ON THE PHYSIOLOGY OF THE OPEN-AIR TREATMENT.

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You heard on Wednesday Professor William Bulloch's lecture with regard to the infection of consumption, the origin of contagion, and so on. He laid before you the results that have been recently communicated by Hamburger, who reached the conclusion that 95 per cent. of all the children in Vienna, aged 15, are infected with tuberculosis. The evidence shows that the infection is not by the bowel, but by aspiration through the air, and the contagion is spread in almost all cases from man to man; milk is of very minor importance indeed. He concludes that almost every human is disposed to infection, and is infected in the conditions of city life; that a certain immunity to subsequent infection is established from the first infection, and that there is a great tendency to relapses with a later infection. The conclusion, then, is that practically all infection occurs in childhood through inhalation. The primary infection is through the lungs, but most children recover from that primary infection. There is a tendency to relapse afterwards, and that relapse may be due to reinfection, or to the old infection working out again. There are predisposing factors which bring about this relapse. Pulmonary tuberculosis is a late form of the disease; once started, it shows a tendency to increase. Therefore, supposing these conclusions are just—and there is a very great deal of evidence in favour of them, which Professor Bulloch brought before you—what we have to do is to take the greatest care in prophylaxis, to prevent infection during the first year or two, and in later life to prevent those conditions which bring about a relapse.

That brings me to the subject which I propose to deal with to-day—namely, the effect of open air and exercise, and how it is we believe, and what grounds we have for believing, that this is effectual as a method of treatment, or still more as a method of prevention; how it is that open air and exercise act, what the

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physiological basis of this treatment is, and what effect they have upon the human body.

**The Chemical State of the Air.**

It has generally been supposed that all the bad effects of close, crowded, and confined places are due to chemical impurity of the air, that the air is contaminated by the exhalations of human beings, and that it becomes impoverished of oxygen; but if we consider what people complain of, we find that people who are in crowded and confined places never complain that there is too little oxygen in the air, or too much carbonic acid in the air. What they always complain of is the heat, and want of movement of the air. They say: "How close and warm it is! There is not a breath of air." "Let us go out and get cool," is the expression one hears in a ball-room. "Let us find a cool place." The ladies have fans, and they put on the thinnest clothes when attending social functions and so forth, all showing that what is felt is not chemical impurity, but some other conditions of the atmosphere which affect the heat loss of the body.

*Excess of Carbonic Acid.*

Now a great deal is made of carbonic acid in the air, but physiological experiment has conclusively shown that the percentage of carbonic acid in crowded rooms has nothing whatever to do with the cause of discomfort, for this simple reason—carbonic acid cannot get into the body. The respiration is so controlled by the breathing centre that the excess of carbonic acid in the atmosphere cannot enter into the body, and the percentage of carbonic acid in the lungs is always kept the same. It is the percentage in the lungs which controls breathing, and if we breathe an atmosphere containing, say, 1 per cent. of carbonic acid, the only result of breathing that atmosphere is that we breathe a little more deeply. We ventilate our lungs a little more in order to keep the normal percentage of carbonic acid in the lungs, and the excess of carbonic acid can never get into the body, and can never act as a poison; so that we can dismiss carbonic acid altogether. All that carbonic acid can do is to increase the breathing. If there is 2 per cent of carbonic acid in the inspired air, it will increase the breathing by about 50 per cent; this is only what happens when we take a little exercise—we produce a little more carbonic acid in our body, and we increase our breathing by 50 per cent, and we do not feel it. If we are walking we do not notice that the breathing has
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increased; nobody would notice an increase of 50 per cent. If I put you into an atmosphere containing 2 per cent of carbonic acid, not one of you would be aware of the fact: there would be no discomfort. That I have proved, and others have proved, by confining a man in a chamber and having a bag containing carbonic acid gas secretly emptied into the chamber so as to raise the constituent CO₂ in the chamber to 2 per cent or 3 per cent. No one in the chamber knows when the carbonic acid is introduced, or has the least evidence of it having been done. If we raise the carbonic acid percentage to 3 per cent, we should increase the breathing by about 100 per cent; if we raise it to 4 per cent we should increase the breathing by about 200 per cent; to 5 per cent by about 300 per cent, and to 6 per cent by about 500 per cent. To increase your breathing by five times means, of course, that you are then breathing in the same kind of way that you would be breathing on taking fairly severe exercise. Of course, the breathing goes up naturally. We breathe, let us say, 7 or 8 litres a minute; if we take hard exercise we should be breathing five or six times that amount; if we took excessively hard exercise we should be breathing ten times that amount. Supposing there is 3 per cent of carbonic acid in the air already, we should be breathing twice as much as normally. If we then tried to take severe exercise we should get into trouble, because we should not be able to breathe sufficiently to get rid of the carbonic acid which we were generating in our bodies. As long as we kept quiet we should not be in trouble at all; all we should feel, if anything, would be that we were breathing more deeply. Anybody who was watching us might see that we were breathing more deeply than naturally. Otherwise, carbonic acid has no effect at all. It is not till you get to 6 per cent, which is the normal percentage in the lungs—it is always kept at about 6 per cent—it is not till you rise above that, that you feel serious trouble. If carbonic acid accumulates in the body it begins to act as a poison by increasing the acidity of the blood, but it is a very slow poison even then.

