NATIONAL SECULAR SOCIETY

PHYSIOLOGY OF THE HOME.

DIGESTION.

As it will be impossible for me in the small compass of four lectures to deal with the structure and functions of every organ of the body, I propose to select those an elementary knowledge of which will be most useful in home life. Much discomfort, much diminished vitality, much actual disease, are caused by ignorance of the simplest facts about our own bodies. How we digest, how we renew wasted material, how we breathe—these are matters closely concerning every one of us, and yet a majority of people are densely ignorant about them, and a vast mass of unnecessary suffering is the direct result of this ignorance. The object of these four lectures will be to throw a little light on the functions of digestion, circulation and respiration.

The most indifferent glance at the world of which we are a part reveals to us two great classes of phænomena; we see one kind of matter inert, passive, receptive, wrought upon by influences surrounding it but not actively moulding in return: clay, rock, metal, earth, all these are. examples ready to our hands, and we label them non-living matter. The man lying on the cliff distinguishes between himself and the chalk on which he lies. He says, "I live; that lives not." The distinction may be accepted as a rough one, although it would be hard enough to draw the exact line which separates the living from the non-living, but for convenience sake we separate off the palpably living, and we call the science which deals with them Biology, the science of living things (βιος, life; λογος, a discourse).

Our work falls under this title. But the man on the cliff sees life around him other than his own; there is life in the trees, in the grass, in the flowers. Of living things there are again too great classes, and though the student knows that these again melt the one into the other, yet in the higher forms of each there is such great divergence that we label them off separately once more, and call them severally Animal and Vegetable, and the sciences which deal with them Zoology (ζοον, animal ; λογος), and Botany (βοτανη, a plant). Our work, again, falls under Zoology. We narrow it down yet further by putting on one side all animals save the highest, Man. And in studying man we find two great classes of facts ; facts of Anatomy (ανα, up ; τεμνο, I cut), facts of structure, which have to do with the form, material, and position of the organs of the body ; and facts of Physiology (φυσις, nature : λογος), facts of function, which have to do with the work discharged by the organs. Both these last classes of facts will come under our notice, for though I shall deal mainly with functions, it will be necessary to touch briefly on the organs with which the functions are connected.

If you take a rope and use it constantly the material gradually wears away by friction until the rope is no longer serviceable ; you throw it away and get a new one. If you work your muscles constantly the material of your muscles gradually wears away; you do not, however, require to throw them away and procure new ones. Why? The material of the rope is worn away bit by bit, and is not renewed ; the material of the muscles is worn away bit by bit and is renewed. The wearing away of the muscle is as real as the wearing away of the cord ; a man weighed before and after many hours of hard muscular exertion actually weighs less at the end than he did at the beginning. Even if he be idle the wearing away goes on, although less rapidly than when he is actively exerting himself. The place of this lost material must be filled up, else the muscle will wear out like the rope. The place of the wasted material is filled up in the living ; and the discomfort caused by the blood exhaustion, consequent on repairing the waste, is known as the sensations of hunger and thirst, and the material is ultimately renewed by means of the food which appeases the want.

There are four chief ingredients in organised bodies ; other substances also enter into them, but they are mainly made up of these four. Of these, three are gases, and one is a solid. The three gases are hydrogen, oxygen, and nitrogen ; the solid is carbon. These four substances are now before you, three are invisible, one is visible. But the three invisible ones are easily distinguished from each other by their properties. Without going fully into these—as the Chemistry of Home will be dealt with by my successor—I can show you that each apparently empty bottle contains a different substance. I apply a light to the first; it burns; it is hydrogen. I plunge a light into the second; the light is extinguished; it is nitrogen. I blow out a light leaving a red spark, and place it in the third; the spark bursts into a flame; it is oxygen. We have then, here, four different substances, from which we are to obtain muscle and nerve, blood and sinew, by which we are to replace the wasted materials in our bodies. The materials are scarcely promising. A starving man would hardly thank us for our three bottles and our lump of charcoal. But these four substances, elements as they are called, useless for food at present in their separate condition, have the useful property of combining very readily. Three chief combinations, or compounds, must be considered; water, carbonic acid, and ammonia. For convenience sake we use only the first letter of each element, instead of the full name. We have:

H	O	N	C
Hydrogen	Oxygen	Nitrogen	Carbon

These form:

H_2O	CO_2	H_3N
Water	Carbonic Acid Gas	Ammonia

And this is the first step towards our food-stuffs. The water is at once utilisable, but the other two are not yet food for us. But they are food for plants. The plants take into themselves the CO_2, and expelling the oxygen retain the carbon; they take the nitrogen from the ammonia and from ammoniacal bodies, and within themselves they so recombine them as to form food-stuffs suitable for animals. You will notice that the first compounds are each made up of two elements; the next set, manufactured by the plants, are mostly made up either of three or of four. They consist either of carbon, oxygen, and hydrogen, or of carbon, oxygen, hydrogen, and nitrogen. The two great divisions of food-stuffs depend on the presence or on the absence of nitrogen.

Let us take the non-nitrogenous, or as they are sometimes called the non-azotised, first. They are the food-stuffs containing only carbon, oxygen, and hydrogen. These are: (1) All the starchy matters; if you look at thin slices, sections, of potatoe, rice, sago, corn, and many other vegetable productions, under the microscope, you will see grains of starch in them; that starch has been manufactured by the plant and contains nothing but carbon, hydrogen, and oxygen in certain definite proportions. Gum, and other amyloids (from *amylum*, starch) are also found in plants. (2) All the sugary matters: the sugar of every-day life is obtained from the sugar-cane, the maple and the beet-root; the sweetness of ordinary fruit is due to the presence of another kind of sugar. Yet other kinds are formed by animals, and are present in milk, in muscle, in liver. (3) Fats and oils: some of these are formed in plants—such as palm-oil; others in animals. Now the whole of these three classes of food-stuffs have one main use when taken into our bodies: they produce heat. I must again so far trespass into chemistry as to tell you that heat is caused by the union of oxygen with some other substance. When oxygen enters into combination with other bodies heat is always given out. The substances that we have been considering part with oxygen very readily; they give it up as they are decomposed inside the body, and thus animal heat is maintained. Hence the necessity of starchy, sugary, and oily food-stuffs; the colder the country the more need for fatty articles of food. The Esquimaux finds the blubber of the whale delicious; the Arab would turn from it in disgust. Why? because the bitter cold of the North chills the body, and the body, in order to keep up the temperature necessary to life, needs a large supply of fatty matter, which readily yields up its oxygen for new combinations, that is which gives the agent needful for the production of heat. On the other hand the warmth of Arabia renders a comparatively small amount of fatty matter necessary for the maintenance of animal heat.

There are certain other food-stuffs, consisting of carbon, oxygen, and hydrogen, which are mainly stimulating. Such are the acids produced in fruits, the alcohols, and ethers. These substances act rapidly on the body, but their effect is not permanent. Brandy may appear to warm more immediately than a good meal, in which fat plays a part, but an hour afterwards the man who has taken the brandy will be colder than before, while the man who has eaten will be thoroughly warm. Alcohol—generally termed spirits—is invaluable where a stimulant is necessary, say in the case of a person insensible from exposure to cold; it is not good as an ordinary article of diet.

