the gas. It has been calculated that a single gas-jet with an ordinary burner produces in the course of an hour as much carbonic acid as seven adult human beings. To warm yourselves, therefore, by means of burning gas, without providing an effectual means of escape for the invisible smoke that it produces, is to expose yourselves to great risk of gradual deterioration of health, and often of immediate headache, from the noxious fumes that you take into your bodies.

But having noted the sources of variation of carbonic acid, and the means by which its quantity is in great measure controlled, it may fairly be asked, What proportion of the gas must be regarded as constituting an impurity injurious to health? Here we come upon what at first seems to be a serious discrepancy in the teaching of our doctors of sanitary science. It has been shown, on the one hand, by different observers, that as much as 17 to 23 per cent of *pure* carbonic acid, if mixed with oxygen, may be breathed for some time without much bodily injury; and yet, on the other hand, the whole school of sanitarians agree that an addition of anything more than 2 parts per 10,000 of CO_2 (or half as much again as there was at first), is likely to produce serious harm to the constitution. How are we to reconcile these contradictions? The explanation is really simple enough. It is not so much the carbonic acid that has to be guarded against as the company that it usually keeps—it is shunned for the sake of its bad companions.

1. Carbonic acid, when it is produced in ordinary combustion, is not pure—it is accompanied by a still more deadly gas, carbonic oxide—by certain sulphur compounds, and as we know to our cost in Manchester, it is often accompanied by soot and tarry matters, which together make up that enemy of all purity, *Black Smoke.* I cannot stay now to reckon up all the evil that has been wrought by this grievous compound, whose presence in the air of our towns is the more to be regretted, because it has been proved over and over again by practical men to be quite unnecessary and easily to be prevented. Floating over our great centres of industry like a dense cloud, it shuts off the genial light of the sun, and deprives the inhabitants of one great stimulus to vital action. It also passes with the air into their tender delicate lungs, and by its constant irritation, leads to the large class of diseases of the respiratory organs that forms so large an item in the Registrar General's returns from this part of the country. It not only descends upon our public buildings, erected at great cost, and destroys their delicate tracing and artistic decoration, and makes our statues of public men into ludicrous caricatures, but it likewise penetrates into the homes of our industrial population. It makes cleanliness almost an impossibility, and thus takes away the inducement to that important element of social happiness and health; and what is still more detrimental from our point of view, it causes all who do make any effort at cleanliness to close their doors and windows, and thus prevents fresh air of any kind from reaching the interior of the dwelling.

2. The second source of CO_2 is still more certainly the origin of dangerous poisonous emanations. The aqueous vapour arising from the breath, and from the general surface of the body, contains a minute proportion of animal refuse matter which has been proved, by actual experiment, to be a deadly poison. I have, in a number of instances, estimated chemically the proportion of this organic matter, and have shown that it contains ammoniacal compounds, such as urea, resulting from the decomposition of the animal body. Dr. Hammond, an American, has also shown its poisonous properties. He kept a small animal under a bell glass well supplied with air and free from the influence of carbonic acid gas, but in the space of forty minutes it died, poisoned by the organic emanations from its own body. It is this substance that gives the peculiar, close, unpleasant smell which is perceived on leaving the fresh air and entering a confined space occupied

by human beings or other animals, and it is really this material that is aimed at by sanitarians when they tell us to avoid air containing more than 6 parts per 10,000 of carbonic acid gas. Experiments have proved that when air is contaminated to this extent by respiration it contains sufficient organic matter to make it distinctly appreciable by the senses, and any excess beyond this is likely to be decidedly injurious to health. Air thus charged has been fully proved to be the great cause of scrofulous or tubercular diseases, and it is the home and nourisher of those subtle microscopic forms of life that have lately become so well known under the title of germs of disease, or microzyms. It is probably the source of a large part of that increase of mortality that seems inevitably to follow the crowding together of the inhabitants of towns. Dr. Farr has shown that as the density of a population increases, as the people get thicker on the ground, in that proportion also does the general mortality increase. We learn, on further inquiry, that the increase takes place not only in fevers and chest disorders, but also in complaints of the nervous system, in gastric affections, and in infant mortality. Organic matter is almost the only ingredient that can be said to be truly foreign to atmospheric air. Fresh air naturally never contains the smallest particle of the kind. The oxygen contained in air is so entirely hostile to it that if it can be swept away for a short time into the depths of the atmosphere it is completely burnt up and changed into innocent gaseous substances, And here it is that we come upon the chief reason for the insistance of sanitarians for plentiful currents of air wherever living beings are living under shelter from the elements. Most of the other impurities of air are diffusible, and make their escape through any hole or cranny they can find, but the substances we are now dealing with are not diffusible—they are not of so active a nature as vapours and gases, and therefore they are much more difficult to get rid of. Organic impurity, however it may be formed, if left to itself floats for a time in the atmosphere, just as we see in the motes that fleck the sunbeam, and then, instead of passing away like a gas, it settles quietly down, and only very slowly changes through the operation of ordinary putrefactive forces. It needs, in truth, the agency of the wind to move it on; and hence the word ventilation, in the full sense of its derivation (from *ventus*, the wind), expresses most accurately the only mode in which it can be swept away, and its noxious properties burnt out of it by the oxygen or ozone of the atmosphere.

And now we find ourselves on the borders of a subject of great difficulty. Who is there that has not heard of the various systems of ventilation that have been tried at different times, and of the many failures that have resulted from these trials? It would be presumptuous in me if I were to attempt to deal thoroughly with so difficult a subject, and yet there are certain considerations concerning it that may afford serviceable hints for each one's guidance. Almost any system of ventilation is, in truth, better than none.