We can therefore dismiss carbonic acid as having anything whatever to do with the question. The excess of carbonic acid in the air in a crowded room, if anything, will only make people breathe a little more deeply and make them ventilate their lungs more fully. If you want to make people breathe deeply, there is no easier way than to let them breathe an excess of carbonic acid. To make them expand their lungs, give them a tube to breathe through. Take a broad india-rubber tube a foot long. That will
make them breathe a little deeper. If you put another foot on that, you will make them breathe still more deeply; another foot, and they will breathe more deeply still. You can adjust the pulmonary ventilation to what you like by extending the length of the tube and giving oxygen. That is a method of making people breathe more deeply which is useful from a clinical point of view.

Diminution of Oxygen.

As to the question of the oxygen in the atmosphere, there again the oxygen in a crowded room is never diminished by more than 1 per cent. The cracks and crannies in a room are always such as to let the outside air in. The diminution of 1 per cent of oxygen has no physiological effect whatever. That is shown by the fact that when you go up an altitude, as in the Alps, where there are health resorts 5,000 ft. high, you will find a diminished partial pressure or concentration of oxygen in the atmosphere. At all those famous health resorts there is less oxygen by weight in a litre of air, considerably less oxygen than in the most crowded room. We know that people live in the Andes at heights of 10,000 to 12,000 ft., and even 15,000 ft. up. While the normal partial pressure of oxygen in the atmosphere is 21 per cent of an atmosphere, in the alveoli of the lungs it is normally 13 or 14 per cent of an atmosphere. We can go up to such an altitude that the partial pressure of oxygen in the atmosphere drops down to 13 or 14 per cent without noticing it, at any rate as long as we are resting; if we took hard exercise we would notice it. People get a little mountain-sick from want of oxygen when they first go up to these altitudes, but they soon get accustomed to it unless they have heart disease or there is some failure of the normal mechanism of the body. Changes take place in the blood, in the amount of haemoglobin and the affinity of haemoglobin for oxygen, which adapt the body to the lessened oxygen pressure. The body sets its own rate of metabolism, and so long as it gets enough oxygen to satisfy its needs it is uninfluenced by the concentration of oxygen in the atmosphere. These considerations show conclusively that oxygen has nothing to do with the question.

Therefore the chemical state of the atmosphere, so far as regards carbonic acid and so far as regards oxygen, has nothing whatever to do with the discomfort which is felt in crowded and confined places, and it has nothing whatever to do with the success which results from open-air treatment.
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THE SUPPOSED EXISTENCE OF ORGANIC POISONS IN EXPIRED AIR.

We now come to the supposed existence of organic poisons in expired air. A great deal is made out of that. It has got into all the popular books on hygiene; but when we come to examine that question we find that there is no evidence worth anything at all as to the existence of this organic poison in expired air.

Negative Results of Experiments.

The evidence was first brought forward by Brown-Séquard and d'Arsonval, and what they did was this. They expired through a vessel surrounded with ice, and the water exhaled in the breath was condensed. They took that condensation water and injected it into animals. They said the animals were poisoned by it; therefore, they said, there was poison in this condensation water which was exhaled. That was one of their experiments. Another of their experiments was to put a number of animals in glass vessels and draw the air from vessel to vessel, so that animal No. 6 was breathing the air which had come through the other five vessels where the other five animals were. They said that Nos. 6 and 5 got poisoned, while Nos. 1 and 2 remained in perfect health. Those were the kinds of experiment that were brought forward. Well, now, a great number of very trustworthy and skilled investigators have now repeated those experiments, and they have found no evidence in favour of the existence of these poisons. All the evidence of the men we can trust best is wholly negative. To take the second kind of experiment, it has been shown that why these animals died in the last boxes, Nos. 5 and 6, was because errors were made in experimenting; the tubes were wrongly placed, and leaked so that the current of air did not come through at all and the animals were merely asphyxiated from want of air; or else the current of air was made so slow that the last animals were given something like 15 per cent of carbonic acid to breathe—a poisonous amount. Errors of that kind were made.

I have tackled this question in such a simple way that there is no question about it at all. I do not have a number of chambers and tubes leading through from animal to animal. What Dr. Martin Flack and I do in our laboratory is to take a number of deep boxes and put a number of guinea-pigs and rats at the bottom of those boxes and have the lids shut down to such an extent that day and night there is more than 1 per cent of carbonic acid in those
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boxes. There the animals live every day; they are thoroughly cleaned and well fed, and they live at the bottom of those boxes, breathing in the exhalation of their own breath day after day, and the ventilation is so arranged, as I said, that at least 1 per cent of carbonic acid (produced by themselves) is in the boxes. These animals do not suffer; they live week after week. We have had them in the boxes for months. They beget young under those conditions. We have to remove them when pregnant to other boxes, because the conditions are not favourable to maternity in a crowded and confined space like that. We put in young ones, and under those conditions there is no sign of poisoning; the animals live and grow. We have also a number of control boxes, containing guinea-pigs, perfectly ventilated. In the cool weather—there were some frosty days—the ones that were living in the closed boxes were warmer in the bottom of their boxes and put on more weight than those living in well-ventilated surroundings. I do not say they are harder; the others may be harder, if we could test it, but, at any rate, there is no sign of poisoning at all.