I have said that the chief use of the starches, sugars, and fats is as heat-producers; the chief use of the second great class of food-stuffs, the nitrogenous or azotised, is as tissue-formers, that is, as builders up of the various tissues of the body. It may be well to note, in passing, that while nitrogenous food-stuffs are primarily tissue-formers, they do help, in small measure, to produce heat, and that while non-nitrogenous food-stuffs are primarily heat-producers, they also, to a small extent, aid in the formation of tissue. Nature refuses to be marked off by our sharp lines of division, and in her order work of one kind glideth ever into work of another.

In this great second class of food-stuffs, nitrogen—as the name of the class implies—is always present in combination with the carbon, hydrogen, and oxygen. The chief tissue-forming substances are albuminoids, like albumin, the white of eggs, and gelatinoids, like gelatin, the soft matter in bone. The albuminoids are some vegetable, some animal. Albumin is present in vegetables generally; legumin is found in such vegetables as peas, beans, pulse, etc.; gluten in cereals of all sorts. Hence the great value of wheat and of beans of all kinds as articles of food. Animal albuminoids are found in meat, blood, milk, and eggs.

Some nitrogenous food-stuffs, like some non-nitrogenous, are stimulating. Among these we find Thein, the essential characteristic of tea; Caffein, that of coffee; Theobromin, that of cocoa. These, like alcohol, are stimulants, but the nitrogen present in them adds to their nutritive power.

If you take these various food-stuffs, sugar, starch, fat, albumin, and so on, and place beside them some muscle, some nerve, some brain, and some blood, you still have the problem before you: How is the food-stuff changed into the materials which make up the body? In their solid form these substances are useless. There are no openings whereby solid matter can pass into the blood and reach the tissues; all nourishing matter passes into the blood by a process called osmosis. Osmosis means passage through a membrane. If you take a bladder and fill it with sugar and water, and then place it in a vessel of pure water for an hour, you will find at the end of the hour that the water in the vessel is sweet. Some of the sugary water has passed out of the bladder into the vessel, while some of the pure water has, in turn, passed into the bladder. This exchange of liquids through a membrane which has no holes in it is called osmosis. By osmosis all the nutritive part of our food passes into the absorbent vessels, and it is, therefore, absolutely necessary that it shall be dissolved, that it shall be in solution, otherwise it cannot be taken up and used in the reparation of tissue. The next lecture will deal with the organs of digestion; at present I want only to show you the changes that take place in the food.

Take, first, the sugars. These are soluble in water. Place a piece of sugar in cold water inside a bladder; place the bladder in water. The sugar will dissolve, and by osmosis will pass into the water outside. We can prove its presence there by adding to the water copper sulphate and caustic soda, and then heating: if sugar be present, a red-brown powder is precipitated. The sugar is, then, very easily prepared for osmosis; it dissolves in simple water.

But the starch presents a difficulty. I have here some starch that has been placed in a bladder with water, and surrounded by water for twenty-four hours. But the water outside is as pure as when placed there. The starch has not passed through; we test the water by pouring in a little iodine, a substance which gives a purple re-action with starch; we find nothing. Starch, then, as starch, is useless in the body. But in this second bladder starch has been placed, mixed with saliva, with the fluid poured into the mouth while we are eating. We test the water outside, and we find it is not pure water; it gives the characteristic re-action for sugar. What, then, has happened? The saliva has turned the insoluble, and therefore useless, starch into soluble sugar, ready to be taken up and used in the body. Whenever you eat bread this change goes on in the mouth. Hence the importance of thoroughly chewing the food, and the importance of checking children when they eat too fast. If bread is "bolted," the starch in it remains starch; it is useless for nutrition. It is true that there is another fluid (from the pancreas, or sweetbread) which takes up the work left undone by the saliva, but if the saliva has not done its share too much work is thrown on the other; hence discomfort, and indigestion.

The fats are not affected by the saliva, and they pass through the stomach unaltered. They become very finely divided, made into "an emulsion" as it is called, in the upper part of the small intestine, and so become capable of osmosis.

The albuminoids are insoluble in their native state, but are acted upon in the stomach by the gastric juice, and are turned into what are called peptones. Peptones are merely albuminoids, so far as their composition is concerned, but their properties have been changed. You know that if you boil an egg the white "sets"; but white of egg which has been standing in gastric juice will not "set"; it is not affected by heat. White of egg will not pass through a membrane, and therefore cannot be absorbed; but white of egg, after standing in gastric juice, can pass through, and can be absorbed. Albuminoids, then, are changed in the stomach itself into the soluble form of peptones, and become ready to be taken up.

The food-stuffs, thus rendered soluble, are absorbed by a large number of little vessels which project into the small intestine; these vessels run together into one large one; the large one opens into a vein, and in this way the nourishing part of the food passes into the blood. The blood carries it to all the tissues of the body, and each tissue takes up the kind of material that it requires to make good what it has lost, and so the tissues, constantly wasting, are as constantly built up again.

It will now be very plain to you that the quantity and the quality of food required will vary very much according to the age and the work of the person dealt with, and will vary also with the climate in which he lives. A man who works hard, and therefore uses up his tissues quickly, will require more food than an idle man. An ordinary man in good work requires daily about 44,500 grains of food, and of this 4,000 grains should be carbon and 300 nitrogen (Huxley). He may choose for himself the form in which he will take them. To live entirely on meat is not good, for 1,000 grains of meat contain (roughly) 100 of carbon and 30 of nitrogen, so that it would be necessary to eat some 6 lbs. of meat to get carbon enough, although $1\frac{1}{2}$ lbs. give sufficient nitrogen. On the other hand, if you live only on bread, you must eat twice as much carbon as you require in order to get enough nitrogen. In either case the system is overworked by more matter being put into it than is required. A mixed diet of animal and vegetable food is the diet recommended by Physiology. Animal food seems especially necessary for the reparation of nervous tissue, but further experiment is wanted before we can lay down exactly the kind of food needed for the reparation of each tissue of the body.

The food of children should be, above all things, nourishing and easily digestible. The corn-flours so largely sold for children's food are mostly deficient in gluten, while rich in starch, and are not, therefore, sufficiently tissue-forming. The same is true of ordinary white bread. Milk, wholemeal bread, beans of all sorts, oatmeal, and fruit, with comparatively little meat, form the most wholesome diet for children.

The mineral constituents of food have been omitted in this rough sketch; with the exception of salt, they are taken in as part of ordinary animal and vegetable food, and are found unaltered in the various tissues. The chief of these are: Sodium Sulphate and Sodium Phosphate in the blood and secretions; Potassium Chloride, Potassium Sulphate, and Potassium Phosphate in the muscles; Calcium Carbonate, Calcium Phosphate, and Magnesium Phosphate in the bones; Iron Oxide in the blood.

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ORGANS OF DIGESTION.

In speaking last week of facts of Zoology, we divided them into two classes:—Anatomy, which includes all facts of structure; Physiology, which includes all facts of function. Our work this week is chiefly anatomical; we are to deal with the Organs of Digestion.