An enormous supply of fresh air is needed in order to preserve the degree of purity that I have mentioned, namely, freedom from perceptible smell, and an increase of only six parts per ten thousand of carbonic acid gas. Even in rooms that are quite clean to begin with, three thousand cubic feet, or about ten thousand gallons, of fresh air have to be supplied per head per hour. It is this necessity that causes the great difficulty of the subject. This quantity cannot possibly be supplied without much movement of the atmosphere—without, in fact, that true ventilation, that action of wind—which we have already seen to be necessary. But nobody likes a draught. Thomas Hood retorts upon the poet Thomson, when he speaks of the "ethereal mildness" of spring, that he "finds her breath a bitter blighter, and feels her blows as though they came from Spring the fighter." And so I suspect it is with most of us. If the air that we have seen to be needful comes in upon us in the form of a thin fine current directed upon one small portion of our bodies, we try to move out of its way, and very often we proceed to stop up the chink through which it comes. Patent ventilators, after no very long lapse of time, are often found closed or stopped up with any handy stop-gap that people can readily find. But are ventilation and draughts really synonymous terms? Can we not in some way circumvent them? I believe that in most cases we certainly can.

Our power of perceiving currents of air depends upon (1) their velocity, (2) their size, and (3) on the warmth or coldness with reference to the sensitive parts of our body.

1. Now the hand is especially the seat of the sense of touch, and can best appreciate changes of temperature; and yet if the hand is moved through the air at ordinary temperatures at the rate of 1½ feet per second, it will not detect the impact of the particles of air upon the skin. Any current, therefore, flowing into a room at a less rate than ninety feet in a minute will not be felt by the inhabitants. To cure a draught, then, the velocity must be diminished, or its temperature must be increased. But in order to introduce a given quantity of air into a chamber in a certain time, a slower

rate of movement will be required in exact proportion as the opening through which it flows is larger. Hence we learn the lesson always to make the ventilating openings large enough, and if they let in draughts to make them larger still, but to shut out any outer wind by external shutters that break its force.

2. When you have obtained a sufficient column of air for the purpose of ventilation, you may break its force by making it pass through a number of fine openings, such as there are in perforated zinc, or by passing it through thin layers of cotton wool; and this plan has the further advantage of filtering it from the soot and other foreign particles, in which the air of towns abound.

3. A draft may often be prevented by directing the air current so that it may pass first into parts of the room where our bodies are not likely to be. It may thus be made to strike against other air in the room, or against the ceiling or walls, until its force is broken, and it will mix gently with the general atmosphere. Air is a fluid, like water, only more subtle in its character, and thus its currents will usually flow in straight courses, unless they are turned aside by obstacles in their way. You can, therefore, guide them in any direction you please, and it is thus that the Sheringham valves act. These are shutters placed inside a room, opposite an opening in the wall, so as to direct the current upwards. The upright tubes advocated by Mr. Tobin and others work in a similar manner. The sashes of an ordinary window-frame, as Dr. H. Bird shows, may be made to answer the same purpose, by partially opening the top sash of the window, and filling up the upper vacant space by finely-perforated zinc, or a gauze frame partly filled with cotton-wool. In this way two openings are left—an inlet formed by the space between the sashes, and an outlet above—and from neither of these ventilators need any draft flow. The air will be directed upwards or obliquely inwards by the shape of the lower opening, and its force may further be broken by putting cotton-wool, loosely packed, into the crevice between the sashes.

4. The sensation of a draft may be diminished by warming the air. This is partially accomplished by the means just described, by which the cold current is made to mix with the already warm air of the room before it reaches our bodies; but it is still better when the air can be warmed by other means before it is introduced at all. There are many methods of accomplishing this. Various grates and stoves, with chambers in which the air is heated before it enters the room, and some of those that are heated with gas, are a very simple and economical mode of heating and ventilating

a bedroom; only be very careful (1) that the air entering the room comes from the outside, and that it is from a pure source, not near any source of impurity; and (2) that all the products of combustion are safely conveyed to the outside—if possible along a flue—and be very sure that there is no down-draft to carry the vapours back into the room.

By one or other of these means I am quite sure, from actual experience, that you may obtain the required enormous quantity of air, without draughts, but with sufficient power to sweep all noxious non-diffusible materials out of your rooms. Only one further caution will I give, and that is to take good care that your supply of air does not come from your drains.

I have said but little in this lecture as to the nature of the external supply of air. This is not so much within your own control. We cannot all rush away into the country when the day's work is done. But bad as a town atmosphere generally is, it is far better than indoor air. It is every man's duty to see that the manufacture of black smoke is controlled as much as possible, that no nuisances should be allowed to exist, and, most important of all, that space should be given throughout a town for the free circulation of the beneficent winds of Heaven. But in these things you must work by the intermediation of your town authorities, whereas all else that I have told you has an immediate and direct personal application.

This indeed is the conclusion of the whole matter. We have heard some of the fatal results of breathing impure air. We have seen the properties of the constituents of the atmosphere, and the readiness with which they are altered, and some of them made poisonous. We have traced the course of respired air through the body, and have seen some of the delicate textures that it has to traverse, and how readily these may be injured by impurities. The sources of some of these impurities have been examined, especially those from combustion and respiration. Lastly, we have seen the very large quantity of fresh air that is required by every living being. Let the result of all this teaching be, that we resolve strongly to breathe air as pure as it can possibly be got, and in fully as large a quantity as is necessary. Remember that every breath of impure air endangers health and takes away energy from the body—that we cannot breathe any portion of the air that has already passed through the lungs without danger of harbouring the seeds of that fearful disease, consumption—and that a close unozonised atmosphere necessarily weakens our powers and debilitates our systems.