As to the condensation water, the experiments which have been done are really too absurd. You would hardly credit how absurd these experiments are. The condensation of water is obtained by making the man breathe through a vessel surrounded by ice perhaps for eight or nine hours. One gramme of that condensation water has been injected into a mouse weighing 13 grm. This is equivalent to injecting 5 kilo of water into a man weighing 65 kilo. Five kilogrammes of water equals 5 litres of water, and there is 1¾ pints in every litre. What man is going to stand having 5 litres of water put into him suddenly, perhaps not even warmed? It is a most ridiculous experiment. And yet the mouse has not died in many cases, but only shown signs of illness, which are supposed to point to poison being in the condensation water. That is the kind of experiment upon which these assertions about the chemical organic poison in exhaled air are based, assertions which have got into all the popular books and been spread all over the world. It is known that water, even distilled water, is toxic. Any distilled water in the laboratory gets infected with bacteria. There are swarms of bacteria that live in a vessel of water on the traces of ammonia and salts that are dissolved out of glass, and the traces of ammonia and dust in the atmosphere. Such water is toxic, and the cause of symptoms of poisoning sometimes observed when salvarsan is injected has been traced by my colleagues, Drs. Fildes and McIntosh, to the use of water contaminated with
bacteria. If you use water that is freshly distilled and contains no bacteria at all, you never get toxic symptoms. Such condensation water experiments as I have mentioned can be dismissed as not worthy of notice. They are too silly for words.

**Asserted Presence of Volatile Protein in Exhaled Breath.**

Rosenau and Amoss, in America, recently have supported the organic poison theory. They obtained condensation water by breathing for many hours into a vessel surrounded by ice, through a plug of glass wool which acted as a filter, and said the condensation water was pure, and could not be contaminated with saliva, because the plug of glass wool would keep it all back. They injected it into guinea-pigs, and a month later they injected into a vein, or straight into the heart, of those guinea-pigs a trace of human serum. There resulted in these animals anaphylactic shock, and some died. Rosenau and Amoss concluded that human protein was exhaled in a volatile form which passed through the plug of glass wool and was condensed with the water by the ice, and that this volatile protein sensitized the guinea-pigs, and hence the anaphylactic shock when, a month later, they put in the human serum. My criticism in regard to this experiment is that when one breathes for many hours through a plug of glass wool the plug will get wet through with saliva. The expired air will then carry droplets of saliva away from the further side of the plug, and the condensation water will inevitably get contaminated with saliva which contains human protein—viz., mucin. It is that which sensitized the guinea-pigs. The experiment does not prove the existence of a volatile protein (a toxic substance in the exhaled air), as Rosenau and Amoss thought.

Dr. McIntosh and Dr. Martin Flack and I have tried the experiment in what I consider a far simpler, and—if I may say more sensible manner. We have taken guinea-pigs and rats, and put them (to live together) at the bottom of those boxes which I have described to you. There they have lived week after week, the guinea-pigs breathing the rats’ exhaled air. If there was any protein exhaled in the rats’ breath that protein would be breathed in by the guinea-pigs. Rosenau and Amoss assert there is such a volatile protein, and that an inhalation into the lung goes straight into the blood. Of course, we know that a foreign protein which is eaten and taken into the alimentary tract does not sensitize us. We eat beef and yet are not sensitized to ox serum. Rosenau and Amoss go so far as to say that people who live with horses—hostlers,
and so on—may get sensitized by breathing the exhalations of horses, and that is why some are found to be sensitized to a first dose of antidiphtheric serum. I should have thought rather of the hair and epithelial scales which a hostler rubs off a horse—in order to prevent breathing too much of which he makes that peculiar hissing noise. These contain protein and get into the throat and respiratory tract. Well, we have kept the rats and guinea-pigs together at the bottom of the boxes for weeks and weeks, and at the end of the time we have injected into the guinea-pigs' veins a trace of the rats' serum, with no result at all. Not a single guinea-pig has been made ill to the slightest degree. A month later we put into those same guinea-pigs another trace of rat serum. The first trace sensitized them, and every single guinea-pig that got the second trace rolled over dead. How sensitized they were is shown by the fact that in one case we put the syringe into the ear and missed the vein; we squeezed the syringe the least little bit, and a trace of the rat serum went into the tissues of the ear, not into the vein. We pulled out the syringe and prepared to try to get it into the vein for the second time, but the guinea-pig rolled over dead, poisoned by the minute trace that went into the tissue of the ear. That shows how tremendously sensitive to anaphylactic shock are guinea-pigs which have received an injection of rat serum. Our experiments show that there is no volatile protein exhaled in the breath at all. Rosenau and Amoss' claims are entirely devoid of support.

BAD SMELLS: THE INFLUENCE OF THE IMAGINATION.