Let us be sure, first, that we understand the words we are using. What is an *organ?* What is *digestion?*

An organ is any special portion of a body which is set apart for any special kind of work. In the lowest animals all parts of the body do all kinds of work equally well. The Amœba, for instance, grasps, eats, digests, breathes all over its body. There are no special portions set apart for special work: that is, there are no organs. A little higher up in the scale a mouth appears, and a bag that receives the food. Instead of taking in food all over, the food is taken in at the mouth. The mouth is the organ for food-reception, and so on. The higher the animal, the more complete is this division of labor, and the organs become more and more different, more and more perfect in the discharge of their particular work.

Digestion is, to borrow Dr. Aveling's definition, "the preparation of food for absorption." Absorption is the taking up of digested food, in order that it may be carried to the blood, and so reach the tissues; digestion is getting the food ready for absorption, so changing it that it may be fit to be taken up.

To sum up, "organs of digestion" are specialised parts of the body which prepare food for absorption.

All the changes undergone by the food during digestion take place in the alimentary canal. Aliment is merely another name for food, and the alimentary canal is the tube along which the food passes. This tube begins at the mouth and ends at the anus, and is about 30 feet in length. You will remember that there are no openings in it save these two, excepting, of course, the openings into it of ducts, little tubes, from its own appendages. Imagine, then, a long tube, expanding at one end into the mouth, expanding again, some way down, into the stomach; twisting and turning very much as the small intestine; expanding for the third time to form a little side-bag, the cæcum; widening to make the large intestine which encircles the small, and the short comparatively straight rectum. This canal has three coats: one is of mucous membrane, and forms the lining of the canal, so that it comes into contact with the food; the middle one is of fibrous tissue, and serves to connect the important inner and outer coats; the outer coat is muscular. This last coat is composed, excepting in the stomach, of two layers of muscles. One layer is of fibres running round the tube; the other layer is of fibres which run lengthwise along the tube. Now muscle has one great quality, it contracts. If you take a piece of indiarubber and pull it, it yields to your pull and stretches; when you let go, it springs back. You say it is elastic; it lengthens easily and shortens again when released, or you may shorten it by pressure and it will lengthen when released. This is just what muscle does; it stretches readily and contracts readily. Hence the use of the two layers in the muscular coat. The circular layer contracts, and makes the tube narrower and longer; the longitudinal layer contracts, and makes it shorter and wider. We shall see presently how useful these contractions are. The alimentary canal has, further, various appendages connected with it, each appendage having its own definite function. Having thus briefly described it as a whole, let us now turn to details.

THE MOUTH AND ITS APPENDAGES.—The mouth is nearly oval in shape, and is the organ which receives the food, and in which digestion begins. The soft red lining is the mucous coat. The chief appendages are the tongue, the teeth, and the salivary glands. *The Tongue* may be dismissed in a sentence: it is a thick strip of muscle, the organ of taste, and serves to turn the food about in the mouth so as to submit it to the action of the teeth, and finally to roll it into a ball and pass it backwards to the top of the gullet.

The teeth are the organs of mastication; their work is to crush and bruise the food, to break it up. The use of this is obvious. If a cook is going to make soup, she does not throw the bones in whole: she breaks them up into pieces, so that all parts of them may come into immediate contact with the water, and thereby more quickly and readily yield up their useful components. What the cook does to the bones, the teeth do to the food. By breaking it up, all parts of it come into contact with the saliva and more readily submit to its action. How necessary this is, you will remember from last week. The teeth, however, are not all alike; the first set, or milk-teeth—cut during infancy—are twenty in number. These teeth begin to develop in the seventh week of fœtal life; a little groove appears, running along the jaw, and in this groove grows up a ridge of soft (mucous) tissue; parts of this ridge die off, and so leave little projecting pieces, called papillæ; each of these represents a future tooth. I have not time to describe all the changes that go on; it must suffice to tell you that the sides of the groove bend over and close in the papillæ, so that when the child is born you see no groove and no papillæ, but only the smooth surface of the gum. The papillæ develop into teeth, hard matter being laid down in them, and they cut their way through. The permanent teeth have been forming at the same time, and move gradually round underneath the milk-set. The latter fall out from about the sixth year onwards, and the permanent teeth come through; they are supposed to be complete about the twenty-first year, when the "wisdom teeth" ought to be through. There are 32 permanent-teeth; 8 incisor, or cutting teeth, the "front teeth"; 4 canine, the long pointed teeth on either side, above and below; 20 "double teeth," for grinding. The canine teeth are for tearing, and are of no particular use to us, but they are interesting as showing our descent from animals who tore their food. A glance at a picture of a double tooth shows the structure of all; you see the fang, which is imbedded in a depression (called an alveolus) and holds the tooth firmly in its place; then comes the neck, the narrower part, and then the crown, visible above the gum. This crown is covered with enamel, the hardest tissue in the body, which protects the tooth from injury. If this gets worn away, or injured, the softer parts underneath rapidly decay. Hence the importance of keeping the teeth thoroughly clean, and of not taking into the mouth substances which injure the enamel. Inside the tooth is a cavity filled with pulp and with a nerve running into it. Toothache constantly arises from the hard part of the tooth getting worn through, and this nerve becoming exposed. When this happens, the only thing to do is to have the nerve killed and the hole filled up—stopped, it is called: the remainder of the tooth may thus be saved.

The Salivary glands are six in number—three pairs, the parotid, submaxillary, and lingual. Each of these consists of masses of cells, or vesicles, and from these masses of vesicles go ducts which run together to form a larger duct, which opens into the mouth. A gland is an organ which secretes. To secrete (from *secreto*) is to separate one thing from another, to take out one kind of substance and leave the rest. The cells, or vesicles, of the gland do the work, and they take out of the blood substances which are needed for use in the body, or sometimes which need to be expelled from the body. The salivary glands secrete saliva, and they pour this substance into the mouth and there it works, as we saw last week, on the starchy constituents of food.

From the mouth the food passes over the windpipe, which is closed by a sort of trapdoor, into the PHARYNX, the part just behind the mouth. From the pharynx a tube, about nine inches long, goes to the stomach, and this tube is called the ŒSOPHAGUS. And now comes in the use of our two muscular layers. Food which leaves the pharynx does not tumble down into the stomach. It is seized by a ring of the circular fibres, which contract on it; when they let it go, the next ring seizes it, and so it is handed on step by step till it reaches the stomach. Some of you may have seen a conjurer drink water while standing on his head, and may have wondered how it got up, instead of down, to his stomach. It is the circular rings of the œsophagus that do all the work, and as the food is handed on to ring after ring, it makes no difference whether it goes upwards or downwards.