From what I have said, then, we may dismiss the chemical organic poison theory. The ill-effects of a confined atmosphere are not due to excess of carbonic acid nor to want of oxygen; and there is no organic poison in exhaled breath. Of course, we get other exhalations besides the breath in crowded rooms—exhalations from the skin, exhalations from the alimentary canal, and so on. So do the guinea-pigs that live in the bottoms of our boxes, and live in health and grow and breed. All these small animals live crowded together in their sleeping places. So long as the atmosphere is not too warm, rats prefer to sleep in a chamber that has got 3 to 4 per cent of carbonic acid in it. They will sleep there rather than go out into the cold; but if we put in some wet bread and raise the temperature inside, the rats will come outside—they do not like it. They do not like a high wet temperature. That will bring them out. They do not mind 3 or
4 per cent of carbonic acid a bit. They are quite comfortable in that. These animals when they are huddled together in their nests naturally breathe a relatively large percentage of carbonic acid. They naturally breathe air containing less oxygen, and naturally breathe each other's breath. Every one of us naturally breathes his own breath, because when we exhale we leave our air-tubes, the nose and so on, full of exhaled air; at the next inspiration we draw that back again. We are always inhaling about one-third of the air we exhale. All that goes to show that exhaled air is not poisonous. As regards other exhalations from the body, they certainly make the air smell, but to say that the air smells is quite a different thing from saying that it is poisonous. I admit that the air smells. I admit that that smell may have a depressing action on the nervous system, especially of sensitive people and people who think it will do them harm, because the imagination plays a great part and has a tremendous influence upon humanity. I had an excellent example of that only the other day. The secretary of a large institution said the clerks on the third storey were being poisoned by stove fumes that came up into the room. Would I mind coming to have a look to see what I could find out about it? I found there was a stove down below which was heating the boiler—a coke stove. The coke fumes leaked round the hot-water pipes, especially when the clinkers were taken out by the engineer; they found their way into the well of a lift, which terminated in this clerks' room three storeys up; they came out from the top of that well through the cracks in the door, and made their way towards the fireplace, and the clerks sitting between the fireplace and the lift smelt those fumes. The lady clerks told me a tale about how they suffered and felt faint, and all the rest of it; but the man down below who was turning the clinkers out of the stove, what about him? He was breathing, say, fifty times more of these fumes than the lady clerks, and yet he was doing his work and not complaining. The imagination of these lady clerks had led them to exaggerate the effect of these fumes to an extraordinary extent, and, as one can easily see, if they were made so ill by the fumes the man ought to be dead.

People who have to deal with horrible smells—that is, smells which are horrible to us—get quite immune to them, and as to those men who have to deal with these offensive smells, such as sewer men, men in bone manure and soap factories, men in fried fish shops—there is no evidence that their health suffers from the smell. You rapidly lose all sense of a smell if you are obliged to
carry out one of those trades, and very rapidly indeed if you go into a sewer, even if you are not used to it. We will grant that smell puts one off one’s appetite and makes one feel depressed, and so on, and therefore that smell should be got rid of; but the way to get rid of smell is not by trying to blow it out by ventilation, but by cleaning the source of it up. Pettenkofer once remarked that if there was a dunghill in a room it was no good trying to blow away the smell by means of ventilation; the right thing to do was to clear out the dunghill. If a room smells, it is because the room is not clean, or the bodies of the people are not clean, or their clothes are not clean, and the right thing to do is to clean up the room and the people in the room.

**How does the atmosphere affect people?**

We now come to the question of how the atmosphere does really affect us. We know that we catch catarrhs, &c., by infection, and in the matter of consumption I think there is no doubt Hamburger is right.

*Spray Infection.*

There is a method of infection which is of the utmost importance, that is, spray infection, which Fluegge brought into prominence by a series of admirable experiments some years ago. The real infection that matters is the infection by the spray of saliva direct from man to man. While we are breathing quietly and normally the expired air is almost sterile. But if we sneeze, or cough, or sing, then the explosive output of the expired air carries away the finest spray of saliva which spreads to an extraordinary distance. I have seen Professor Bulloch place culture plates along a table 10 ft. in length, wash his mouth out with a harmless bacterium which can be easily identified, stand at the end of the table and say a few words, then cover up every culture plate and place them in the incubator; colonies are found in every single culture plate—crowded in the plates near the speaker, and a few colonies in those far away. I must, as I am speaking, I am sorry to say, be disseminating this excessively fine spray of saliva to an extreme distance all over the room, and so is everybody when he coughs, or sneezes, or speaks. If you are speaking close to a man, straight face to face, it is obvious that the spray will give a most massive infection, that the spray of saliva droplets may contain hundreds of bacteria. Supposing the other man was just inhaling with his mouth open, and a person with the
infection is just speaking, some droplets of saliva may be carried straight down his windpipe right down into the lung.

The other day there was a case that came under Professor Bulloch's notice—a man with acute pneumonia, who traced back his infection to a company meeting at which the secretary present had a cold. With streaming eyes and sneezing continually, this secretary appeared to be at the height of an infectious cold. At this same company meeting there was a man who got pneumonia and died. There was another man who caught a cold, which affected his ears, so that his tympanum was opened and the pneumococcus was found. The third man, who came under Professor Bulloch's care, was a typical case of pneumococcic infection. It is quite clear those three men were infected at that meeting by the spray sent out into the air by the secretary, who was expounding the business of the meeting. This spray infection cannot be prevented very easily if people are going to cough and talk and sneeze and go about among the company in crowded rooms with these infectious colds. Any infectious cold may be a pneumococcic cold. There are very many persons who are walking about with hardly any symptoms of disease, but whose saliva is teeming with tubercle bacilli. I remember the case of a young woman in perfect health, apparently. She complained of a little cold, she was hoarse for singing. Could something be done to prevent that hoarseness? Professor Bulloch examined her sputum and found it swarming with tubercle bacteria. This woman was spraying the bacteria into the room whenever she spoke, sang, or coughed. She went about her business and made a complete recovery. The only way we can prevent spray infection is by keeping people isolated in acute infective states, keeping them away, making them stay at home, or by teaching them to sneeze and cough always into a handkerchief, and if they are speaking we can induce them to speak with a newspaper held in front of their mouths, which would catch all the spray quite effectively; or, if we want to protect ourselves against such a person, we could casually hold a paper in front of our mouths without being rude. In that way, by such simple means, I believe that infection from these colds, which cause so much misery and discomfort, might be limited to a large extent. If people could all be trained when they get into a state of acute infection with catarrh of the nose, to cough and sneeze into handkerchiefs and to speak with a newspaper held in front of their mouths, or at least to keep at home if they are not content to do that, that would prevent the spread of these infections.
Influence of Warm Confined Air on Nasal Mucous Membrane.

Dr. Muecke and I have lately been examining the nose to see what happens to the mucous membrane in a warm atmosphere. Of course, it is quite clear that infection occurs in certain states of weather; that colds run round when there is a sudden change to cold moist weather. We wanted to see if there was any reason behind that. When people are away at the seaside or on the mountains, where they are exposed to any weather, rain and wind, and live in the open air, they get no colds. Children who are out on the shore paddling and exposed to weather and wind and all that kind of thing never get any colds. The moment they come back to crowded places and chill autumnal weather they get them in the schools, and these colds run round and everybody catches them. What is the reason for all that? There must be some fairly simple condition which causes that. There is infection in crowded places to begin with. But then, at the seaside in little cottages and lodgings people crowd together in the evenings, and they would infect each other if a cold were going round, but the 'cold' does not go round in those conditions. It is when you get the cold autumnal winds and you begin to shut up the windows and light fires, and start the heating apparatus, and so on, that the 'colds' begin to come back.

This (see coloured plate, fig. 1) is the condition of the nose as seen under normal conditions when a person comes in from cool surroundings, a cool atmosphere, or the outside air. The mucous membrane is shrunk; it is taut. If you touch it with a probe you cannot pit it, it is not congested, and there is very scanty secretion. That (see fig. 2) is the effect of going into a heated chamber where the air is at a temperature of about 80° F. and pretty well saturated with moisture, conditions such as exist in crowded places, meeting-houses, or ballrooms. The mucous membrane of the nose becomes turgid with blood, and it is covered with a very thick secretion, and the tissues are all swollen. You can push the probe into the tissues and depress them, and it does not come out for some little time, showing how boggy it is. The airway is so diminished that if you have got a spur or anything of that kind you cannot breathe through the nose when you get into these hot conditions. That (see fig. 3) is the effect of putting on a fan in the hot room and whirling the same air. The air so whirled by the fan will bring the nose to more like the conditions shown in fig. 1 and lessen the constriction of the air channels. That (fig. 4) is the effect of going
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out in the open air for a few minutes, the cool open air of last month, of winter—not very cold, but cool open air. The blood goes out as the vessels contract, but one still finds that the mucous membrane is boggy, that it pits, and that there is a great deal of this thick secretion upon it. You see the conditions are such when you go into these hot places that the mucous membrane becomes greatly swollen; there is a great deal of tissue lymph in it, a great deal of thick secretion; the exhaled bacteria that are thrown in masses on it are caught in the thick secretion. Then when you come out into the cold again the blood-vessels shrink up so that heat should not be lost from the body, and you are left with a nose containing thick secretion and a great deal of tissue lymph, a medium for the growth of bacteria, while it loses the blood which defends it from infection; whereas if you never go into a hot room at all you have a nose in good condition, taut, and with a scanty secretion; and the organisms have not got a hold on the mucous membrane, and there is nothing for them to grow in. When the mucous membrane is kept taut and the flow of blood is rapid the inhaled air is warmed up quickly and moisture evaporates from the nose, so as to saturate this air at body temperature; that means more plasma comes out of the blood-vessels, and this contains the immunizing substances. The ciliated cells are well supplied with plasma, and they lash well, and the offensive bacteria are kept out. But when you come back to this condition where you have much secretion and boggy tissue, and the blood has been shrunk out by vaso-constriction, then you have got a suitable nidus for bacteria to grow in.

The Effects of Open and Confined Air upon Metabolism.

I maintain that the whole of the bad influence of confined quarters and the good influence of open air is a question of the heat and moisture of the atmosphere. The evidence that heat and moisture of the atmosphere have a physiological effect, a potent, a tremendous effect, upon the metabolism of the body, is as strong as anything can possibly be. We fail to find any evidence of the toxic effect of exhaled air, but we find any amount of evidence of the most convincing kind to prove that the temperature and moisture of the air have a most profound effect upon the metabolism of the human body.