THE STOMACH. The œsophagus opens into the stomach, the expanded part of the alimentary canal, the opening being closed except when food is passing by a ring called a sphincter muscle. The stomach is like a bag, larger on the left side than on the right, and lies across the body just below the liver. As it is part of the alimentary canal it has, of course, the regular three coats, but the muscular coat has three layers instead of two, and in addition to the longitudinal and circular it has also a layer of oblique fibres, and when all these are contracting and lengthening a kind of churning motion is given to the contents of the stomach, and the food is turned over and about, and thoroughly mixed. In the lining, or mucous coat, there are a number of little glands of different kinds, which secrete fluids and pour them into the stomach. The most important of these are the peptic glands, which secrete the gastric juice. When albuminous matter arrives in the stomach, this gastric juice is secreted and is poured out; the movements of the stomach mix the juice well up with the food, and the changes we spoke of, and which you saw last week, take place. As the gastric juice does its work the soluble portions of food—called chyme—are pumped out of the stomach into the small intestine. They pass through another sphincter muscle, the pylorus or door keeper, and until the stomach digestion is finished, this muscle will not allow any solid matter to pass. When the stomach has completed its work neither food nor chyme remains in it; it is left perfectly empty, and the secreting action of the glands stops entirely.

THE SMALL INTESTINE AND ITS APPENDAGES. The small intestine is about twenty feet long, and is divided into three districts, the duodenum, jejunum, and ileum. In the *duodenum*, active digestion continues. Into this part of the intestine are poured the secretions from the liver and pancreas, as well as fluids secreted by little glands in its own lining mucous membrane. The liver is the large organ which you see covering the stomach, and lying to the right side of the abdominal cavity. It secretes the bile, and as it secretes constantly while the bile is only used intermittently, the bile is stored up in the pear-shaped organ attached to the liver, called the gall-bladder. The exact work of the bile is still rather a matter of dispute. It appears to act as a stimulant to the intestine, it is to some extent an excrementitious product—that is, a waste fluid carrying off matters injurious to the body—and it is also certainly antiseptic—that is, prevents decomposition. The pancreas lies partly in the fold of the abdomen and secretes the fluid which, as we saw last week, makes an emulsion of the fats and oils, and also finishes work left undone by the saliva in turning starch into sugar. The pancreatic fluid runs down a little duct, and joins the duct from the liver, the two opening together into the duodenum.

The *jejunum* is so called because it is generally found empty after death, the *ileum* because it is much twisted. All these three parts of the small intestine are thickly studded with villi, little projections like the finger of a glove, which stick out into the canal of the small intestine. Each villus has a little tube, or tubes, in it, called lacteals, and all these are plunged into the digested food—now called chyle—and suck it up as fast as they can. They absorb the nutritive matter, the fluid passing through their delicate walls, as you remember, by osmosis. As the villi continue to suck up the fluid, the contents of the intestine become more and more solid; they are slowly passed along by the muscular movements of the intestine until they arrive at the cæcum.

THE LARGE INTESTINE.—The large intestine commences at the *cæcum*, and is about five feet long. The cæcum itself is a mere blind bag, small in man, but large in many of the lower animals. So far as we know, it serves no useful purpose in man, but it is occasionally the cause of disease, by lodging hard particles which give rise to inflammation. When the digested food reaches the cæcum, it has yielded up most of its nutritive material, and the remaining matter is useless, and has to be expelled from the system. The large intestine, here called the *colon*, passes first upward (ascending colon), then turns to the left and crosses the body (transverse colon), turns downwards (descending colon), and then makes a remarkable S-like turn (sigmoid flexure). Throughout its length it is sacculated—drawn into little bags, or sacculi—and as the superfluous portion of the food, now called fæces, passes along it, being carried on as before by the muscular movements of the intestine, it gets lodged in the sacculi, and is so prevented from falling back between the contractions. This muscular movement—peristaltic action, as it is termed—may be very easily seen by pinching the intestine of an animal which has been lately killed: a slow wave of movement will run along it. The last six or eight inches of the intestine are named the *rectum*, and extend from the sigmoid flexure to the anus. The rectum is not sacculated, increases in diameter as it descends, and ends in a sphincter muscle.

You may reasonably ask, what causes all these movements, whereby the food is propelled along the alimentary canal, from mouth to anus? We are not conscious of these muscular contractions, nor are they, mostly, under the control of the will. When a morsel of food has reached the top of the œsophagus it passes out of our power. We do not even feel it pass down the œsophagus unless it is very hot, very cold, or actively injurious. Unhappily our time is too brief to allow us to go fully into this interesting question. It must suffice to say that muscle left to itself does not contract. But distributed to all these muscles of the alimentary canal are a number of fine cords called nerves. When the nerve contracts it moves the muscle, and all the muscular movements are the result of nervous action.

But you may again ask: What causes the nervous action? It is a property of nerve to respond to a stimulus. When the nerve responds to an external stimulus, and responds without sensation—that is, the stimulus causes action, but we are unconscious of the action—such nerve-action is called reflex. Reflex action is action caused by external stimulus, and performed without sensation. The whole of the movements of the œsophagus, stomach and intestines are reflex. The stimulus is the food pressure. The food presses against the delicate nerve fibres; the nerve-fibres, responding to this stimulus, are set in motion; moving, they move the muscles to which they are distributed, and the muscles contract. The food is pushed on by the contraction, presses against fresh nerve-fibres, and so on. If the nerves are destroyed, the muscular contractions stop, showing that the muscles do not contract of themselves. Destroy the nerves, and the food may press for ever against the muscles without causing them to contract.

We must now return, in conclusion, to the small intestine, and see what becomes of the chyle. We have already seen that each villus contains a tube or tubes; these minute tubes run into glands (mesenteric glands) in the mesentery, the thin membrane that connects together the folds of the intestine, and here the chyle undergoes considerable changes. Corpuscles—small rounded bodies that we shall speak more of when we come to deal with the blood—make their appearance, the constituents of fibrin are formed, and the chyle changes in color from white to a pale reddish-yellow. This modified chyle is collected in a triangular cavity or cistern (*receptaculum chyli*), which lies at the back of the body, against the backbone. From this cistern a duct (thoracic duct) runs up along the backbone as far as the root of the neck, being from eighteen to twenty inches in length; at the top it turns to the left and arches downwards, entering the blood system at the junction of the internal jugular and subclavian veins, and pouring its contents into the blood.

We have thus traced our food from its four primary elements until it reaches the blood, which is to carry it to repair the tissues, and have briefly sketched the organs which work upon it and change it. The next lecture will deal with the organs to which the food is now committed, and with the way in which the blood nourishes the body.

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CIRCULATION.

WE defined an *organ* last week as "any special portion of a body which is set apart for any special kind of work." The first things we have to consider to-night are the Organs of Circulation, the special portions of the body concerned in the circulation of the blood.

The organs of circulation are of four kinds: the heart, the arteries, the capillaries, the veins.