If the atmosphere is cool and moving it will continually carry heat away from the skin. It will keep the vessels of the skin contracted; the blood will be driven into the viscera, where it will
become metabolized, not drawn into the skin but driven through the viscera and through the brain where it is required. Moreover, the cool moving air acts upon the skin and stimulates the nerves, and the cutaneous nerves have a very great influence upon our comfort. When we get into confined places the air becomes monotonous; it is not moving; we get a monotonous, uniform temperature of the skin; the skin gets hot, flushed with the blood, and the temperature of the skin gets almost the same as the temperature of the body. Instead of being considerably lower than the temperature of the viscera, it gets to almost the same point, and if the room is very hot it gets quite up to that point. The sensory nerves are no longer stimulated because there is no change. If, on the other hand, the air is continually moving, sometimes blowing, sometimes not blowing, it is continually stimulating the nerve endings of the skin and the nervous system generally, and it rouses us to activity, for in order to keep warm we have to use our own body furnace, and that is what we ought to do. We do not want to trust to clothes and fires altogether, because that means we are not using the natural body furnace. We take refuge in these other mechanisms for keeping warm if we do not use our own body furnace. What does that mean? That means that our metabolism is reduced to a low level. That means that we keep quiet and do not have to move. That means that we do not circulate our blood well, because exercise has the most colossal effect upon the circulation. The whole of my researches on the circulation go to show that the duty of the heart is to deliver the blood to the capillary vessels and it is the duty of the muscles to support the arteries and pump the blood back again into the heart, and if the muscles are not doing their work the circulation cannot be efficient. When the muscles are at work the heart beats more quickly, and the blood is carried round the body much more quickly; each minute the whole blood volume is carried round the body many times.

Then when we are taking exercise we breathe more deeply in order to get rid of the carbonic acid, and we take in more oxygen, the blood is more oxygenated, the lungs are better expanded, and this is a most important thing for resisting infection—the expansion and oxygenation of the blood takes place in every part of the lungs. Every part of the lungs is expanded if you take exercise. The ventilation of the lungs may be ten times as great as normal if you take extremely severe exercise—five or six times as much during ordinary hard exercise. That has a most colossal effect upon the
lungs, expanding every part of them, and it has a colossal effect upon the circulation of the blood. And then, as we are using up energy in our muscles, we have to supply that energy, and that means we have to eat more, so that the appetite is excited; we eat more and absorb better. The food that we eat is all absorbed and utilized by the body; it does not go into the great bowel, as a great deal of our food does when we are living sedentary lives. Rejected by the absorbing mechanism because the body does not want it, its fate is to become decomposed by bacteria and turned into faces and wind and toxic products of bacterial decomposition, which, if absorbed into the blood, may give us all the symptoms of chronic poisoning, such as anaemia and headache. That is all the fruit of sedentary work and living a sedentary life. If you are going to live a sedentary life and keep warm by means of clothes and fires, you knock down your body furnace to such an extent that you want very little food, and the only way to live healthily and not degenerate our tissues by the products of bacterial decomposition thrown out of the large bowel is to live a very simple life and eat sparingly. If you live a sedentary life and eat large meals and drink alcohol, you will get your body into such a condition that its metabolism must go wrong after a certain number of years. Either excessive substances are going to be absorbed into the blood which are not wanted, or you are going to be poisoned by toxic products derived from bacterial decomposition in the great bowel, and then the surgeon comes along and says the drainage system is out of order and he must short-circuit it.

Exposure to wind and cold leads to increased activity on the part of the body and increased metabolism, and it is that which has an effect upon tuberculosis; it is that increased metabolism which is the end we have in view to get more blood circulated, more oxygen breathed in, the lungs better expanded, more food eaten, and if we eat more food we are more likely to get those building stones which are found in food, some of which are exceedingly rare substances, like the vitamins, which are found in outer husks of wheat and rice berries, but are not found in white bread or polished rice. These are the kind of things which are absolutely necessary to the growth of the body, these vitamins. If we do not eat enough food to get sufficient of them, then the metabolism of the body suffers. Therefore it is wise to use our body mechanism so as to be able to eat enough food to get all the building stones required to nourish our frames and produce all the secretions of the body that are necessary for its metabolism.
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Increase of Tuberculosis in Confined Spaces.

That is the effect of open air and the way it acts. To show that confinement acts in spreading tuberculosis in two ways there is the evidence communicated to me by Dr. A. W. Wakefield coming from Labrador and Newfoundland, where the fishermen live in little shanties and the atmosphere is perfectly pure—e.g., along Hudson Bay. They live in little shanties heated by American stoves, and they shut themselves up and keep the temperature at something like 80°F. The women and children there hardly ever put their noses outside the door during the winter; the men just go out to fish. They live on white bread and molasses, and tea, which they brew in the pot by adding a little more to the leaves that are already in, and do not empty the pot till the leaves come out of the top and they cannot get water in. They only have in addition a little fish sometimes, and that they eat boiled and throw away the water, and so they do not get the vitamins I have been talking about. These shanties are so small that Dr. Wakefield, when he was travelling, found there was hardly room for a visitor to sleep with the family on the floor. That shows how small these shanties are. The water ran down the walls and the windows were covered with moisture, and if there was a case of tuberculosis the patient would spit all round and the others know nothing about the danger of infection. These fishermen, whether suffering from tuberculosis or not, would spit anywhere till the spittle dropped down the window frames of the shanty, absolutely indifferent to what happened. Such conditions as those, of course, are just what would spread infection among the unfortunate children. We have got all the conditions for massive infection there, with a confined and hot atmosphere, which limits the metabolism, the ventilation of the lungs, the intake of oxygen, the circulation of the blood through the lungs; everything leads to or is in favour of infection, because the immunity depends upon the blood and the serum which passes into the tissues, and the lungs, if not ventilated properly, do not get enough oxygenated blood in all their parts. Investigating the oxygen content of the blood taken from the median vein, J. F. Twort and I have found it increased 5-10 per cent by deep breathing, and this proved that in parts of the lung during quiet respiration the blood is not oxygenated.

From Lofoten, in Norway, I have had evidence sent me through the medical officer in Tromso. He says that at Lofoten in 1907 the cases of tuberculosis among the fisherfolk were in the proportion
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of 5 males and 6 females; in 1908, 5 males and 5 females; in 1909, 7 males and 5 females; in 1910, 9 males and 7 females; in 1911, 14 males and 4 females. There is a striking increase in the proportion of males who are infected, going up from 5 to 14; while the females vary between 4 and 7. This he puts down to the fact that the fishermen in Lofoten have given up their old open boats. They used to fish in open boats during the spring and summer ever since the time of the Vikings, and lived in draughty shanties and walked about the shore. They have given them up and taken to motor-boats. They live in these small motor-boats—day and night, six or eight men—and fish nearly all the year round and sleep in the cabin heated by the motor, where they sit and smoke and eat, as well as sleep, living in a confined space which is built of iron, so that no ventilation can take place through the walls of it. That is the cause of the increase of the disease amongst the men. Directly you get these confined spaces with American stoves or motors to heat them, then you have the conditions which spread the infection. That is my contention.

Ventilation in Ships.

In our battleships, of course, we have got exactly those conditions. The Local Government Board insist that a pauper should have 1,000 cubic feet of space allotted to him in a dormitory. In our Dreadnoughts 80 cubic feet is the space for each sailor, and in some cases it is even lower than 80. A battleship is not a brick building. In a brick building a great deal of ventilation takes place through the walls and windows and doors, even if it is shut up, but a battleship is a steel structure, and no ventilation of that kind can take place at all. Therefore, it is absolutely necessary to have artificial ventilation. In these battleships they have air-trunks which convey the air driven in by fans. The louvres open in the ceiling, but the men, when they feel the cold air blowing on them, can very easily put their hands out and shut them up. The British sailor does not like cold air, and he pushes out his hand and shuts the ventilator up near his hammock. I have seen the louvres sealed up with canvas and painted over in a super-Dreadnought. Here again the conditions which matter are the moisture and the heat of the air. In many places in these battleships you will find a wet bulb temperature of from 80° to 90° F. To be under those conditions depresses the vitality of the body, and if there is a tuberculous subject there the spray of his saliva will be carried from him.
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to others. The saliva spray will not be cooled down, and the tubercle bacilli may preserve their vitality undiminished in the warm atmosphere. The right thing to do under all these conditions is to bring in fresh air through hose-pipes, and have extraction fans working, and so on, in order to keep the air cool and moving in every possible way.

Recently Mr. James Keith, of Messrs. Keith, Blackman and Co., told me some facts about the Lusitania. In the Lusitania engine-room, working at full steam, the temperature used to reach 150° F. It is distressing for the men to work in that temperature; it strains the heat-regulating mechanism of the body, and some of the energy which ought to go to external work is used to keep the temperature down. The blood is sent to the skin and the heart has to exert its power in order to drive the blood to the skin and cool the body instead of sending it to the muscles and viscera where it is wanted; so the health of the men is depressed. Mr. Keith has put a big air-trunk in, 5 or 6 ft. in diameter, which goes straight down from the deck, and at the bottom of that trunk he has put a 5-ft. fan, which pulls in the outside air, not warmed in any way, and to such an extent that it pulls in 6,000,000 cubic feet of air an hour. The result of that is that the temperature is brought down from 150° to 70° F., and no draught is felt at all. So long as it is as warm as that no draught is felt, and the comfort to the men and the effect on their health, I am quite sure, will be extraordinarily good.

Ideal Conditions.

In all our rooms we want to have the air moving—I do not say to make an unpleasant draught, but to have the air gently moving. The ideal conditions are radiant heat, such as you get on a spring day when the sun is shining and there is frost in the air and a gentle breeze, with a warm sun. Those are the ideal conditions. In our rooms we want to get radiant heat. We never want to heat the air if we can help it. In heating a room let us heat it to the lowest degree compatible with comfort. Try to heat it by radiant heat and keep the air moving.

Demonstration of Importance of Moving Air.