THE HEART.—The heart lies obliquely between the lungs in the upper half of the trunk, the apex pointing forward and rather to the left, the broad upper end being in the middle line of the body. The average adult human heart is about 5 inches long, 2½ inches thick, and 3½ inches broad in the widest part. It is conical in shape and hollow, and is divided within into four compartments, the right and left auricles, and the right and left ventricles. A septum (*septum*, a fence) runs from base to apex, completely dividing the right side from the left, so that there is no communication possible between the two sides in a healthy person. This septum has an auricle and a ventricle on either side of it, and each auricle communicates with the ventricle of its own side. The material of the heart is muscle, of which you will remember the chief characteristic is contractility. The muscular walls are not of the same thickness throughout; those of the auricles being considerably thinner than those of the ventricles, and the wall of the right ventricle being thinner than that of the left. You all know that exercise strengthens muscles; the arm of a blacksmith is larger and harder than that of a writer, and when we find that there is so great a difference between the walls of these cavities we may feel sure that the greater thickness is the result of greater work. The work of the heart is to propel the blood, and the propulsion of the blood outside the heart falls wholly on the ventricles; the muscular walls of the ventricles, being more used, generation after generation, have become permanently thicker than those of the auricles; similarly, while the right ventricle has only to propel the blood round the lungs, the left has to drive it all round the body, hence the muscular wall of the left is thicker than that of the right. The openings (auriculo-ventricular orifices) between each auricle and the ventricle of its own side are oval in shape and surrounded by a fibrous ring. The openings are guarded by valves, folds of the lining membrane of the heart, which are in such a position that they can completely close the aperture. On the right side the valve is composed of three triangular segments (tricuspid valve, from *tres*, three, and *cuspis*, a point), while the similar valve on the left side has two (mitral valve, so-called from its supposed resemblance to a mitre). The description of one of these valves will serve for both. The segments of the tricuspid valve are attached by their bases to the fibrous ring, their points being free. From these free points and from the surface on the ventricle side, go thin cords of tendon, a fibrous inelastic tissue, and these cords (*chordæ tendinæ*) are attached to little muscular pillars (*musculi papillares*) three or four in number, projecting from the inner wall into the cavity of the ventricle. These cords are long enough to allow the segments of the valve to join each other and completely close the auriculo-ventricular opening; they are not long enough to allow the points of the valves to be pushed up into the auricles. We shall now be able to understand what happens when the heart "beats," that is contracts and expands; the "beat" is caused by the apex of the heart striking against the wall of the chest. Imagine the heart empty, or, if you are wise, get a bullock's heart and experiment; imagine some fluid pouring into the right auricle, till it is full; the auricle contracts and presses on the fluid; the fluid tries to escape, and the easiest way out of the auricle is through the opening into the ventricle; it pours through, the valve yielding readily and being flattened against the walls of the ventricle by the rush from above; the ventricle becomes full and begins to contract, forcing the fluid once more to escape. Meanwhile the segments of the valve have been pushed up as the ventricle fills until they nearly meet, and the fluid, pressed by the contraction of the ventricle, pushes against them and completely closes them; it continues to push against them, but the *chordæ tendinæ* prevent them from going upwards any further, and the fluid is compelled to escape into an open tube, called the pulmonary artery, leading out of the ventricle. A very sharp hearer might say: "As the ventricle contracts the sides come nearer together, and therefore the valve would gradually rise into the auricle if pressed from below." Quite so, if the cords were attached directly to the wall of the ventricle, but you will remember that they are attached not to the wall, but to little pillars projecting from the wall, and as these also are of muscle they contract at the same time as the wall, and becoming shorter keep the cords tense. There are not many adaptations more beautiful and more remarkable than this, so to speak, compensating contraction.

ARTERIES.—An artery is a vessel, a tube, which carries blood away from the heart. This tube has three coats, a lining of serous membrane, a fibrous, better termed a muscular coat, and an outer of a very simple tissue, called connective. The middle coat is thick and strong in the large arteries, hence these are exceedingly elastic. Two great arteries rise from the heart, the pulmonary (*pulmo*, a lung) from the right ventricle, the aorta from the left. The pulmonary divides and sends a branch to each lung; these branches divide again and again within the lung. These are the only arteries in the body that contain impure blood. The aorta sends branches all over the body, to the head, trunk, and limbs, and these contain pure blood, keeping every tissue in working order.

CAPILLARIES.—The arteries, after dividing in this fashion, open at length into the capillaries (*capillus*, a hair), minute vessels varying in diameter from $^1/_{1500}$ to $^1/_{3000}$ of an inch. These capillaries form a fine, close network, the meshes of which vary very much in size. The network is closest wherever nourishment is most required and most rapidly used, for the actual work of nutrition goes on in the capillaries. In some parts the space between the capillaries is actually less than the diameter of a capillary, so that the nourishing blood is brought into the very closest contact with every part of the tissues. When I add that the wall of a capillary is a very delicate homogenous membrane, you will see how easily the tissues can, by osmosis, take out of the blood whatever they require.

VEINS.—A vein is a vessel which carries blood towards the heart. Like the artery, it has three coats, but the middle one is very thin, and in consequence of this the veins are but slightly elastic. Another great distinction between arteries and veins is the valves found in most of the latter. These valves are folds of the lining, shaped much like watch-pockets, with the opening directed towards the heart

If, therefore, the blood be flowing towards the heart, the valves are pressed against the walls of the vein, and offer no impediment to the circulation. But if the blood begin to flow back, the pockets at once fill, become distended, and bar the passage. The use of this is obvious. Blood has to return to the heart from the lower part of the body against the force of gravity, and these valves prevent it from falling backwards. The veins begin where the capillaries end, just as the capillaries begin where the arteries end. The veins nearest the capillaries are very minute; they join to make larger ones, join again and again, until at last all the blood from the lower part of the body is gathered in the inferior *vena cava*, and all the blood from the upper part, except from the lungs, into the superior *vena cava*, and these two pour their contents into the right auricle. All the blood from the lungs is poured into the left auricle by four pulmonary veins.

Course of Circulation.—We can now trace the course of the blood. We divide the circulation of the blood into two systems—the greater, or systemic, and the lesser, or pulmonary circulation. We will take the greater first. Blood that has been aërated in the capillaries of the lungs is poured into the left auricle through the pulmonary veins. It passes through the auriculo-ventricular opening into the left ventricle. As the heart contracts, it is forced to find a way of escape. The mitral valve closes the opening into the auricle, but the aorta is open, and it rushes into that. Through artery after artery it travels, its containing vessel ever growing smaller and smaller, until it reaches a capillary network. Through this it travels slowly, very slowly, yielding up its nutritive material, and at length passes into a vein. Travelling now towards the heart, it passes on and on, its containing vessel ever growing larger and larger, until it reaches either the inferior or the superior *vena cava*. It flows into the right auricle, and through the auriculo-ventricular opening into the right ventricle, and has concluded the systemic course. There is, however, no rest for it. The contracting ventricle drives it out, and as the opening into the auricle is closed by the tricuspid valve, it is driven through the only other opening into the pulmonary artery. It goes either to the right or left lung, through the capillaries, through the veins, back into the left auricle, whence we traced its course, thus completing the pulmonary circulation. All the blood that has been round the body goes to the lungs; all the blood that has been round the lungs goes to the body. Why?

Arterial and Venous Blood.—The question finds its answer in the difference between the blood returned to the heart from the body, and that returned to it by the lungs. The words "arterial" and "venous" are not very accurate, but they are generally used; they are inaccurate, because the pulmonary artery contains venous blood, and the pulmonary vein arterial. The most striking difference between arterial and venous blood is that of color; the arterial is scarlet, the venous purple. The most important difference is the presence of much oxygen in the arterial, of much carbon dioxide (carbonic acid gas) in the venous. Oxygen is breathed in by the lungs, and this oxygen is carried by the blood to the tissues; it enters into combination with the carbon of the tissues, and carbon dioxide (carbonic acid gas) is formed; this is not wanted, is even harmful, in the body, and it is carried away by the blood. In the arteries there is scarlet oxygenated blood; in the capillaries the oxygen is yielded to the tissues, the carbon dioxide is taken from the tissues; in the veins there is purple deoxidised blood, charged with CO_2, requiring purification in the lungs.

Cause of the Circulation.—This constant movement of the blood now needs to be explained. The primary cause of the movement is the alternate contraction and expansion of the heart. The heart is a muscle, it is therefore very contractile. The stimulus to the nerves, causing them to act on the muscle, is the blood. When the blood fills the heart, it stimulates nervous action, the nerves act on the muscular fibres and they contract. The blood expelled, the stimulus is absent, the muscle relaxes and the heart expands. And so, alternately, we have contraction and expansion. Remembering that the blood will always move in the direction of least resistance, we at once understand why, on being pressed out of the heart, it rushes into the pulmonary artery and the aorta. The movement of the blood, however, does not depend only on the contraction of the heart; the elasticity of the arteries aids and regulates the flow. The moment the rush of the blood consequent on the contraction of the heart has ceased, the aorta in turn contracts on the blood; it would flow back to the heart, but the ever useful valves, this time (semilunar valves) round the aortic opening interpose, and the contracting artery forces the blood onwards. This action of the arteries gives rise to the "pulse." The pulse is the expansion of the artery at a particular point, responding to the impulse sent from the heart. The blood is thus pushed on through the arteries, each "beat" of the heart driving fresh blood into the aorta, so pressing on the blood already there. In the capillaries the blood is pushed on from behind, and is also aided by several agencies classed under the head of "capillary action," which time does not permit me to deal with. In the veins it is propelled by the pressure from behind, and also sucked on, as it were, by the emptying of the heart in front. Any attempt to flow backwards is, as we have seen, checked by the valves. It is practically useful to remember the several directions in which the blood flows in the arteries and veins; suppose a limb be badly cut and a surgeon be not at hand. If the cut have severed an artery the blood will be bright scarlet, and will flow in regular jets, like water pumped out; if this be the case, remembering that arterial blood flows away from the heart, twist a bandage very tightly *above* the injury, so as to cut off the supply coming from the heart. If a vein be severed the blood will be dark and flow steadily, without any jerking motion; in this case, remembering that venous blood flows towards the heart, twist the bandage tightly *below* the wound, so as to cut off the supply coming from the capillaries.

BLOOD.—It is time to answer the question; "What is blood?" Gray very well defines it as "a fluid holding a number of minute cells or corpuscles in suspension." The corpuscles (*corpusculum*, a little body) are of solid matter, forming about $^1/_7$ of the blood; there are also other solid materials in the blood, albumin, fat, salt, and sugar, making up another $^3/_{28}$, so that $^1/_4$ of the blood is solid and $^3/_4$ water. This calculation is very rough, for the composition of blood is not a constant. If blood be left standing, the liquid and solid parts will separate out, and we have a clot surrounded by fluid. In the clot, entangled among structureless strings, called fibrin, we find the corpuscles, and these are of two kinds, white and red. The white are cells, constantly change their shape, and closely resemble the white corpuscles of chyle; the red are semi-solid bi-concave (hollowed on each side) discs, and are two or three hundred times more numerous than the white. These corpuscles are the gas-carriers, and the difference of color between arterial and venous blood is thought to be due merely to the difference of the refraction of light severally from rounder or more flattened corpuscles.

The function of blood is to nourish and to equalise the temperature of the body. We have seen food transmuted into chyle, and the chyle poured into the blood system; when we further learn that the liquid part of the blood (*liquor sanguinis*) and the liquid part of the chyle (*liquor chyli*) are identical, and that little difference can be found between the white corpuscles of the blood and those of the chyle, we have not much difficulty in tracing our foodstuffs into the capillaries and, by osmosis, into the tissues.

Evolution of Heart.—In studying the wonderful mechanism of the heart, the marvellous adaptation of the organ to the function which it is its work to discharge, we are almost compelled to ask: "How did all this come into existence?" If the human heart were the only one known to us, the question would be hard to answer, but we are fortunately able to trace the evolution of the heart from a most imperfect beginning to its present condition. Without dwelling on the mere tube of insects, and passing over the very simple hearts of the invertebrate animals, let us hastily glance at the hearts of the great divisions of the vertebrate (back-boned) kingdom. The lowest class of the Vertebrata is that of the fish, Pisces. In the lowest again of these, the Amphioxus, the heart is a simple tube, a "pulsatile cardiac trunk" (Huxley), and "contractile dilatations" aid in propelling the blood. The typical fish's heart has two chambers, one auricle and one ventricle, and may be regarded as the tube, bent upon itself. In the highest fish, the heart acquires three chambers, two auricles, and one ventricle, thus graduating into the normal heart of the second vertebrate class, the Amphibia, of which the common frog is the best-known representative. Here the heart has two auricles, of which the right receives the venous blood from the body, and the left the arterial blood from the lungs. Unfortunately the frog has only one ventricle, and as both auricles open into it, and discharge their contents into the ventricle at the same time, the blood it contains is to a great extent mixed. Certain folds and valves tend to prevent complete mixing throughout, but the result is scarcely satisfactory. An advance is made in the next case, the Reptilia, and here we may take the snake as an example. The snake's heart has two auricles and one ventricle, but there is an incomplete partition separating the ventricle into two halves, one containing venous and the other arterial blood, and when the heart contracts, this partition almost divides the ventricle into two chambers. In the highest Reptilia, the crocodile has a four-chambered heart, the septum becoming complete; this great advantage is, however, neutralised by the main arterial and venous trunks crossing just outside the heart and communicating by an opening, or foramen as it is called, and the blood mixing through this. In the birds (Aves) and the mammals (Mammalia) the heart has four separate chambers and the arterial never mixes with the venous blood.

We have thus a steady gradation from the tube of Amphioxus, through the two-chambered heart of the common fish; the three-chambered of the frog; the three-chambered, but with partially divided ventricle, of the snake; the four-chambered, but with communication outside, of the crocodile; up to the four-chambered, with uncommunicating vessels, of the bird and the mammal. Thus we see gradual evolution of a more perfect type, each improvement first hinted at, then introduced, then perfected.

In the development of the individual a similar evolution takes place. The heart is at one time a mere straight tube, the veins connected with one end, the arteries with the other. It soon becomes doubled on itself, and shortly afterwards a longitudinal septum grows out dividing it into two chambers. Later, two septa grow out transversely, dividing off the auricles from the ventricles. Still the separation of arterial and venous blood is not complete, for there is an opening between the auricles, the *foramen ovale*, and there is also a duct from the right ventricle to the aorta. The *foramen ovale* closes at birth, except in cases of disease (*morbus ceruleus*), and the duct is completely closed by the tenth week after birth. Thus the evolution of the race is to some extent repeated in the evolution of the individual, and the development of the infant traces for us the development of humanity.