The thermometer is not an instrument which tells us what the body feels. Suppose I put eight students packed like sardines in my little experimental chamber (it contains 3 cubic metres), seal
them up air-tight, and by their own body heat let them raise the
temperature to 85° F. and saturate the atmosphere with their own
moisture. Let them stay till the carbonic acid rises to 4 per
cent, and the oxygen diminished below 17 per cent, so that they
cannot light a cigarette. They will try and try in vain, and think
there is something wrong with their matches, and borrow matches
from somebody else. They do not feel any want of oxygen, and so
do not know why they cannot light a match. They get uncomfort­
able, hot, flushed, and wet with perspiration, and cease laughing
and talking. I have got in the chamber a powerful fan. I put that
on and stir the air, and everybody is perfectly comfortable, and they
all begin laughing and chaffing. It is just the same old air with
4 per cent of carbonic acid in, but the air at 85° F. is thoroughly
stirred, and the fan blows away the stagnant air in their clothes
which is heated up to the body temperature and saturated with
vapour; it blows that out and brings the air at 85° F. in contact with
their body. Instead of having stagnant air at 99° F., they have air
at 85° F. blowing round their body; that cools them and makes them
feel all right. That experiment shows that it is the body-heat
stagnation which is troubling them.

Suppose the thermometer in the chamber registers 85° F. wet
bulb and 86° F. dry, and the fan is on. Switch the fan off; the
thermometer still says 85°-86° F., although you feel thoroughly
miserable when the fan stops. You put the fan on and you feel
perfectly comfortable, but still the thermometer says 85°-86° F. That
shows how the thermometer fails to demonstrate the conditions
which we feel. It is no use for people to trust to the ordinary
thermometer, neither wet nor dry, because it does not show heat
loss. It only shows the temperature of the room, the average
temperature of the furniture and surroundings and walls; it does
not show us the heat loss of the body.

_The Kata-Thermometer_1 or Comfort Meter: An Apparatus for
showing Rate of Heat Loss.

I have instruments here which I have contrived for showing the
rate of heat loss, and I believe these will prove to be of general
utility. I have two large bulbed spirit thermometers. The bulb of
one is covered with muslin. The stems are marked at 110°, 100°,

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1 The kata-thermometers are made by Mr. J. Hicks, 8, Hatton Garden, E.C.
and 90°F. I warm the bulbs to 110°F. in warm water, then take them out and dry one, and jerk the excess of water off the other. I let them cool and take the time occupied by the menisci in falling from 100°F. to 90°F. The wet bulb loses heat by evaporation and the dry by radiation and convection. On an ideal spring day the wet took 45 seconds and the dry 2 minutes 20 seconds. In a room with closed window and door, and heated up to 70°F. by an anthracite stove, they took about 1 minute 30 seconds and 5 minutes. Well, the conditions must be altered there, so that they fall in times approximating to those of the ideal spring day. The ventilating and heating should be arranged so that the instruments fall from 100°F. to 90°F. in about 45 seconds to 1 minute and 2 minutes 30 seconds to 3 minutes, and then comfort and healthy conditions will be obtained, particularly if the source of heat is a radiant one—an open fire or modern gas fire.

*Effects of Cold Moving Air on Temperature of Skin and Metabolism.*

Another thing I would like to tell you is, I have got a little wet and dry thermometer here which I can carry this way. I slip it down my shirt like this, between the skin and the shirt. I have been taking a number of observations with this on wintry days. I am accustomed to getting up at 6.30 in the morning and taking a cycle ride up to a fine bathing pool in Epping Forest; I have a dip in this water and out again, and cycle back to breakfast. I have kept that up with few days off this winter. Once or twice I had to get into an ice-hole. Riding up to this pool I have been observing what happened to the skin-shirt temperature. Ordinarily, sitting in front of a drawing-room fire one’s skin-shirt temperature is about 32°C.—dry 32°C., wet 30°C. (I am afraid I must give you figures Centigrade.) The body temperature is about 37°C. Riding home after my bath in the face of a cold wind the temperatures are far lower. Once they were 14°C and 11°C.; another time 16°C and 14°C. After my bath I am cooler than I am when riding to the bath, because the bath constricts the vessels of the skin. These temperature readings show you what a colossal effect cold moving air has in cooling the skin. Instead of being 32°C., as it is in front of a fire, if you go out in a wind in a motor-car or on a bicycle with the wind going through you, you have skin-shirt temperatures of more like 16°C and 14°C. This has a great effect in driving the blood into the body, stimulating activity and increasing metabolism.
To sum up. I am convinced that the whole of the effect of open-air treatment is due to the movement, temperature and moisture of the air, and has nothing to do with its chemical properties. Conformity to a better mode of life will enormously increase the health and happiness of everybody. Modern life is tending to put people into confined places, heated by convectors, with perfectly made windows, no draughts, and that kind of thing, and it is diminishing the metabolism, and vigour, health and happiness of everybody, quite apart from causing consumption. Man cannot go straight into these artificial conditions when he has been for a million years living an out-door life, facing every element, wind, cold, and rain. He cannot do that. What we have got to do is to compromise and arrange matters so that we may get open-air exercise and exposure to wind and weather. Do not let us put up these great skyscrapers, or have these artificial cellars for people to live in, but let us have facilities for open air, and playing fields, and exercises of the body, and then we shall enormously increase the happiness of the people.