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RESPIRATION.

Respiration is the purification of the gases of the blood. We have seen that the corpuscles of the blood are gas-carriers; that they carry to the lungs from the tissues the carbonic acid gas which has been formed in work and which needs to be expelled, and also carry from the lungs to the tissues the oxygen which is required for use in the body. We have now to investigate the organs of respiration and the method in which the function is discharged.

Organs of Respiration. These are: the nose; the mouth; the pharynx; the larynx; the trachea; the bronchi; the bronchial tubes; the air-sacs and air-cells; the skin. The bronchial tubes, air-sacs and air-cells may be included generally under the *lungs*; the nose, mouth, pharynx, larynx, trachea and bronchi, may be regarded merely as the *air passages* leading to the lungs. Some of you may be surprised at my mentioning the skin as an organ of respiration, but when I remind you that the body of a medium-sized full-grown man daily gets rid of 400 grains of carbonic acid gas through the skin, you will see that the skin comes fairly within the definition of an organ of respiration, that is, of a special part of the body which purifies the gases of the blood.

We will consider 1st, the air-passages; 2nd, the lungs; 3rd, the skin.

The *air-passages* opening on the exterior are two, the nose and the mouth. Both these passages open internally into the pharynx. If the mouth be closed, respired air passes into the two anterior nares, or nostrils, up the nasal fossæ (*fossa*, a ditch or trench), and through the two posterior nares, little openings into the pharynx. The air has thus arrived at the top of the throat, just behind the mouth. If, instead of breathing through the nose, you breathe through the mouth, the air passes straight to the pharynx; so that in either case it arrives at the back of the mouth. The presence of these posterior nares, or internal nostrils, explains how, if you are bathing, water may run up your nose into your throat, or how, in smoking, you may take smoke into the mouth and breathe it out at the nose. Into the pharynx opens the *larynx*, a kind of box, triangular above, rounded below, which is situated at the top of the trachea, or windpipe. The larynx is formed of nine cartilages, one of which, the thyroid, is especially prominent in men, and is known as the *pomum Adami*, or Adam's apple. It is closed above by a little lid of cartilage, the epiglottis, and contains the vocal cords, the delicate strings of our voice-machine. When food passes from the mouth to the œsophagus it goes over this lid, the larynx being drawn beneath the tongue ; the lid is then shut down, the hinge, so to speak, of the lid being just behind the tongue. When food "goes the wrong way," it is because this process has been imperfectly performed, and the morsel has slipped into, or wedged itself against the larynx, so obstructing the air-passage. Hence the danger of laughing or speaking when food is passing into the gullet. "Don't speak with your mouth full," is a maxim of physiology as well as of politeness. Any action which raises the epiglottis opens the air-passage, and a passing morsel may enter and cause suffocation. We have not time to dwell on the action of the vocal cords, we must content ourselves with passing by them into the trachea, or windpipe.

The *trachea* is a tube of about 4½ inches in length, and is formed of membrane with cartilaginous rings running two-thirds of the way round. These rings are imperfect behind, where the trachea comes into contact with the œsophagus, along the front of which it lies. The trachea divides into the two *bronchi*, the right bronchus, about an inch long, going to the right lung, and the left, about two inches in length, going to the left. When the bronchus enters the lung it divides and subdivides, forming the *bronchial tubes.*

The lungs are partly made up of the numberless ramifications of these bronchial tubes, but before dealing with these it will be well to pause for a moment on the *thorax*, the cavity which contains the lungs. This cavity is a perfectly air-tight box, bounded by the backbone behind, the breast-bone in front, and the ribs on either side, the interstices of the ribs being filled with the powerful intercostal muscles.

The bottom of the box is formed by the diaphragm, a remarkable muscle, shaped something like a fan, attached in front to the lower end of the breastbone, at the sides to the ribs, at the back to the vertebral column, and arching over the abdomen. The diaphragm is pierced by the œsophagus and the great blood vessels, but adheres closely round them, permitting no air to enter. The thorax contains, besides the lungs, the heart which lies between them and all the great vessels and nerves connected with heart and lungs, as well as the greater portion of the œsophagus. The liver and stomach lie immediately below it, being separated from the thorax by the diaphragm. The position of the diaphragm varies according to circumstances. When the lungs are partially emptied the diaphragm is much arched, the concave side being toward the abdomen. When air is breathed in the diaphragm is partially flattened, enlarging the cavity of the thorax. After a full meal, the diaphragm is pushed upwards by the extension of the stomach, and the oppression in breathing felt after an excessive meal is due partly to the upward pressure of the diaphragm against the lungs.

Before quitting the question of the thorax, a few moments must be devoted to the cause of our regular breathing. You will have noticed that I have laid stress on the fact that the thorax is perfectly air-tight. If it were not so breathing would be impossible. When air is expired from the lungs it is driven out partly by the elasticity of the lungs themselves, the bronchial tubes contracting upon it and expelling it. The outward motion is also perhaps assisted by delicate cilia—hair-like processes from the lining of the tubes—which constantly sweep outwards the solid and liquid contents. The muscles of the chest also come largely into play in expelling the air, by lessening the cavity of the thorax. Their several movements are too complex to be described in a lecture like this. The diaphragm, lastly, does a share of the work; like all muscles it contracts, and when it contracts it becomes flatter and therefore descends, and as the ribs are rising while the diaphragm is descending, the thoracic cavity enlarges, and air rushes in to fill the space thus given. The whole of the muscular action is, as before, controlled by nerves, and is reflex, not voluntary. We can partly control it by our will, and we can voluntarily hasten or slacken the movements; but in the normal healthy condition, respiration goes on without our notice. As the normal number of respirations in a minute is fifteen, it would clearly be excessively troublesome if the brain had to see that the work went on properly; the task falls conveniently to the nonsensating division of our nervous system.

One difference may be worthy noting, the difference between male and female breathing. In the male the diaphragm is very much used; in the female it plays a comparatively small part, while the muscles connected with the ribs are the chief agents. Notice the breathing of a man and a woman, and see how much more the bosom of the latter rises and falls; the upper ribs are coming largely into play, while in the man they do but little work. A moment's thought, and the remembrance of the way in which Nature adapts beings to their life-conditions, will suggest to you the "why" of this difference. Woman is the reproducer of the race; during many months of her life, before she gives birth to a child, violent movement of the diaphragm would result in injury, and the condition necessary for health in one part of life becomes a sexual characteristic, common to the whole.

Let us return now to the anatomy of the lung, the surroundings of which we have been considering. Each lung is covered by a double membrane, one fold of the membrane clothing the lung, the other fold lining the cavity of the thorax, in which the lungs and heart are enclosed. Between these two folds is a small quantity of fluid, which enables them to run smoothly over each other. Inflammation of the pleuræ, or of these coats of the lungs, is the painful and dangerous disease known as pleurisy. The lung is composed of a large number of lobules, or little lobes. Each lobule consists of a little branch of the bronchial tube—which subdivides, each subdivision ending in a minute expansion or *air-sac*—and the nerves, blood-vessels and lymphatics in close relation to it, all being held together by connective tissue. A number of these lobules make up a lobe, and of these lobes the right lung has three, the left two. Reverting for a moment to the air-sacs mentioned above, it is necessary to add that in the walls of the air-sacs are little alveoli, depressions, very badly called *air-cells*. These range from $^1/_{70}$ to $^1/_{200}$ of an inch in diameter, and over the walls of each of these cells spreads a net work of capillaries, into which pours the dark carbonic-acid-burdened blood from the subdivisions of the pulmonary artery, and out of which flows the scarlet oxygen-laden blood to the pulmonary veins. So close is the capillary net work that the space between the capillaries is only from $^1/_{500}$ to $^1/_{125}$ of an inch. By osmosis, once more, the carbonic acid gas passes out and the oxygen passes in. The oxygen is brought down to the air-cells as part of the air through all the passages that we have been considering. Air is a mixture chiefly of oxygen and nitrogen, the nitrogen serving merely to dilute its too vigorous companion; the oxygen in the air breathed into the lungs is seized upon by the corpuscles, and they give up in exchange the deleterious carbonic acid gas, which passes up the air-passages and out of the mouth or nose.

The exchange of oxygen for carbonic acid gas is not the only difference in inbreathed and outbreathed air. Expired air is of a higher temperature than inspired, and it is also charged with a considerable amount of water in the condition of steam. It is estimated that the lungs of an ordinary adult send out daily about 5,000 grains (9 ozs.) of steam, and 12,000 grains of carbonic acid gas, but it must be remembered that the amount of steam and of carbonic acid gas thus exhaled depends not only on the age, but also on the work of the individual.

Before speaking of the effect of this action on the air, we must complete our brief study of the organs of respiration by considering the *skin.* The skin is composed of two distinct layers, differing in nature, the scarf-skin, cuticle, or epidermis above, and the true skin or derma lying below. In the true skin, or sometimes just below it, are a number of small bodies called sweat-glands, and from these run ducts, which open by a tiny valve on the exterior of the body. By these is discharged the watery matter, known as perspiration, and if a limb be tied in an indiarubber bag it is found that the air within the bag becomes charged, not only with aqueous matter but also with carbonic acid gas. Since 400 grains of carbonic acid and 10,000 grains of water are thus discharged daily by the skin, the enormous importance of the healthy action of the skin at once becomes apparent. Let dust fall on the skin and mixing with the perspiration clog the openings of the valves, and the discharge is at once checked; the matter that ought to be got rid of is kept in the body; the other excretory organs try to get rid of it, the lungs chiefly working at the carbonic acid gas and the kidneys at the water; over much labor is thereby thrown upon these organs, and they suffer. How is all this mischief to be prevented? The answer comes in one word: cleanliness. The body needs to be thoroughly washed, and where people work hard in dusty atmospheres the necessity is the more stringent. The public baths now found in London are veritable hygienic institutions, and men, women, and children who visit them will find doctors' visits less frequent.

VENTILATION.—We have seen that every person is continually breathing oxygen into the body, and is continually breathing out carbon dioxide, or carbonic acid gas. Hence it results that if a person be shut up in a room to which oxygen has no admittance, he will gradually use up the oxygen therein contained, and gradually replace it with carbon dioxide. As soon as the carbon dioxide amounts to 1 in 1,000 parts, the air of the room will begin to have an oppressive odor. The man will get drowsy and disinclined to exertion; a little later he will sink down half-sleeping, half-fainting; if he be left unrescued, he will die, and he will die not of any active poison administered to him, but from privation of the oxygen necessary for the maintenance of life. Carbon dioxide is sometimes called a narcotic poison, but it is not the presence of carbon dioxide that kills; it is the absence of free oxygen. When in crowded rooms people faint, they faint from want of oxygen; the venous blood carried to the lungs is not oxygenated there; it goes back to the left side of the heart still charged with carbon dioxide. In this condition it is supplied to the tissues. The brain receives this, instead of the fresh bright blood which it is in need of; giddiness, drowsiness, faintness, are the immediate consequences, and, if the mischief be allowed to continue, these result in death. A modified form of this injury is caused whenever a room is "close," although actual faintness may not ensue. People are so afraid of "draughts" that they prefer the "closeness," not knowing that the latter is really more dangerous than the former. But there is no need to suffer either from draughts or from closeness. Cut a slip of wood, about an inch thick, to fit along the bottom sash of a window; shut the window down upon this. It will seem quite closed; but if you look at the middle of the window, where the bolt comes, you will see a slit as wide as your piece of wood. Fresh oxygen from outside will rise through this, and, spreading upwards, will cause no draught. If, in addition, you leave your window half an inch open at the top, you will feel no uncomfortable stream of cold air, but your room will be healthily ventilated, and your brain will be the clearer for it. One other agent we may call to our help in ventilating our rooms. Flowers are not only beautiful, they are also health-giving. They feed on the carbon dioxide, so long as light falls upon them, and, retaining the carbon, they excrete the oxygen. Although they breathe just as we do, taking up oxygen and breathing out carbon dioxide, yet, as long as they are in the light, they feed so much more than they breathe that their total effect upon the air is to diminish the carbon dioxide in it, and to increase the free oxygen. Flowers are, therefore, really useful in the room, and while they bring light and grace, color and sweetness into our homes, they also come as messengers of health, working for us as purifiers of the air.

Much unnecessary lung disease is caused by mere carelessness. Remembering the delicate machinery of capillary network and minute air-cell that I have traced for you, you will readily understand that rapid changes of temperature, or the introduction of foreign materials would very easily disorganise the mechanism. Yet people go suddenly out of a hot, close room into keen, cold air, unthinkingly subjecting these exquisite machines to the mischievously sudden alteration of temperature. A handkerchief placed over the mouth for a few moments after passing into the outer air from a hot room would prevent many a "bad cold on the chest."

Various trades are characterised by special lung diseases. If you pay a visit to a surgical museum, you may see lungs preserved there of miners, cotton-spinners, etc. The miner suffers from coal-dust breathed into the lungs in the air; the cotton-spinner from cotton-fluff carried thereinto in similar fashion; the Sheffield grinder from steel-dust. These dangers might be lessened in the last two cases by the continual swinging of large fans in the work-rooms, driving away the dust; they might be completely avoided by the wearing of respirators by the workers, as all dust would be stopped in these, instead of going on into the lungs.

Again, as to clothing. The apex of each lung rises about an inch or an inch and a half above the line of this first rib. The lower part of the neck, therefore, needs to be protected even more than the chest itself. Yet mothers let babies and little children play about in the open air in winter in low-necked frocks, and then wonder that they suffer from cough, bronchitis, and inflammation of the lungs.

This brief course of lectures has now come to an end. I shall have wholly failed in my object, if it has only served to amuse some idle hours. I trust rather that our talks may have raised the desire to know more of a most interesting subject, and will lead many to study fully that which has been so superficially treated here.

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